

# ANATOMICAL STUDY OF VOLAR FACE OF DISTAL RADIUS AND COMPARISON WITH THE SHAPE OF LOCKING VOLAR PLATES

## ESTUDO ANATÔMICO DA FACE VOLAR DA EXTREMIDADE DISTAL DO RÁDIO E COMPARAÇÃO COM O FORMATO DAS PLACAS VOLARES BLOQUEADAS

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### ABSTRACT

**Objective:** To evaluate the volar cortical angle (VCA), the variation in lateral and intermediate columns, the shape and pattern of the watershed line (WL) of the distal radius and its correlation with locking volar plates available. **Methods:** 27 human cadaveric radial bones of the Department of Morphology and nine locking volar plates of six different companies were analyzed. VCA were measured from lateral and intermediate columns and their corresponding values on plates, as well as comparing the relief of radius and plates. In the WL analysis, we compared the standard format found on the radius and its equivalent on plates and divided into four types: biconvex, convex, ulnar convex and plan. **Results:** VCA varied between columns of the distal radius extremity. The mean in the lateral column was 153.40 degrees and 146.06 degrees in the intermediate. Four of nine plates showed no variation in volar angulation. From 27 distal radius, 13 showed convex pattern and 12 had biconvex, whereas most plates (seven of the nine analyzed) were biconvex drawing. **Conclusion:** Radial bone anatomy was variable. The intermediate column was, on average, steeper than lateral column. Synthes®-2 plate presented the closest design to the anatomy of the distal end of the radial bone, followed by Newclip®-2 plate. **Level of Evidence II, Anatomic and Descriptive Study.**

**Keywords:** Anatomy, Regional. Radius Fractures. Bone Plates. Radius.

### RESUMO

**Objetivos:** Avaliar o ângulo palmar cortical (APC) da extremidade distal do rádio, sua variação nas colunas lateral e intermédia, o formato e o padrão da watershed line (WL) e sua correlação com as placas volares bloqueadas disponíveis no mercado. **Métodos:** Foram analisados 27 ossos rádios do Departamento de Morfologia e nove placas de seis fabricantes diferentes. Medimos os APCs das colunas lateral e intermédia dos rádios e seus correspondentes nas placas, além de compararmos o relevo do terço distal do rádio e das placas. Quanto a WL, comparamos o formato nas peças e seu equivalente nas placas, sendo classificados em quatro tipos: biconvexo, convexo, convexo ulnar e plano. **Resultados:** O APC variou entre as colunas do rádio, sendo a média da coluna lateral 153,40° e, da intermédia 146,06°. Quatro das nove placas não apresentaram variação na angulação volar. Dos 27 rádios, 13 apresentaram padrão convexo e 12 biconvexo, enquanto a maioria das placas (sete das nove analisadas) tinham desenho biconvexo. **Conclusão:** A anatomia dos rádios foi variável entre as peças, sendo a coluna intermédia mais inclinada que a coluna lateral. A placa Synthes®-2 foi a que apresentou relevo mais próximo dos achados anatômicos da extremidade distal do rádio, seguida pela Newclip®-2. **Nível de Evidência II, Estudo Anatômico Descritivo.**

**Descritores:** Anatomia Regional. Fraturas do Rádio. Placas Ósseas. Rádio (Anatomia).

**Citation:** Lima LC, Costa AC, Salgado OS, Onoue ACF. Anatomical study of volar face of distal radius and comparison with the shape of locking volar plates. *Acta Ortop Bras.* [online]. 2022;30(5): Page 1 of 5. Available from URL: <http://www.scielo.br/aob>.

### INTRODUCTION

Fractures in the distal end of the radius are frequent in an orthopedic surgeon's routine, being responsible for 18% of all fractures.<sup>1-4</sup> They present a bimodal distribution, affecting mainly children between the ages 10 and 14 and women over 50, the latter related to bone fragility.<sup>5</sup>

Currently, several therapeutic options are available: plaster casts, external fixators, percutaneous pin fixation, and modern locking volar plates.<sup>1,6</sup>

Locking volar plates were introduced in clinical practice in the 1990s, showing excellent biomechanical results,<sup>1,7</sup> with fewer complications

All authors declare no potential conflict of interest related to this article.

