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Correlation of the radial inclination angle in the distal part of the radius with the volar cortical angle and age-related changes of these angles

Korelacija ugla radijalne inklinacije sa volarnim kortikalnim uglom i promene tih uglova sa starenjem

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Abstract

Background/Aim. The radial inclination (RI) and volar cortical (VC) angle values used in the treatment of radial distal end fractures may vary depending on factors such as the age and gender of the patient. That raises the question of the compatibility of the standard anatomical plates, which are frequently used in the surgical treatment of these fractures. The aim of the study was to evaluate the VC and RI angles depending on the age and gender of subjects and determine the correlation between these two angles. **Methods.** A total of 121 individuals (59 females and 62 males) aged 10–65 years were included in the study. The individuals were divided into two groups: a group of 60 adolescents (31 females, 29 males) 10–20 years old and a group of 61 adults (28 females, 33 males) aged 20–65 years. The subjects were also evaluated between themselves, independently, within each age group. Radiographic images were evaluated by using the 3.0.1.55 version of the KarPacsViewer application. Measurement points were determined, and angles between these points were measured. Statistical analyses were made using the SPSS 15.0 program. **Results.** When the correlation for 121 individuals was assessed independently of their gender, no statistically significant relationship was found between the RI angle and age ($p = 0.616$; $r = -0.046$). A statistically negative (or opposite) relationship was found between the VC angle and age ($p < 0.001$; $r = -0.396$). When women and men were compared in terms of the RI and VC angles, no statistically significant difference was found ($p = 0.958$, $p = 0.165$, respectively). The VC angle decreased as the age increased in females ($p = 0.004$; $r = -0.365$), while both the RI and VC angles decreased with increasing age in males ($p = 0.032$, $r = -0.273$; $p < 0.0001$, $r = -0.445$, respectively). **Conclusion.** Our findings regarding the RI and VC angles offer an advantage in terms of determining which plate designs are most appropriate for planning surgical procedures and treatment processes.

Key words:
age factors; bone plates; radiography; radius fractures; weights and measures.

Apstrakt

Uvod/Cilj. Vrednosti radijalne inklinacije (RI) i volarnog kortikalnog (VK) ugla, parametri koji se koriste u lečenju preloma distalnog okrajka žbice, mogu varirati zavisno od faktora kao što su godine i pol pacijenta. To dovodi u pitanje kompatibilnost standardnih anatomskih ploča, koje se često koriste u hirurškom lečenju tih fraktura. Cilj rada bio je da se procene uglovi VK i RI, u zavisnosti od starosti i pola ispitanika, kao i da se utvrdi korelacija između ta dva ugla. **Metode.** U studiju je bilo uključeno ukupno 121 osoba (59 žena i 62 muškarca) starosti od 10 do 65 godina, podeljenih u dve grupe: grupa od 60 adolescentnih ispitanika (31 žena, 29 muškaraca) starosti od 10–20 godina i grupa u kojoj je bilo 61 odraslih osoba (28 žena, 33 muškarca) starosti od 20–65 godina. Takođe, sprovedene su i nezavisne procene između pojedinaca unutar svake pojedinačne grupe. Radiografske slike procenjene su uz pomoć 3.0.1.55 verzije aplikacije *KarPacsViewer*. Određene su merne tačke i izmereni uglovi između tih tačaka. Statističke analize rađene su pomoću programa SPSS 15.0. **Rezultati.** Kada je korelacija kod svih 121 ispitanika određivana nezavisno od njihovog pola, nije pronađena statistički značajna veza između ugla RI i starosti ispitanika ($p = 0{,}616$; $r = -0{,}046$). Nađen je statistički negativan (ili suprotan) odnos između ugla VK i starosti osoba

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($p < 0,001$; $r = -0,396$). Kada su žene i muškarci upoređivani u odnosu na vrednosti uglova RI i VK, nije utvrđena statistički značajna razlika ($p = 0,958$, $p = 0,165$, redom). Ugao VK je opadao sa porastom starosti žena ($p = 0,004$; $r = -0,365$), dok su uglovi RI i VK opadali sa porastom starosti muškaraca ($p = 0,032$, $r = -0,273$; $p < 0,0001$, $r = -0,445$, redom). **Zaključak.** Naši nalazi procene uglova RI i VK pružaju prednost kod izbora najprikladnijeg dizajna anatomskih ploča, onog koji najviše odgovara za planirane hirurške procedure i proces lečenja.

