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SECTION IDENTIFICATION

Estimation of stature in a young adult indian population using the carrea's index

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ABSTRACT

The stature or height of an individual is useful for assisting in forensic identifications. Teeth can act as a valuable tool for stature estimation when only the skull is available. Carrea's index estimates the stature of a person from the dimensions of lower anterior teeth. The aim of this study was to assess the reliability of the Carrea's index in an Indian population. Data was collected from plaster models of 125 undergraduate students for examination. Each hemiarch was considered separately equaling 250 inferior hemi-arches, which were divided according to the dental alignment into normal, crowded and diastema and the measurements (Arch and Chord) were made with a 'divider caliper'. A statistically significant difference between the types of dental arch was obtained for both males and females with regards to the different dental alignments; where normal dentition (94.03%) obtained the highest success rates for males and crowded dentition (87.87%) for females. Statistically significant differences were also found between the types of arches for both right and left side ($p<0.001$; $p=0.004$). The presence of diastema reduced the success rates when compared in terms of both sex and side of the arch. It was concluded that the Carrea´s index is a reliable method for height estimation in arches with normal and crowded dentitions, useful for both sexes, and for both right and left side of the arch. However, the method was not reliable for hemiarches with a diastema.

KEYWORDS**:** Forensic Odontology, Stature Estimation, Carrea's Index, Dental Arch.

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INTRODUCTION

Forensic odontology and anthropology provide valuable support with regards to human identification. In cases where soft tissue is destroyed, carbonized or absent for whatever reason, bones and teeth become the only source of information about the identity of the deceased. In human identification, any variation from normality becomes an important tool when trying to establish the identity of the deceased.[1]

Stature is the height of a person in the upright posture[2] and has a definite and proportional biological relationship with each and every part of the human body, i.e. head, face, trunk, extremities.[3] This relationship helps a forensic scientist to calculate stature from dismembered and mutilated body parts during forensic examinations and thus aids in narrowing down the investigation process by providing useful clues to the investigation agencies. The dental arch has many variables which makes it almost impossible for two people to have identical tooth features. Teeth are special in cases of identification of deceased since they can resist the effect of time, are resistant to fire and trauma and can also provide information on species, race, gender, age, height and individual characteristics. Teeth have also added advantage of standard anatomical landmarks which are easy to locate.[4]

Many studies have been conducted on the estimation of stature from various body parts like hands,[5] intact vertebral column,[6] upper and lower limbs,[7] individual long and short bones,[8] foot and footprints[3] etc. Only a few studies have been conducted on the cephalo-facial region with respect to the estimation of stature.[9-12]

From this perspective, Carrea[13] conducted studies to estimate height, based on the fact that there is proportionality between the diameter of the teeth and body height, and used it to estimate height from the dimensions of the anterior mandibular teeth. Carrea's index basically measured two dimensions: the Arch and the Chord. The 'arch' represented by the sum of mesiodistal widths of anterior teeth on one side and the 'chord' represents the direct distance between mesial edge of central incisor and the distal edge of canine on the same side. Using these measurements, the upper and lower range of the height estimates are derived. Similar studies conducted by Silva (1990); Sampaio(1995); Cavalcanti et al (2007), have verified this fact.[14-16] A recent study was also conducted regarding the estimation of stature from teeth dimensions however the buccolingual and mesiodistal dimensions of all teeth (except third molars) were assessed instead of just the mandibular anterior teeth where correlation analysis revealed that 21 of the 56 tooth crown variables had a low albeit statistically significant correlation to stature ($p < 0.05$). They concluded that moderate correlation is probably due to early completion of growth of tooth crowns vis-à-vis other parameters such as long bones that mature later and have a higher stature-correlation.[17] Looking at the scarcity of studies pertaining to the estimation of stature from dental dimensions in the Indian scenario, the present study provides anthropometric relationships of dimensions of certain teeth with stature based on the Carrea's Index and to test the reliability and accuracy in a sample taken from mixed population of North India.