The study was conducted at School of Medical Sciences of Santa Casa de Misericórdia de São Paulo.

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Article received on 11/03/2021, approved on 01/28/2022.



related to soft tissues than dorsal plates<sup>6,8-12</sup> and allowing early wrist movement.<sup>3,13</sup> The main indications for locking volar plate treatment are: unstable extra-articular fractures (especially in osteoporotic bones), most articular fractures, and vicious consolidations of the distal third of the radius.<sup>14</sup>

Several studies demonstrate an incompatibility between plates and the anatomy of the radial distal end.<sup>1,15</sup> Most plates have a 155° palmar cortical angle (PCA) over its entire length, which is the angle between the volar lip cortical and the radial shaft. However, Bassi et al.<sup>16</sup> demonstrated 143° as the mean value, whereas Evans, Ramasamy and Deshmukh<sup>7</sup> demonstrated a 147° mean. Parameters such as the distal transverse relief of the radius and the watershed line (WL) design were less studied. The design of the implants used, and their positioning related to the WL may influence the occurrence of iatrogenic tendon injuries.<sup>9,17</sup>

Our objectives are to study the relief of the volar face of the distal end of the radius, especially the difference in the volar inclination between the columns and the WL shape, and to compare it with other locking volar plates in the market.

## METHODS

After the Research Ethics Committee's approval (Opinion No. 1,226,567), we conducted a study with 34 pieces of radial bones from the Department of Morphology of the School of Medical Sciences of Santa Casa de São Paulo.

Bones with damaged features and/or less than 21 cm of length were excluded, resulting in 27 bones.

Transparent adhesive tape was used on the radiuses to mark the anatomical references with a permanent pen without damaging the pieces. The length was measured and divided by three to calculate the distal third of the bone. A transverse line was drawn along the axis of the radius, passing through the largest diameter of the distal end of the bone. With the aid of a pachymeter, the midline of the radius was identified, connecting the midpoint of the distal end to the midpoint of the transition between the middle and distal thirds of the radius, in the coronal plane. Then, two lines parallel to the midline

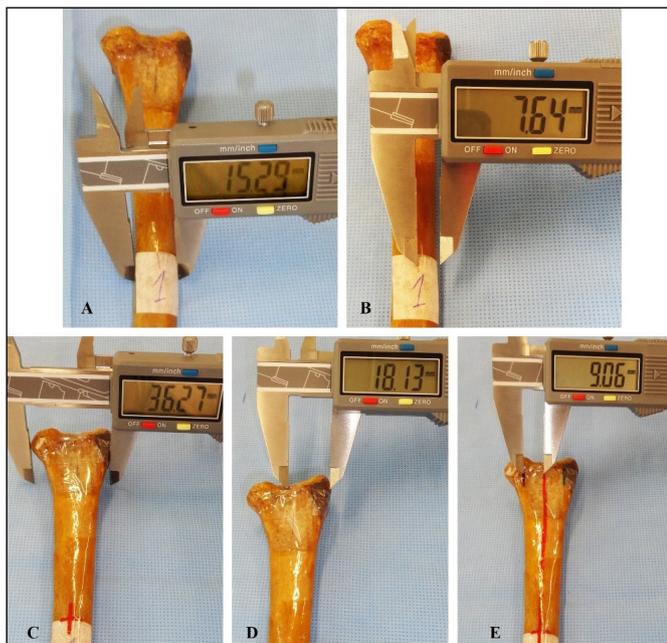
were drawn, which divided the transverse line into four equal parts, corresponding to the midpoint of the lateral and intermediate columns of the distal third of the radius (Figure 1). The WL was then drawn.