Ključne reči:
životno doba, faktor; pločice za kost; radiografija; radijus, prelomi; mere i merenja.

Introduction

Wrist movements are the actions we actively use in everyday situations, such as eating, drinking, using phones, and reading books. Any restriction that may occur on the wrist will negatively impact our daily life. During wrist-related movements, there is harmony between the bone, tendon, joint surface, and soft tissues. Wrist kinematics are examined under radiocarpal, carpal, and distal radioulnar joints [1, 2].

Five to ten percent of fractures in the skeletal system occur in the forearm. About 75% of these fractures were found to be distal radius fractures (DRF). Those who apply to the emergency department for DRF constitute 1/6 of all fracture applications. Twenty percent of DRF consist of unstable fractures and require surgical procedures. Fractures occur during high falls, motor vehicle accidents, or athletic activities at young ages. In elderly individuals, even the simpler falls may result in fractures [3–5].

The classification of fractures has a high impact on the treatment process today. This classification allows applying a treatment plan according to the fracture type and describing the relationship with soft tissue lesions. It is essential to have a good determination of the type of fracture and the level of injury. Thus, the treatment will be easier, and the recovery process will be accelerated. Colles fracture, Smith fracture, Barton fracture, Die-punch fracture, and Chauffeur's fracture are some of the DRF types [6].

Clinical and radiological findings of patients who applied to the hospital with wrist complaints are preliminary for treatment procedures. Direct radiography of DRF is the first step in evaluation. The initial assessment of direct radiographic images should include at least two radiographs – anteroposterior (AP) and lateral images. Oblique radiographs are also recommended for better visualization of various fracture lines. The long axis of the radius is used as the primary axis in all parameters used in the treatment and radiological follow-up of the fracture in the taken radiographs. Two of these parameters are radial inclination (RI) angle and volar cortical (VC) angle [7–9].

The RI angle is the angle between the tip of the styloid process and the vertical line drawn on the radius from the radial part of the distal radioulnar joint on the AP graph [10, 11]. The VC angle is the angle between the volar line drawn on the distal radius shaft and the line drawn to the distal metaphysis of the distal radius in the volar direction [12–14].

Volar plates aim to provide constant fixation in surgical procedures and are designed to reflect the natural anatomy. In certain DRF, the plates should fit anatomically on the volar surface of the distal radius. However, personal factors should be considered in the treatment planning of DRF, as well as clinical and radiological data. Factors such as age, gender, physical and cognitive condition, patient occupation, and open or closed fracture type are also important in planning treatment [15, 16]. Based on these specified factors, it is predicted that there may be changes in the anatomical VC angle according to age and gender. That has brought the discussion of how compatible standard anatomical plates will be.

In this study, we investigated the VC and RI angles depending on age and gender and the correlation between these two angles. That will allow preferring a suitable plate for the individual's anatomy during surgical procedures.

Methods

The research was carried out at the Adıyaman Provincial Health Directorate, Adıyaman Training and Research Hospital, and the Department of Orthopedics and Traumatology, Turkey. Our study was carried out by examining the records of patients who came to the Department of Orthopedics and Traumatology between January 1, 2015, and September 1, 2019. Ethical Approval (No. 2019/6-13, from September 17, 2019) was given by the decision of The Ethics Committee of Adıyaman University Faculty of Medicine.

Characteristics of the study groups

This study covers X-ray images of 121 adolescents and adults between the ages of 10 and 65 years who were admitted to the hospital between the specified dates and reported as healthy from patient records. Individuals with anatomical deformities in the distal radius due to traumatic, congenital, rheumatic, and similar conditions and those who had undergone surgical procedures on the distal radius were not included in the study.

