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Stature Estimate by the Upper Arch – Carrea´s Method Modified

Estimación de la Estatura por Medio del Arco Superior – Método de Carrea Modificado

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ABSTRACT: The Carrea's index is an alternative to estimate the human stature. However, in cases when the jaw is affected, this technique becomes impracticable. Expanding the use of the Carrea's index, by extending it to the upper elements, would increase the chances of the method, especially in cases when only the skull is available for analysis. The aim of the study was to test a new denominator for Carrea's index, so that it could be used for the upper arch, aiming at a new feature to estimate human stature. Plaster models of the arch and the string of the upper arch of 107 dentistry students, aged between 18 and 30 years, previously submitted to anthropometric analysis, were measured with a digital caliper. The data found were inserted in software developed to find a denominator that would result in a higher number of correct answers to real statures, evaluating the left and the right hemiarch, and their average. For the right hemiarch, the denominator with more accuracy for the real stature was the interval from 2.573 to 2.583, with 58.9 %. For the left hemiarch, the best values were from 2.553 to 2.554 with 63.6 %. The average of hemiarchs had as ideal denominator values between 2.579 and 2.581, with 60.7 %. We found no significant statistical difference between denominators. It was possible to obtain a new denominator to apply Carrea's index for the upper arch. The new method had satisfactory accuracy rate and should be tested in other populations to verify its applicability.

KEY WORDS: forensic dentistry, forensic anthropology, skull, body height, dental arch.

INTRODUCTION

Due to the effectiveness demonstrated by the use of the dental elements for human identification, nowadays dental surgeons are widely respected as a source of valuable data to elucidate issues raised during a death investigation, mainly those related to the determination of the individual's identity (Sweet, 2001; Pretty & Sweet, 2001; Verma *et al*., 2014).

Teeth peculiarities allow to identify bodies found in various situations: stage of decomposition, skeletonization, carbonization or fragmentation. The dental analysis permits not only the identification by comparative techniques, but also the reconstruction of the individual's biological profile, making a generic identification possible, from the survey of characteristics such as sex, age, ancestry and stature (Cattaneo, 2007; Prabhu *et al*., 2013).

Stature corresponds to the vertical measurement of a living being in upright position, and being an inherent feature, its estimate is considered an important evaluation for the identification of unknown human remains (Krishan & Sharma, 2007; Cattaneo; Pelin *et al*., 2010). Estimating stature restricts the possibilities in an investigation (Krishan, 2008; Pelin *et al*.) and can even exclude or confirm the identity of an individual (Iscan, 2005), what makes essential its research for anthropological examinations.

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Studying the proportionality of the human body, Carrea (1920, 1939) compared the mesiodistal diameters of the central incisor, the lateral incisor and the canine – teeth that belong to the same side of the mandibular hemiarch, with several distances between cranial points – and deduced two formulae to estimate stature. One of them estimates the human height, while the other estimates the maximum height of an individual, assuming that the actual individual's height should be between the two.

Nowadays, the formulas proposed by this author are in the literature and are used for anthropological inspections as additional examination or when other methodologies to estimate the stature can no longer be applied, situation commonly observed when the skull and teeth are the only remains found.

Considering that the method proposed by Carrea comprises only lower dental elements, its use would be impossible in case of disarticulation and loss of the jaw, or in case of fractured or missing teeth. To extend the use of Carrea's index, our study proposed to modify the formula developed by the author, so that it could be used for the upper teeth.

MATERIAL AND METHOD

The execution of the study was preceded by the evaluation of the Research Ethics Committee of the Faculty of Dentistry at Piracicaba – UNICAMP – and approved under Protocol 082/09.

The sample was composed of 107 plaster models of the upper arch from dentistry students of Federal University of Paraíba/Brazil, aged between 18 and 30 years, who were previously submitted to anthropometric analysis. Among these, 62 were female and 45 male.

With the models, the following elements of the Carrea's formula were measured: the arch, formed by the sum of the mesiodistal diameters of the central incisor, lateral incisor and canine; and the chord that corresponds to the extent of the straight line located between the mesial surface of the central incisor and the distal surface of the ipsilateral canine. Originally in Carrea´s method, the arch and the chord are measured with the lower dental elements, but in this case, they were measured with the upper teeth to test the possibility of modifying the formula (Fig. 1).

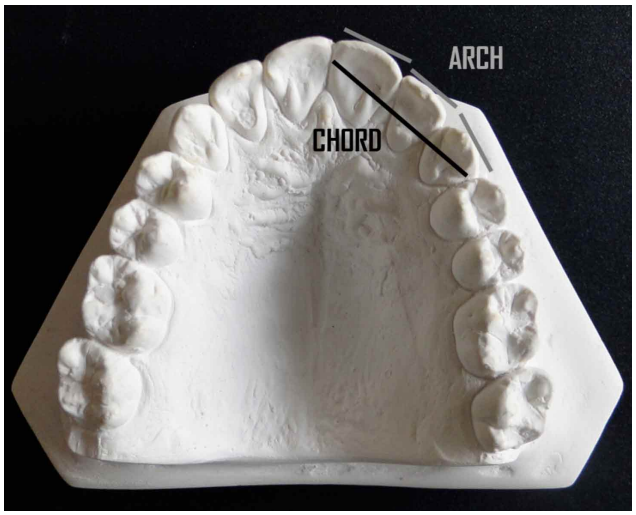

Fig. 1. Scheme to demonstrate the arch and the chord.