With the aid of a contour gauge (*General*<sup>®</sup>, no. 337, USA), the transcription of the radial volar face was performed at four points: a) longitudinal plane, in the midline of the volar face of the distal radius; b) longitudinal plane, at the midpoint of the volar face of the lateral column; c) longitudinal plane, at the midpoint of the volar face of the mid column; d) transverse plane, perpendicular to the long axis of the radius, 1 cm proximal to the radial volar edge.

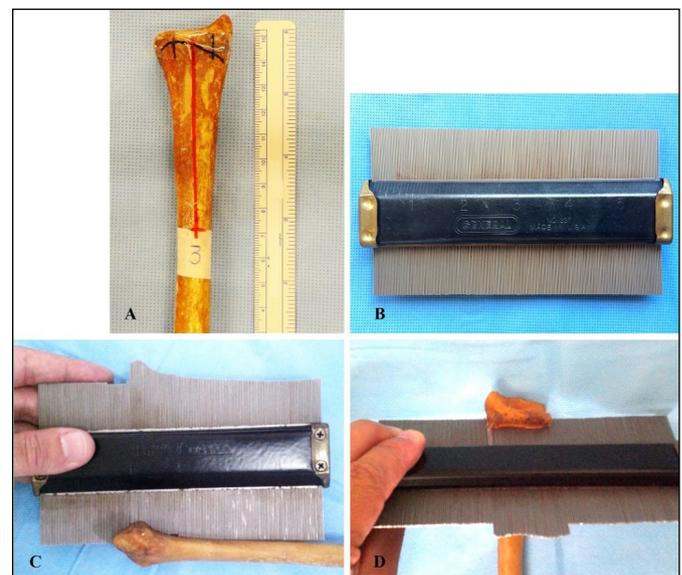
We used a Sony<sup>®</sup> DSC-H70 digital camera with a tripod, at a standard distance, to photograph the volar face of the radiuses and the transcriptions with the gauge (Figure 2).

The images were evaluated using the AutoCad 2015<sup>®</sup> software, with measurements of the inclination angle of the distal surface of the radius in the volar plane of the lateral and intermediate columns and in the midline of the distal end. A line was drawn on the gauge corresponding to the shaft of the radius (A) and another line corresponding to the distal volar cortical of the radius in each column (B). The angle between these lines was measured and represented as PCA (Figure 3).

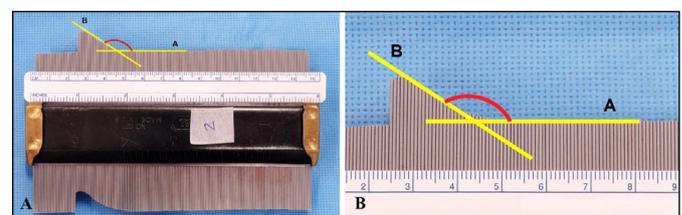
To delimit the WL, the bone crest present on the volar face of the radial distal third was drawn, considering the most prominent point. Points A (crossing with the lateral column) and B (crossing with the intermediate column) were identified. A straight line was drawn by joining points A and B to measure the WL angle (between the AB line and the midline of the radius) on the ulnar side of the radius (Figure 4). Three classifications were created for this study, all performed by three orthopedists specialized in hand and wrist. One of them analyzed the WL design, dividing it into four types: I) biconvex; II) convex; III) ulnar convex; IV) flat (Figure 5).



**Figure 1.** A) Measurement of the radial width; B) Midpoint identification; C) Measurement of the width of the distal epiphysis; D) Midpoint identification, where the midline passes; E) Identification of the midpoints of the lateral and intermediate columns.



**Figure 2.** A) Radial volar face after marking the references; B) Contour gauge; C) Longitudinal transcription of the midline; D) Transversal transcription.