The patients in this study were divided into two groups, a group of 60 adolescents (31 females, 29 males) under the age of 20 and 61 adults (28 females, 33 males) aged 20 and above. The 10–19 and 20–65 age groups were frequently used in previous wrist radiology studies. These age ranges were chosen in order to be compared with previous data [17–19]. In this study, two independent sample *t*-test procedures of the G*power (version 3.1.9.2) software were used to calculate the sample sizes of the groups by power analysis. The impact size was 0.85, targeted power 0.90, and significance level of 0.05 were considered bidirectional.

Radiographic evaluations

Wrist evaluation of patients was made with SG Healthcare Jumong U brand digital X-ray imagining system. In AP X-ray examination, the shoulder is positioned at 90° abduction, and the elbow is at shoulder level and 90° flexion. The palm is then placed on the X-ray machine. This position is the neutral supination-pronation state of the forearm. In lateral radiography, the patient is seated so that the forearm and hand are at the same level on the table. The shoulder is positioned at 0° abduction. The elbow is flexed 90°. The plane of the palm and the axis through the epicondyles of the humerus should be perpendicular to the table. The forearm should be in a fully lateral position. The wrist is placed sideways on the table so that the radius and ulna overlap and are superposed [20].

Measurement tools and techniques

One hundred and twenty-one patients with forearm and wrist complaints, who had not experienced any wrist trauma or surgical procedures, applied to the Department of Orthopedics and Traumatology of the Adıyaman Training and Research Hospital. The radiographs of these patients were taken by the standard radiographic imag-ing technique. The relevant points were marked, and measurement points were assigned with the 3.0.1.55 version of the KarPacsViewer application. Then, the distance between the determined points was measured with the aid of the application. The VC angle was obtained from lateral radiographs: a – straight line drawn along the volar surface of the shaft of the distal radius; b – the line following the anterior cortex of the distal end of the radius; c – VC angle (Figure 1). The RI angle was obtained from AP radiographs: x – the axis along the radius shaft; y – the line drawn between the radius styloid tip and the ulnar border of the distal radius; z – the line perpendicular to the radius shaft; v – RI angle (Figure 2).

Statistical analysis

Statistical analyses were made using the SPSS 15.0 program. The suitability of quantitative variables to normal distribution was evaluated with the single sample Kolmogorov-Smirnov test. An independent two-sample *t*-test was used in the comparison of two independent groups. Results are given as mean ± standard deviation (SD). Linear regression analysis and Pearson correlation status were evaluated for predictions and associations between age and anatomical measurements. The results of the categorical variables were given as frequency and percentage. The significance level was accepted as at least $p < 0.05$. The *r* value indicates the correlation coefficient. The strength of the correlation was determined by the *r* value close to 1 or -1. The strength of correlation was determined according to Quinnipiac University [21].

Results

The RI angle was 23.31° in women and 23.27° in men. The VC angle was 160.10° for women and 158.43° in men. When women and men were compared in terms of VC angles, no statistically significant difference was found ($p = 0.958$, $p = 0.165$, respectively).

When the results were assessed according to gender, there was no statistically significant relationship between RI angle and age in women (n = 59) ($p = 0.301$; $r = 0.137$), while a significant relationship and moderate correlation coefficient were found between the VC angle and age; it was also

Fig. 1 – Volar cortical angle was obtained from lateral radiographs: a – straight line drawn along the volar surface of the shaft of the distal radius; b – the line following the anterior cortex of the distal end of the radius; c – volar cortical angle.

Fig. 2 – Radial inclination angle was obtained from anteroposterior radiographs: x – the axis along the radius shaft; y – the line drawn between the radius styloid tip and the ulnar border of the distal radius; z – the line perpendicular to the radius shaft; v – radial inclination angle.

observed that as age increased, the VC angle was decreasing (p = 0.004; r = -0.365) in women. However, there was no statistically significant relationship between the RI and VC angles (p = 0.854; r = 0.024). In males (n = 62), it was observed that both RI and VC angles decreased significantly as the age increased, and the correlation coefficient was strong (p = 0.032, r = -0.273; p < 0.0001, r = -0.445, respectively). However, no statistically significant relationship was found between RI and VC angles (p = 0.873; r = -0.021) (Table 1).