The actual stature of the students was measured with an anthropometer (Cescorf ®), while the arch and the chord were measured by a digital caliper (King-Tools® - 502.300 BL - 300 mm). The right and left hemiarches were assessed separately, resulting in 214 tests. The values obtained were inserted in Carrea's index, so the minimum height was estimated by calculating the chord (chord $\times 6 \times \pi/2$), while the maximum was estimated through the arch (arch $\times 6 \times \pi/2$). Subsequently, the values found were compared with the actual stature.

The intraobserver error was evaluated by the concordance correlation coefficient, reaching 0.982.

RESULTS

Table I shows that all the tests performed (100 %) presented errors in the estimate of real stature, which did not fit in between the maximum and the minimum calculated on any of the hemiarches evaluated, regardless of sex.

From this finding, the data were submitted to a mathematical analysis, provided by a software specially developed for the study to evaluate measurements and find a denominator for the original Carrea's formula (1939), which would generate a higher number of accurate occurrences for the actual statures of the participants of the research (between the maximum and minimum height).

In Table II, one can verify that the aforementioned software assessed the best denominator so that Carrea's index could suit the upper arch measurements in the three distinct situations. The first of them used as basis for the stature estimation the average of all the measurements of the arch and the right and left chord. The second one assessed stature only with the measurement of the arch and chord of the left hemiarch, and the third one only with the measurements of the right hemiarch.

Based on the existence of three denominators, statistical analysis was carried out to verify the occurrence of significant differences among the percentages achieved.

It was found, as described in Table III that, although the three proposed denominators present different accuracy percentage, there was no significant statistical difference among them (p> 0.005).

Table I. Distribution of accurate occurrences and errors for the application of Carrea's index for the upper arch according to sex.

Sex	Accurate occurences/Error Hit		Errors		Total Group		p-Value
	n	%	n	%	n	%	
• **Male**	-	-	45	100.0	45	100.0	**
• **Female**	-	-	62	100.0	62	100.0	
TOTAL	**-**	**-**	**107**	**100.0**	**107**	**100.0**	

(**): Unable to determine due to the absence of one of the categories.

Table II. Distribution of the best denominators and their respective percentages obtained for Carrea's index in the upper arch.

	The average of hemiarches (F1)	Left hemiarch (F2)	Right hemiarch (F3)
Best denominator	2.579 to 2.581	2.553 to 2.554	2.573 to 2.583
Percentage	60.7 %.	63.6 %	58.9 %.

Table III. Frequency of the number of hits by formula, modified from Carrea's index for the upper arch.

Variable	Formula: n (%)	Formula: n (%)	p-Value
• F1 X F2	F1: 65 (60.7)	F2: 68 (63.6)	$p^{(1)} = 0.453$
• F1 X F3	F1: 65 (60.7)	F3: 63 (58.9)	$p^{(1)} = 0.687$
• F2 X F3	F2: 68 (63.6)	F3: 63 (58.9)	$p^{(1)} = 0.687$

(1): Through McNemmar's test.

DISCUSSION

Several authors emphasize the difficulty in identifying human remains, bones or parts of them (Clark, 1994; Srivastava, 2010; Hinchliffe, 2011). In these cases, the investigation of identity is supported by a compilation of anthropological studies, since there is no method with 100 % accuracy. A set of tests is also necessary to confirm the obtained information by bone analysis.

Another difficulty can be encountered when going further with Carrea's index. In fact, no substantial explanations were found about the mathematical calculation proposed by Carrea (1939). Little is known about the measurements of the teeth and how they are related to the stature itself. Moreover, no reliable data were discovered on the real value of the results obtained by the author's method.

Silva (1990) and Cavalcanti *et al*. (2007), measured the arch with a tape measure and the chord with a caliper and verified the Carrea's index accuracy, respectively, in 70 % of the sample, 36 % for the right

side and 48 % for the left side, without evaluating statistical difference. The first author assessed arches only with normal dental position, while the second did not excluded the crowded ones. The accuracy percentage has increased to 96 % in the same sample of the research conducted by Cavalcanti *et al*. when the authors measured the arch and the chord with a drypoint compass.

Navarro Salazar & Ganoza Paredes (2004) found in the Peruvian population a statistically significant correlation between the actual height and average height, obtained between the maximum and the minimum estimated by Carrea's index, with a variation of ± 4cm, with a percentage of 65 % accuracy, so that the method was more accurate for males (70.8 %) than for females (50 %). Thus they concluded that the actual height is closer to the calculated minimum height, with predilection for people with average and tall sizes.