**Figure 3.** A) Measurement of the PCA in each column; B) Enlarged view.

The relief of the transverse cut to the axis of the radius was classified into four types: I) flat; II) concave; III) convex; IV) S-shaped (Figure 6). We analyzed the locking volar plates of Acumed®, Austofix®, Medartis®, Newclip®, Stryker®, and Synthes®, all supplied by their representing companies in Brazil, which agreed to participate in the study (Figure 7). The plates were photographed and, with the aid of AutoCad 2015®, the palm angles and distal inclination of each plate were taken (Figure 8).

For the distal end design of the plates, the classification was defined in 3 types: I) straight; II) biconvex; III) ulnar convex (Figure 9).

For this statistical analysis, the programs SPSS V17, Minitab 16 and Excel Office 365 were used. A significance level of 0.05 (5%) was adopted, and the confidence intervals were constructed with 95% of statistical confidence. We used the nonparametric Friedman test and the Wilcoxon signed-rank test (paired).



Figure 4. Measurement of the WL angle.

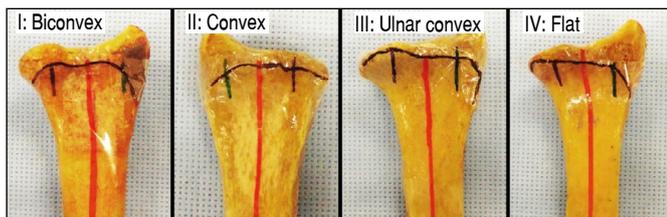


Figure 5. WL Classification.

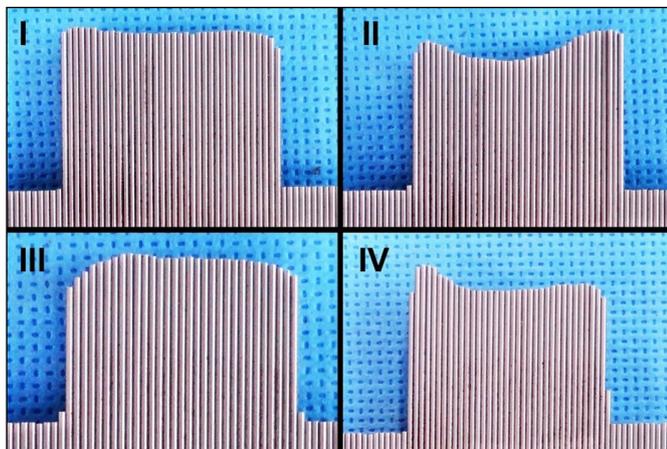


Figure 6. Classification of the transverse reliefs of the distal end of the radius.

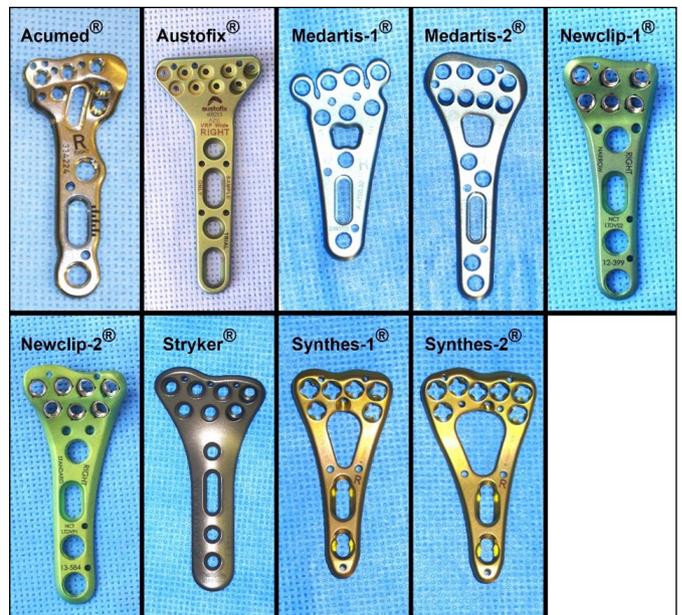


Figure 7. Plates evaluated in the study.