A comparison of the RI and VC angle features by age groups was made in men and women. There was no significant difference in the RI angle among the age groups in women (p = 0.334). In terms of the VC angle, a significant difference was found in age groups (p = 0.005). The RI and VC angle values of the 10–19 age group in males were significantly higher than in the 20–65 age group (p = 0.018, p = 0.0001, respectively). When the angle values of the RI and VC angle properties were examined according to gender groups by making age distinction, it was determined that both the RI and VC angle values did not differ according to gender between the ages of 10–19 years (p = 0.119, p = 0.858, respectively). Similarly, in the 20–65 years age range, it was determined that both the RI and VC angle values did not differ according to gender (p = 0.099, p = 0.077, respectively) (Table 2).

When the regression analysis graph of the angle values between the ages of 10–19 years was evaluated, there was no significant increase or decrease in RI angle with increasing age in this age range (p = 0.753). Angle change was independent of the 10–19 years age range (Figure 3).

When the regression analysis graph of the VC angle values between the ages of 10–19 years was evaluated, the VC angle showed a change with age. There was a significant decrease in VC angle as age increased in the 10–19 years age range (p = 0.012). The correlation coefficient strength was moderate (r = 0.32) (Figure 4).

In Figure 5, the regression analysis graph of the RI angle values between the ages of 20–65 years is given. In this age range, there was no significant increase or decrease in the RI with increasing age (p = 0.868). The RI angle change was independent of the age range of 20–65 years.

In Figure 6, the regression graph of the VC angle values for subjects in the 20–65 years group is given. In this age range, there was no significant increase or decrease in VC angle with increasing age (p = 0.981). VC angle change was independent of the age range of 20–65 years.

Table 1

Relationship of radial inclination (RI) and volar cortical (VC) angles with age and gender

Gender	RI angle	VC angle	Age
Women (n = 59)			
RI angle			
Pearson correlation	1	0.024	0.137
p-value		0.854	0.301
VC angle			
Pearson correlation	0.024	1	-0.365
p-value	0.854		0.004
Men (n = 62)			
RI angle			
Pearson correlation	1	-0.021	-0.273
p-value		0.873	0.032
VC angle			
Pearson correlation	-0.021	1	-0.445
p-value	0.873		< 0.001

Pearson correlation test was applied.

Table 2

Comparison of radial inclination (RI) and volar cortical (VC) angle features by age groups and gender

Parameter	Gender	n	Mean ± SD	*p*-value*	
				gender (w/m)	age groups, yeras (10–19/20–65)
Age 10–19 years					
RI angle	w	31	22.81 ± 4.42	0.119	0.334
	m	29	24.40 ± 3.19		
VC angle	w	31	162.29 ± 5.23	0.858	0.005
	m	29	162.54 ± 5.54		
Age 20–65 years					
RI angle	w	28	23.85 ± 3.71	0.099	0.018
	m	33	22.28 ± 3.61		
VC angle	w	28	157.69 ± 6.85	0.077	< 0.001
	33	33	154.82 ± 5.62		

w – women; m – men; n – number; SD – standard deviation.
*** – two independent sample *t*-tests were used.**

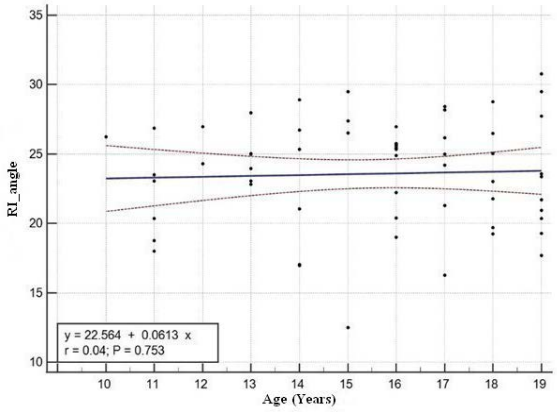

Fig. 3 – Regression analysis graph of the radial inclination angle in the 10–20 years age group.