The aim of the present study was to estimate the height range of a person through measurements of his teeth using the Carrea's index and check its accuracy in different types of dental alignment;also, to compare accuracy between both sides of the arch and determine if there are sex-wise differences in success rates.

MATERIALS AND METHODS

The study protocol was approved by the Institutional Ethical review committee of Sudha Rustagi College of Dental Sciences and Research, Faridabad. A sample size of 250 was found to be sufficient, taking 5% as margin of error at 95% confidence level. The sampling unit was one hemi-arch so 125 subjects were selected to give a sample size of 250 hemi-arches. The study population consisted of students aged 21 to 25 years from a dental college in Faridabad, Haryana. Young people show less physiological wear, less wasting diseases and less periodontal disease which if present, might lead to spacing between teeth thus affecting the accuracy of the method. This population was selected since it comprises of students from all over the state of Haryana and also some neighbouring states, thus a mixed young adult North Indian population.

All subjects willing to participate and who had dimensionally stable teeth i.e. intact crowns without any loss of enamel, were included. The subjects who had any of the mandibular anterior teeth missing or had any structural abnormality were excluded. The subjects who had undergone or were currently undergoing orthodontic treatment were also excluded.

Plaster models of the lower dental arch of each subject were obtained from alginate impressions poured in dental stone. A standardized procedure was followed for mixing of dental stone with water, taking fixed water/powder ratio (W/P ratio) for all the models constructed. A calibrated dispenser was used for dispensing of dental stone and water so that a uniform W/P ratio was maintained.

For examining the plaster models, each hemi-arch was considered separately and was divided into three categories: normal, crowded and spaced. The greatest mesio-distal crown widths of the mandibular anterior permanent teeth and the chord were measured using the modified method for Carrea's index where dividers with fixing device were used. The distance between divider tines was read off on a stainless steel scale and recorded to the nearest millimeter. Although shown to produce systematic errors, use of dividers is an acceptable method.[18] The modified method has presented greater effectiveness in stature estimation when compared with the original Carrea's method.[16]

Carrea's Index:[13] For the Carrea's index, the mesio-distal widths of lower central incisor, lateral incisor and canine (Fig 1) were recorded and summed. This was termed the 'ARCH'. The linear distance between the ends of the arc, represented by the mesial edge of central incisor and the distal edge of canine on the same side, measured on the lingual surface were also measured (Fig B). This was termed the 'CHORD'. The estimated height was calculated using the formula below:

Formula: Maximum Stature = $\frac{\text{arch (in mm)} \times 6 \times 3.1416 \times 100}{2}$

Minimum Stature = $\frac{\text{chord (in mm)} \times 6 \times 3.1416 \times 100}{2}$

The actual stature was measured with an anthropometer, by making the subject stand erect on the horizontal plane, barefooted, in the anatomical position according to the Frankfurt plane, in inspiratory apnoea, aligning the posterior surface of heels, pelvic girdle, scapular girdle, and occipital region to the vertical plane. The stature was measured with the rod of the anthropometer in contact with the vertex.

All examinations and calculations were done by a single dentist. The intra-examiner variability was tested in the measurement of the actual height using the anthropometer and the measurement of the arch and chord of twelve casts using divider calipers.

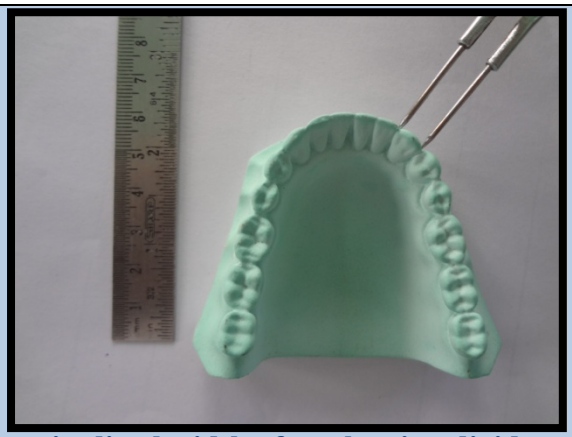

Fig 1: Measurement of mesio-distal width of tooth using divider calipers.