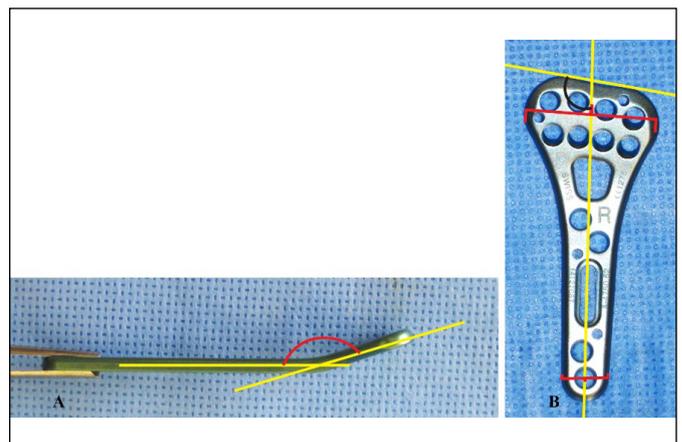


Figure 8. A) Measurement of the volar inclination angle of each plate (equivalent to the PCA of the lateral and intermediate columns); B) Measurement of the inclination of the distal end of the plate.

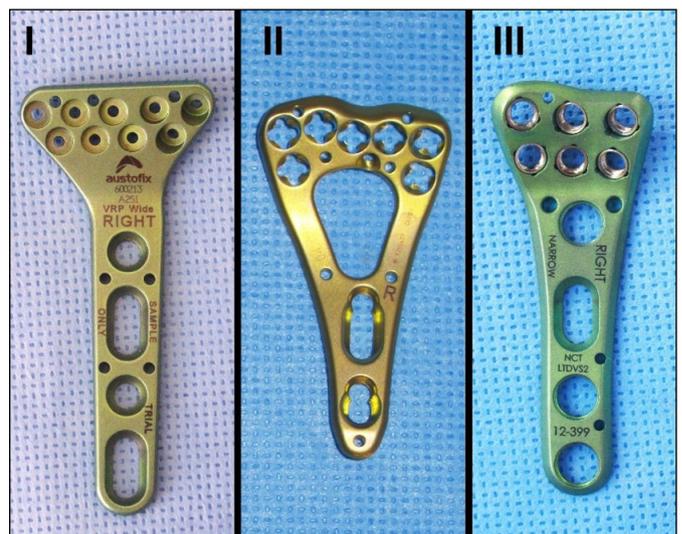


Figure 9. Classification of the design of the distal end of the plates.

## RESULTS

Table 1 shows data measuring the PCA of the radius in the lateral, intermediate, and mid columns. We found statistical significance between the lateral and mid columns ( $P = 0.027$ ), lateral and intermediate columns ( $< 0.001$ ), and mid and intermediate columns ( $< 0.001$ ) when compared by themselves, helped by the Wilcoxon test. Regarding the transverse relief of the radius, we found 4 concave reliefs, 2 convex reliefs, 6 flat reliefs, and 15 S-shaped reliefs.

Regarding the WL design, we found 12 biconvex designs, 13 convex designs, 1 flat design and 1 convex ulnar design.

The mean WL angle of the radial bones was  $95.2^\circ$ . Table 2 provides this measurement and the equivalent angle of the plates.

Table 3 shows the plates, the measurement of the inclination angles of the ulnar and radial ends, and the design of the distal end.

Figure 10 shows the distribution of the angles of the radial and intermediate columns of the radiuses and the equivalent values of the plates.