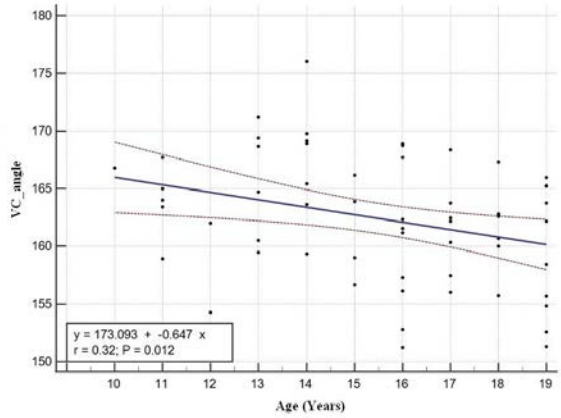

Fig. 4 – Regression analysis graph of the volar cortical angle in the 10–20 years age group.

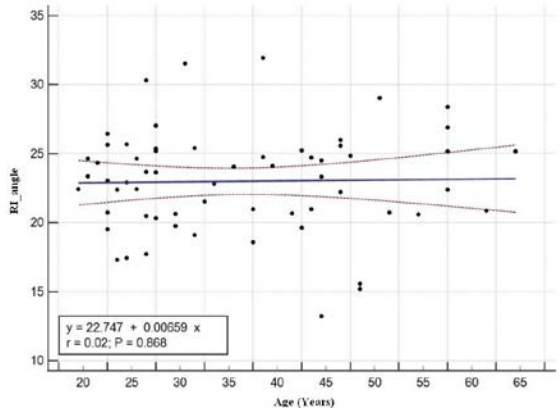

Fig. 5 – Regression analysis graph of radiation inclination angle in the 20–65 years age group.

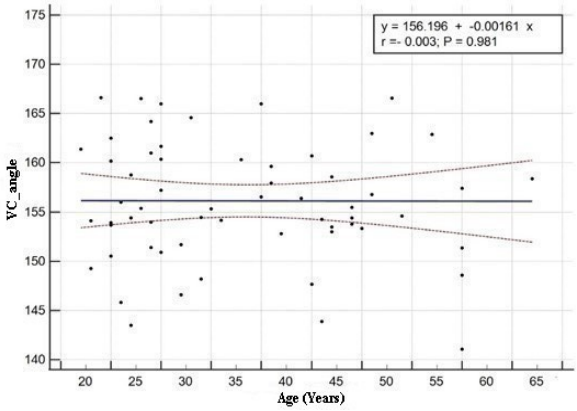

Fig. 6 – Regression analysis graph of volar cortical angle in the 20–65 years age group.

Discussion

The harmony between the bone, tendon, joint surfaces, and soft tissues is essential during hand and wrist-related movements. These structures are affected by fractures and injuries in bones [1, 2], and the VC angle is among the parameters used in the treatment and radiological follow-up of fractures [7–9]. Conservative or surgical operation procedures are performed on the fractures. Plating with volar and dorsal plates, fixation with an external fixator, and wiring with Kirschner wires are among the methods that can be encountered in surgical techniques. Today, fixed-angle anatomical plates are applied. However, since people may have anatomical variations, new techniques have been searched [22–25]. Gender and age factors are important values for us in plate applications. In addition, considering the age factor, the age group under 20 and the age group aged 20 and above should be considered as a category that should be evaluated. In light of this information, the correlation of the distal radius angle with the VC angle and age-related changes was investigated in our study. A few studies on this subject were found in the literature studies.

Namazi and Khaje [18] found the mean angle as 23.78° in individuals over 20 years of age on distal radius radiography images. No significant difference between men and women in any age group regarding mean variables was found. The results of this study and our study are similar. In our study, the angle was 23.31° in women and 23.27° in men. There was no significant difference between men and women in terms of angle. Ağır et al. [13] found that VC angles varied between 134.50 and 158.40. In our research, the VC angle was 160.10° in women and 158.43° in men. The variability of VC angles should be considered anatomically in fixed-angle locked volar plates.