Silva (2012) modified the way to calculate the chord, defining it as the quotient between the arch and a constant value (1.0472) – from the progressiveratio table described by Carrea (1939) – and verified that the amount of individuals whose actual stature was out of the estimated range was high, concluding that this method is not applicable. By analyzing Carrea's index, when measuring the chord in the conventional manner, the author concluded that the method has applicability in individuals with crowded arches, although, in general, it does not have good results for human identification.

Lima *et al*. (2011) and Rekhi *et al*. (2014) tested the Carrea's index in distinct populations for different types of dental position in the lower arch. They concluded that Carrea's index can be used both in men and women, right and left sides, being reliable for crowded and arches with normal dental position. However, for the hemiarches with diastemas the method did not demonstrate to be accurate. It should be noted that the presence of crowded teeth extends the interval between the maximum and minimum height estimated, since it makes the chord value lower by approaching dental elements, which, consequently, increases the probability of accuracy of the actual height.

Furlan *et al*. (2016) found a percentage of 91.6 % accuracy in the measurements carried out for Carrea's index in individuals aged between 12 and 69 years. Only the arcades with normal dental position were included, and the arch and the chord were measured with dental floss, with the measurement transferred to a caliper. The authors found a great difference between maximum and minimum height and dissociation between the effectiveness of the method and the sex or the age group, even though claiming higher accuracy after 30 years of age.

There is a small number of studies that examine the effectiveness of this index (Herrera *et al*., 2014) and still do it with the original method, i.e., in the lower arch, which impairs the discussion about the data obtained in this study and demonstrates the need for new research on the topic. Garrido *et al*. (2012) proposed the use of Carrea's index in the upper right hemiarch; however, they assessed its accuracy percentage of deciduous teeth in children (between 3 and 7 years old). The authors found that the result was negative and concluded that the method does not apply to the deciduous maxillary dentition, suggesting a linear regression (Height = 1358.798 + [arch × (–8.577)] + [arch × (–1.914)]), which reached 57.5 % accuracy of actual stature with ± 5cm.

Gajardo *et al*. (2011) aimed at finding a method to estimate the height by linear regression, in which the dependent variable was the actual height (in meters), according to the dimensions of the arch and chord (in millimeters), measured in the maxillary right hemiarch of 145 patients, aged between 18 and 44. The regression found (Height = 0.538 + [0.036 x Arch] + [0.003 ×Chord]) made it possible to estimate the stature in 54 % of the cases.

Only Lima *et al*. (2008) tested the Carrea's index in the upper arch in permanent teeth and the results showed that there was no stature accuracy in none of the types (normal, crowded and with diastema), and also no accuracy for males or females in both hemiarchs (right and left), demonstrating inefficacy of the original calculation, as well as in our research.

It should be noted that, in our study, the dental arches superiors were divided according to dental alignment and were not excluded due to the presence of crowding or diastema. The analysis only of arches with normal position could present an increased accuracy percentage, since diastemas may affect the estimate of actual stature.

Having all of this in mind, it is possible to infer that with the new denominator found for Carrea's index, we could design a mathematical model for the estimation of human stature through the measurement of upper arch dental elements. The new method has satisfactory accuracy index and must be tested in order to check its validity. However, for human identification, the method should only be used alone if there is a lack of more accurate techniques.

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RESUMEN: El índice de Carrea constituye una alternativa para la estimación de la estatura humana. Sin embargo, esta técnica se torna inviable cuando la mandíbula se encuentra comprometida. Su aplicación a partir de elementos dentales superiores, resultaría de utilidad en los casos en que sólo se dispusiese del cráneo para examinar. El objetivo del estudio fue proponer un nuevo denominador para que el índice de Carrea pueda ser utilizado para el arco superior, en la búsqueda de otro recurso para estimar la estatura humana. El arco y la cuerda fueron medidos, con un calibre digital, sobre los respectivos modelos de yeso superiores de 107 estudiantes de Odontología, que tenían entre 18 y 30 años de edad y habían sido sometidos a análisis antropométricos previos. Los datos obtenidos fueron analizados matemáticamente mediante un programa desarrollado para encontrar un denominador, que proporcionase un mayor número de aciertos para las estaturas reales, evaluando el hemiarco derecho, izquierdo y la media de los hemiarcos. Para el hemiarco derecho, el denominador más apropiado para la estatura real correspondió al intervalo 2,573-2,583, con 58,9 % de acierto. Para el hemiarco izquierdo, los mejores valores quedaron comprendidos entre 2,553 y 2,554, con 63,6 % de acierto. La media de los hemiarcos determinó guarismos ideales, oscilantes entre 2,579 y 2,581, con 60,7 % de acierto. No hubo diferencia estadísticamente significativa entre los denominadores hallados. Se obtuvo un nuevo denominador, que permitió el empleo del índice de Carrea para el arco superior, con una tasa de acierto satisfactoria. No obstante, este método debe ser probado y validado para otras poblaciones, verificando su aplicabilidad.

PALABRAS CLAVE: odontología legal, antropología forense, cráneo, estatura, arco dental.

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