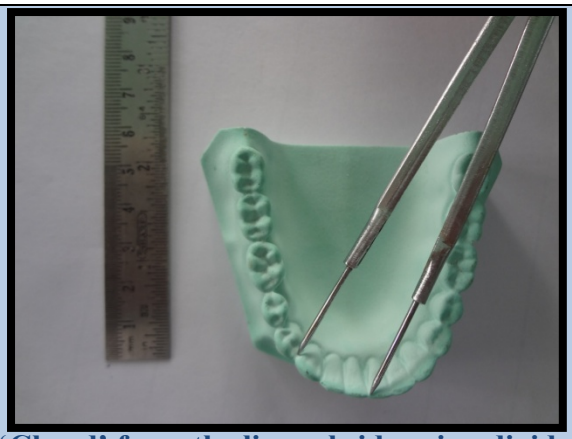

Fig 2: Measurement of 'Chord' from the lingual side using divider calipers.

The data was entered into an Excel spreadsheet (MS Office 2007) and then analysed using the SPSS software (version 11.5). Frequencies of correct height estimation were calculated. Proportion of correct estimations were compared according to sex, side of arch and the types of dental alignment using Chi square test.

RESULTS

Assessment of intra-examiner variability, showed repeatable results for measurements of height, arch and chord with kappa values ranging from 0.76 to 0.82.

A total of 67 males (53.6%) and 58 females (46.4%) were selected. Out of the total of 250 inferior hemi-arches, there were 131 (52.4%) normal arches, 79 (31.6%) crowded and 40 (16%) arches with diastemata (Table 1). The height distribution and mean arch and chord values for both sexes is given in Table 2. Males were taller and had higher mean arch and chord values.

Table 3 shows the overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to sex. A statistically significant association was found in the stature estimation accuracies between the types of arches for both males and females ($p<0.001$ and $p=0.016$ respectively).

Table 4 represents the overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to side. Statistically significant association was found in the differences between the types of arches for both right and left side ($p<0.001$ and $p=0.004$ respectively).

A higher success rate was seen for males (94.03%) as compared to females (87.5%) for normal alignments (Table 1), but there

was no statistical difference between the two (p=0.235). The left side of the hemi-arch showed a higher success rate (93.84%) in comparison to right side (87.87%) but again no statistically significant differences were observed between the two sides (p=0.365).

In case of crowded hemi-arches, a higher rate of success was obtained for males (n=35; 92.1%) and left side of the dental arch (n=38; 92.68%) in comparison to females (87.80%) (Table 3) and right side (86.84%) (Table 4) respectively. However this difference in percentages was not proven to be statistically significant for either sex (p=0.713) nor side of dental arch (p=0.471).

In case of hemi-arches with diastemata, there was a somewhat balanced distribution of success and failure for estimation of height if we compare it with dental arch categories. There was a 58.62% and 54.54% success rate for males and females respectively (Table 3). The left sided hemi-arches showed a higher success rate (68.42%) as compared to the right side (47.61) (Table 4). The differences in case of both sex and side showed no statistical significance (p=1.000 and p=0.216).

Table 1: Overview of statistics related to sex, kind of dental alignment and side of hemi-arch.

ALIGNMENT	NORMAL		CROWDED		DIASTEMA		
SEX							TOTAL
	Right	Left	Right	Left	Right	Left	
MALE	34	33	18	20	15	14	
Total	67		38		29		134
FEMALE	32	32	20	21	6	5	
Total	64		41		11		116
Grand total	131		79		40		250

Table 2: Descriptive statistics of the actual height, arch (mm) and chord (mm) values in the study population

	Males	Females	Total
	Mean (SD)	Mean (SD)	Mean (SD)
Actual Height	174.52 (5.51)	160.87 (5.42)	168.19 (8.74)
Arch (mm)	20.11 (0.97)	18.74 (0.94)	19.47 (1.17)
Chord (mm)	17.51 (1.23)	16.33 (0.87)	16.96 (1.22)

Table 3: Overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to sex.