Kwon et al. [26] investigated the harmony between anatomic plate designs and the morphometric variations of the distal radius in the volar direction. The findings of this study using computed tomography images showed that the results varied by race and gender. Kwak et al. [27] investigated the compatibility of volar-locked plates to the volar cortex of the distal radius, and VC angles of the radial and middle columns of the volar-locked plates were determined. The results were compared with the VC angles of the distal radius of 90 cadavers. Variability was observed in the columns and volar angles. As a result of these studies, it was predicted that the anatomic volar-locked plate should be chosen carefully, and a plate with appropriate angulation should be preferred for each patient.

Gandhi et al. [14] reported that the VC angle decreases with age. In addition, there was a difference between the

genders, and it was observed that the VC angle in men was wider than in women. They found the mean VC angle value greater in terms of the locked plates used. The conclusion of this study that the VC angle decreases with age is similar to the findings of our study. In this study, it was found that the VC angle in men was wider than in women. In contrast, our study showed no statistically significant difference in the values of VC angles in men and women.

Evans et al. [28] investigated the suitability of the VC angle to modern volar plate designs in their studies. The VC angle in men was found to be significantly higher than in females. However, no correlation was found between age and VC angle in the study. This study showed that the VC angle measured at the distal radius is significantly greater than the volar angulation incorporated in modern plate design. In our study, it was determined that VC values did not differ according to gender. Furthermore, in our study, a significant difference was found when the VC angle was compared in men and women according to age groups.

Gandhi et al. [14] reported that the VC angle decreased significantly between the ages of 20 and 80, regardless of gender. In our study, VC decreased significantly only in patients 10–19 years of age. No increase or decrease was observed in later age.

The present study has several limitations. In our study, we included adults from 20 to 65 years old as one of our groups. In order to conduct a more detailed study, it may be beneficial to focus on a specific age group within the range mentioned. Evaluating separately age groups such as 20–35, 35–50, and 50–65 years could provide more in-depth analysis. Therefore, further research is necessary to compare our results.

Conclusion

We believe that our findings regarding the RI and VC angles will offer an advantage in determining the appropriate plate designs and planning surgical procedures and treatment processes. We are also of the opinion that technological advances in medical devices should be followed and applied to patients within specific criteria.

Conflict of interest

The authors declare no conflict of interest.