## DISCUSSION

Locking volar plates have been used in radial distal fracture treatment, presenting a lower degree of complication than other methods.<sup>6,7,11,18</sup> However, several studies demonstrate incongruity between the profile of the plates and the anatomy of the radial distal end.<sup>1,15</sup>

Some studies described the anatomical differences of the sexes regarding measurements and radial surface. These studies observed that the angles of volar inclination of the radius were greater in men.<sup>7,19-21</sup> Gandhi et al.<sup>3</sup> described that the PCA decreases with age, and men have a higher mean PCA, suggesting that current locking plates fit better in older women. Kwon et al.<sup>11</sup> studied differences between Caucasian and Korean individuals, noting that Koreans presented a greater width of the distal region

**Table 1.** Data of cortical palmar angle (PCA) of the radius, in degrees, in the lateral, intermediate, and mid columns. P-value defined by the Friedman test, with statistical significance.

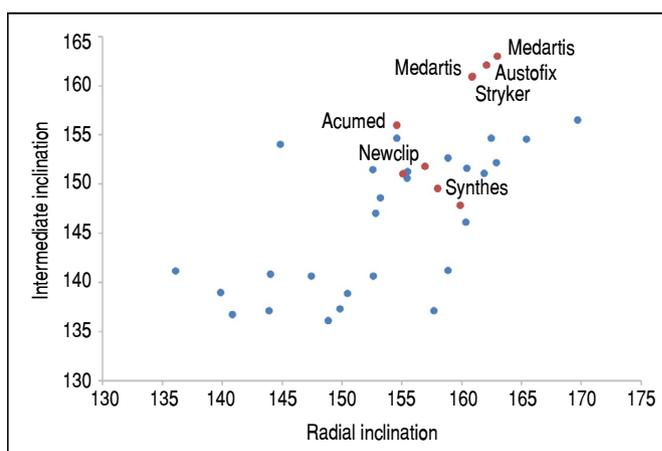
Profile (Bone)	Lateral	Midline	Intermediate
Mean	153.40°	156.20°	146.06°
Median	153.21°	156.39°	147.04°
Standard Deviation	8.35	7.89	6.99
Q1	148.16°	150.20°	139.79°
Q3	159.63°	161.86°	151.88°
n	27	27	27
IC	3.15	2.97	2.64
p-value	< 0.001		

**Table 2.** WL angle measurement, in degrees, on the anatomical pieces and plates.

RADIAL BONES/PLATES	WL Angle
Radial Bones Mean	95.2°
Medartis-2®	100.7°
Stryker®	98.9°
Newclip-1®	98°
Newclip-2®	97.8°
Synthes-2®	94.3°
Synthes-1®	90.9°
Austofix®	87.1°
Acumed®	84.2°
Medartis-1®	79.2°

**Table 3.** Measurement of the inclination angles, in degrees, of the radial and ulnar ends of the plates and design of the distal end.

PLATE	Radial volar inclination	Ulnar volar inclination	Design of the distal end
Acumed®	154.6°	155.9°	biconvex
Austofix®	162°	162°	flat
Medartis-1®	163°	163°	biconvex
Medartis-2®	160.9°	160.9°	biconvex
Newclip-1®	155.1°	151°	ulnar convex
Newclip-2®	156.9°	151.7°	biconvex
Stryker®	160.8°	160.8°	biconvex
Synthes-1®	159.8°	147.8°	biconvex
Synthes-2®	158°	149.5°	biconvex



**Figure 10.** Distribution of the angles of the radial and intermediate columns of the radiuses and the equivalent inclinations of the plates.