SEX	ARCH TYPE	HITS	MISSES	GROUP TOTAL	P value
		n (%)	n (%)	N	
MALES	NORMAL	63(94.03)	4(5.97)	67	
	CROWDED	35(92.10)	3(7.89)	38	
					<0.001
	DIASTEMA	17(58.62)	12(41.37)	29	
TOTAL		115	19	134	
FEMALES	NORMAL	56(87.5)	8(12.5)	64	
	CROWDED	36(87.80)	5(12.19)	41	
					0.016
	DIASTEMA	6(54.54)	5(45.45)	11	
TOTAL		98	18	116	

Table 4: Overall distribution of hits and misses for all three types of dental hemi-arches (normal, crowded and diastema) according to side.

SIDE	ARCH TYPE	HITS	MISSES	GROUP TOTAL	P value
		n (%)	n (%)	N	
RIGHT	NORMAL	58(87.87)	8(12.12)	66	
	CROWDED	33(86.84)	5(13.15)	38	
					<0.001
	DIASTEMA	10(47.61)	11(52.38)	21	
TOTAL		101	24	125	
LEFT	NORMAL	61(93.84)	4(6.15)	65	
	CROWDED	38(92.68)	3(7.31)	41	
					0.004
	DIASTEMA	13(68.42)	6(31.57)	19	
TOTAL		112	13	125	

DISCUSSION

A known biological relationship between bones and body parts exists and this is very useful in determining the estimated height from long bones.[3,8] However, this cannot be said to be true in case of teeth where no defined relation between the lengths of teeth exists in relation to body parts and the development of teeth is not directly related to the development of other body parts. Still, teeth could be used as a reliable source for stature estimation especially in those forensic cases where other body parts are not available for forensic examination.[4] The most traditional method of estimation of human stature by examining the teeth

was proposed by Carrea in 1920 which was based on the relationship of measurements of lower anterior teeth with the actual stature of the person.[13] Unfortunately there is no written description of the origin of this formula since Carrea's studies of 1920 and 1939 were done at a time when papers often lacked important information and methodological patterns were not observed by authors.[13]
The Carrea´s index for normal arches, as originally described has shown significant rates of success among both sexes with no statistically significant difference between them. The same result was seen on left and right hemi-arches, demonstrating that the method can be applied for both sides, without affecting the outcome.

In a study by Cavalcanti *et al*[16] to estimate the stature through Carrea's index, two methods of measuring the arch and chord were used namely the 'conventional' method and the 'modified' method. In case of the conventional method, the arch was measured using a millimeter tape and the chord was measured using a divider caliper whereas in the modified method, both were measured with a divider caliper. Higher success rates were observed in males (100%) as compared to females (93.3%) and equivalent rates were observed for both sides in case of modified method used in the study by Cavalcanti *et al*.[16] The conventional method on the other hand showed lower success rates for both sexes and both sides. These findings are comparable with those found in the present study where the modified method was used. It should be noted that normal and crowed arches were analyzed together in the original studies, without distinguishing between them and arches with diastemata were not mentioned in the original study. This is different from the present study in which the arches were divided into 3 types (normal, crowded and diastema) for separate analysis.

This study has obtained high success rates for crowded dentition for both sexes and both sides which is in contradiction to a study by Croce & Croce Junior [19]who had obtained lower success rates for crowded arches and hence had discouraged the use of Carrea's index for crowded arches.

There was a higher consistency between the stature estimation and the left hemiarch in this study for all the three types of dental arches, even though not statistically significant. This finding was similar to the results by Cavalcanti *et al*[16] which has shown equivalent success rates for both sides by the modified method, and higher correlation to the left hemiarch by the conventional method. When considering the differences between sexes, a higher consistency was observed for males as compared to females, although not significant.