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REFERENCES

1. *Rainbow MJ, Wolff AL, Crisco JJ, Wolfe SW*. Functional kinematics of the wrist. J Hand Surg Eur Vol 2016; 41(1): 7–21.
2. *Rosenauer R, Pezzei C, Quadlbauer S, Keuchel T, Jurkowitsch J, Hausner T,* et al. Complications after operatively treated distal radius fractures. Arch Orthop Trauma Surg 2020; 140(5): 665–73.
3. *Mader K, Pennig D*. The treatment of severely comminuted intra-articular fractures of the distal radius. Strategies Trauma Limb Reconstr 2006; 1(1): 2–17.
4. *Handoll HH, Huntley JS, Madhok R*. External fixation versus conservative treatment for distal radial fractures in adults. Cochrane Database Syst Rev 2007; (3): CD006194.
5. *Balik MS, Gurbuz H*. Results of external fixator treatment in distal radius intra-articular fractures. Hand Microsurg 2019; 8(2): 80–90.
6. *Acosta-Olivo C*. Distal radius fractures: still a common problem. Medicina Universitaria 2017; 19(76): 140–2.
7. *Vatansever A, Pişkin A, Kayalar M, Bal E, Ada S*. The effect of dorsal cortical comminution on radiographic results of unstable distal radius fractures treated with closed reduction and K-wire fixation. Acta Orthop Traumatol Turc 2007; 41(3): 202–6. (Turkish)
8. *Duymus TM, Mutlu S, Komur B, Mutlu H, Yucel B, Parmaksizoglu AS*. Measurement of malrotation on direct radiography in pediatric distal radius fractures: prospective observational study. Medicine (Baltimore) 2016; 95(18): e3569.
9. *Oc Y, Kilinc BE, Gulcu A, Varol A, Ertugrul R, Kara A*. Ultrasonography or direct radiography? A comparison of two techniques to detect dorsal screw penetration after volar plate fixation. J Orthop Surg Res 2018; 13(1): 70.
10. *Stirling E, Jeffery J, Johnson N, Dias J*. Are radiographic measurements of the displacement of a distal radial fracture reliable and reproducible? Bone Joint J 2016; 98-B(8): 1069–73.
11. *Fox S, Johnston G, Stewart S*. Improved precision of radiographic measurements for distal radius fractures after a technique-teaching tutorial. Can J Surg 2020; 63(3): E261–71.
12. *Kilic A, Ozkaya U, Kabukcuoglu Y, Sokucu S, Basilgan S*. The results of non-surgical treatment for unstable distal radius fractures in elderly patients. Acta Orthop Traumatol Turc 2009; 43(3): 229–34.
13. *Ağır I, Aytekin MN, Küçükdurmaz F, Başci O, Tetik C*. Distal radius measurements and efficacy of fixed-angle locking volar plates. Turk J Med Sci 2014; 44(1): 36–41.
14. *Gandhi RA, Hesketh PJ, Bannister ER, Sebro R, Mehta S*. Age-related variations in volar cortical angle of the distal radius. HAND (N Y) 2020; 15(4): 573–7.
15. *Imatani J, Akita K*. Volar distal radius anatomy applied to the treatment of distal radius fracture. J Wrist Surg 2017; 6(3): 174–7.
16. *Jose A, Suranigi SM, Deniese PN, Babu AT, Rengasamy K, Najimudeen S*. Unstable distal radius fractures treated by volar locking anatomical plates. J Clin Diagn Res 2017; 11(1): RC04–8.
17. *Brennan SA, Kiernan C, Beecher S, O'Reilly RT, Devitt BM, Kearns SR,* et al. Volar plate versus k-wire fixation of distal radius fractures. Injury 2016; 47(2): 372–6.
18. *Namazi H, Khaje R*. Normal age-related alterations on distal radius radiography. Arch Bone Jt Surg 2015; 3(4): 250–3.
19. *Ballal A, Sadasivan AK, Hegde A, Shetty A*. Open reduction and volar plate fixation of dorsally displaced distal radius fractures: a prospective study of functional and radiological outcomes. J Clin Diagn Res 2016; 10(12): RC01–4.
20. *Baek GH, Lee HJ, Gong HS, Rhee SH, Kim J, Kim KW,* et al. Long-term outcomes of ulnar shortening osteotomy for idiopathic ulnar impaction syndrome: at least 5-years follow-up. Clin Orthop Surg 2011; 3(4): 295–301.
21. *Akoglu H*. User's guide to correlation coefficients. Turk J Emerg Med 2018; 18(3): 91–3.

22. *Forward DP, Davis TR, Sithole JS*. Do young patients with malunited fractures of the distal radius inevitably develop symptomatic post-traumatic osteoarthritis? J Bone Joint Surg Br 2008; 90(5): 629–37.
23. *Wilcke MK, Abbaszadegan H, Adolphson PY*. Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year: A randomized study of 63 patients with a dorsally displaced fracture of the distal radius. Acta Orthop 2011; 82(1): 76–81.
24. *Roh YH, Lee BK, Baek JR, Noh JH, Gong HS, Baek GH*. A randomized comparison of volar plate and external fixation for intra-articular distal radius fractures. J Hand Surg Am 2015; 40(1): 34–41.
25. *Solarino G, Vicenti G, Abate A, Carrozzo M, Picca G, Colella A,* et al. Volar locking plate vs epibloc system for distal radius fractures in the elderly. Injury 2016; 47(Suppl 4): S84–90.
26. *Kwon BC, Lee JK, Lee SY, Hwang JY, Seo JH*. Morphometric variations in the volar aspect of the distal radius. Clin Orthop Surg 2018; 10(4): 462–7.
27. *Kwak DS, Lee JY, Im JH, Song HJ, Park D*. Do volar locking plates fit the volar cortex of the distal radius? J Hand Surg Eur Vol 2017; 42(3): 266–70.
28. *Evans S, Ramasamy A, Deshmukh S*. Distal volar radial plates: how anatomical are they? Orthop Traumatol Surg Res 2014; 100(3): 293–5.

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