of the radius compared to Caucasians, as well as Korean men when compared with Korean women. Cho, Kim and Kwak<sup>21</sup> also described the width of the distal epiphysis of the major radius in males. The absence of publications about radial shape differences in Brazilians supports the importance of the present study. Rikli and Regazzoni<sup>22</sup> established the concept of the three columns by dividing the distal end of the forearm into: lateral column, formed by the radial styloid and sigmoid notch; intermediate column, formed by the semilunar notch and sigmoid notch; and medial spine, formed by the ulna, triangular fibrocartilage, and distal radioulnar joint. Based on this, we analyzed the PCA measurements in the lateral, intermediate, and central columns of the radius. The intermediate column showed significant mean inclination ( $p < 0.001$ ), since the inclination is inversely proportional to the PCA. Evans, Ramasamy, and Deshmukh<sup>7</sup> also found differences in the lateral, intermediate and medial columns ( $149^\circ$ ,  $145.9^\circ$  and  $146.2^\circ$  respectively). However, they found different values from ours, with a smaller difference between them, since they obtained the three measurements more medially and closer between them. Gasse et al.<sup>23</sup> found  $155.3^\circ$  and  $144.9^\circ$  as the mean angle in the lateral intermediate columns, respectively, values closer to those found in our study. Im and Lee<sup>20</sup> found a greater inclination in the middle column ( $151.9 \pm 7.6^\circ$ ) compared with the lateral column ( $156.1 \pm 7.2^\circ$ ). Kwon et al.<sup>11</sup> also found values close to the studies of Im and Lee<sup>20</sup> and Kwak et al.,<sup>19</sup> in which the mean angle in the mid column was 3 to  $10^\circ$  wider than in the lateral column.

Analyzing the transverse plane was another way of evaluating the difference in relief between the columns. Most radial bones

presented an s-shaped pattern, with the intermediate column having the most swollen end.

In a study of seven types of locking volar plates, Oppermann et al.<sup>15</sup> demonstrated a palmar angle of the plates ranging from 155° to 161°, and they were straight plates that did not present differences in the radial and intermediate columns. These values do not coincide with those found in our study (ulnar inclination ranging from 147° to 163° and radial inclination from 154° to 163°), which may relate to different methods of measuring angles. Kwak et al.<sup>19</sup> compared the PCA of wide and narrow plates of three different manufacturers and observed variations between them: the distally wider plates (with five holes) present a greater inclination of the radial and intermediate columns. In our study, only two manufacturers provided two different plate sizes: Newclip® and Synthes®. The Newclip® wide plate presented the greatest inclination of the radial and intermediate columns, but compared with Synthes®, the narrow plate presented the greatest inclination of both columns. Medartis® provided two plates models, but both are straight, with the same inclination over the distal region.

Of the nine plates studied, four did not show differences between the columns. On the Acumed plate®, the inclination was slightly greater in the lateral column. We believe the inclination of the plate should be greater in the intermediate column. The plates that showed values closer to those of bone anatomy, in this parameter, were Synthes®-2 and Newclip®-2. Oppermann et al.<sup>15</sup> found a better adaptation to the anatomical profile on the Synthes plate®.

Regarding the WL, we believe that, except for a straight plate (Austofix®) and another one with a more irregular design (Medartis-1®), all would adapt well to the WL.

When comparing the WL with the distal inclination of the plates, the Synthes®-2 and Newclip®-2 plates presented an inclination closer to the one found in the bones, whereas the Medartis®-1 and Acumed® plates presented the most distant values from each other.

## CONCLUSION

We conclude that the anatomy of the radial bones was variable between the pieces. The intermediate column presented greater mean inclination than the midline and side columns. The Synthes®-2 plate showed a relief closer to the anatomical findings of the distal end of the radius, followed by Newclip®-2.

Regarding the WL format, except for the Austofix® straight plate and another one with a more irregular design (Medartis-1®), all would adapt well to the WL. When comparing the WL with the distal inclination of the plates, the Synthes®-2 and Newclip®-2 plates presented an inclination closer to the one found in the bones, while the Medartis®-1 and Acumed® plates presented the most distant values from each other.

## ACKNOWLEDGEMENTS

We would like to thank the manufacturers of the plates that agreed to participate in our study and the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Financing Code 001.

**AUTHORS' CONTRIBUTIONS:** Each author contributed individually and significantly to the development of this article. LCL: data collection, data analysis, writing of the article, approval of the final version of the article; ACC: work design, data analysis, writing of the article, approval of the final version; PSS: interpretation of the data, writing of the article, approval of the final version of the article; ACFO: data collection, writing of the article, approval of the final version of the article.

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