In comparison with a study conducted by Lima *et al* in subjects in the age group of 18 to 30 years,[20] contradictory findings were observed where higher success rates for right side were obtained. This finding could be attributed to factors such as plasticity of teeth, eruption sequences of teeth, dentition differences due to differences caused by favouring one side of the mouth and racial differences where Lima had conducted the study among a young adult South American population as compared to this study where a young adult Indian population was taken. Hence age would not be a factor which could lead to these variations.

As stated by Carrea,[21] any hemiarch can be used to estimate the stature, considering the principle of bilateral symmetry, accepting small variations as normal asymmetries. The statistical insignificance of the variation found in this study is in line with Carrea´s theory.

Silva in his study[14] had measured the chord with a caliper, and the arch with a millimeter tape. A 70% success rate was observed when actual height was compared with the estimated height however no distinguishing between the different types of arches was done. Both hemiarches and sex were examined together, with no distinction.

The hemiarches with diastemata had shown low success rates. This could be due to the increased chord value and the small range of estimated maximum and minimum height values. In these cases, the value from chord that predicts the minimum height, was higher than the value from the arch, which estimates the maximum height. This error in the minimum stature value might have been the reason for low success percentages in arches with diastemata. This is in accordance with the study conducted by Lima etal[20] which has also shown lower success rates (50%) when it comes to arches with diastemata.

There are numerous factors which affect the normal development of the dentition. Any deviation leading to an abnormality in the alignment of the teeth results in either crowding or spacing of the dental arches. Crowding occurs when there is disharmony in the tooth to jaw size relationship or when the teeth are larger than the available space. Supernumerary teeth, missing teeth, impacted teeth, or abnormally shaped teeth are other reasons that may cause crowding. Spacing with diastemata occurs when jaw size is greater than the size of teeth or when teeth are smaller than the available space. Other reasons could be due to congenitally missing teeth or due to any habits such as thumb sucking or tongue thrusting.[22]

Overall, this study showed similar success rates for both males and females in all the 3 types of arches (normal - 94.03% & 87.5% respectively; crowded - 92.1% & 87.8% respectively; diastema - 58.62% & 54.54% respectively).

In case of side of the arch, similar success rates was seen for both sides in case of normal and crowded dentition with the left side showing slightly higher success rates in comparison to the right side (normal – 87.87% & 93.84% respectively; crowded – 86.84% & 92.68% respectively). Significant differences in the success rates for both the sex and the side of the arch were found. This might be attributed to the low success rates associated with diastema and is probably not between the normal and crowded dental alignments.

It has been well reported in literature that the stature in adults declines significantly as the age advances.[23-25] Height of the person increases progressively and it becomes maximum at the age between 21 and 25 years. After this, for every 25 years, stature is shortened by 2.5cm.[26] Studies have confirmed this well established fact relating to the substantial decrease in stature once the mature age is attained.[27,28] The stature loss may be associated with the thinning of intervertebral discs and loss of vertebral body height,[25] stooping posture, decreased tone in muscles, and osteoporosis.[29] As the sample age in the study ranged from 21 to 25 years, the criteria for loss of stature was not valid and the results of this study can be generalized over a young Indian population. In some other studies, the age ranges varied between 18 to 30 years[20] and between 18 and 44 years.[30] Further studies could be planned to see the effect of increasing age on the accuracy of this method.

CONCLUSION

Carrea´s index can be used for stature estimation for both males and females as well as in right and left hemi arches in arches with normal and crowded dental positioning. For the hemiarches presenting

diastemata, the method was found to be less accurate..

The present study concludes that, like other parts of human body, dimensions of the teeth can also be used for estimation of stature in forensic applications when remains of other body parts are not found. It is seen that Carrea's formula shows good reliability and applicability of estimates for a sample taken from a mixed population of North India.

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