Original Article

Comparative Evaluation of Vertical Crown Length of Deciduous and Permanent Teeth as a Predictor of an Individual Height by Linear Stepwise Regression Analysis

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ABSTRACT

Background: Establishing the identity of an individual by analyzing the teeth has being a matter of interest in forensic odontology. Dental morphometrics is useful in establishing physical profile of the individual at various stages in forensic studies. Tooth dimensions of both deciduous and permanent teeth can be correlated to various aspects of the facial and physical characteristics of an individual.

Aims and Objectives: The present study was undertaken to investigate the relationship between clinical crown length (CL) of erupted deciduous and permanent teeth and the height of child and adult, respectively. An association between these two parameters, if any, was evaluated to derive a numerical equation that would predict the individual's height from tooth dimensions.

Materials and Methods: Sixty adults (30 males and 30 females) of age range 18–26 years and sixty children (30 males and 30 females) of age range 3–6 years were included in this study. Clinical CL of the permanent teeth (tooth numbers 11, 12, 13, 16, 17) and deciduous teeth (tooth numbers 51, 52, 53, 54, 55) was measured on the subject cast models using digital Vernier calipers. Using a standard measuring tape, individual height (H) was also measured. Ratios (CL/H) of permanent tooth CL to individual height and deciduous tooth CL to the child height were documented. Using linear stepwise forward regression analysis, the probability of CL of the study group teeth that would most likely predict physical height of the child and adult was determined.

Results: Statistical analysis showed strong correlation between the two parameters among children and adults. In permanent dentition, tooth CL of #12 permanent upper right lateral incisor (among the combined group of males and females) was statistically significant in the prediction of the adult height. Mathematically derived equation for adult height prediction using #12 CL based on linear stepwise forward regression analysis (derived from combined data of male and female samples) is 941.286 + 82.146 (#12 CL); in deciduous dentition, (#55) upper right second molar among the males, (#52) upper right lateral incisor among females, and (#53) upper right canine among the combined male and female group were statistically significant and predicted the child height with minimal variations. Equations derived for male child height prediction (using data of male children) is 660.290 + 72.970 × (#55CL), for female child height prediction (using data of female children) is − 187.942 + 194.818 × (#52 CL), and for child height prediction using #53 CL (using combined data of male and female children) is 400.558 + 90.264 × (#53 CL).

Conclusion: There exists a definitive relation between vertical CL of teeth and the height of an individual. This relation is more predictive with teeth numbers 12 in adults and 52, 53, 55 in children. This information is of immense value in identification profiling in forensics.

Key Words: *Clinical crown length, deciduous teeth, forensic odontology, individual height, permanent teeth*

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Introduction

Estimation of stature or physical height is one of the important aspects in anthropological protocol and very essential in initial screening and individual identification from skeletal remains. And here, teeth can be considered as

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an exceptional resource material for forensic investigations because of its high resistance capacity to withstand high temperatures in disasters during natural or artificial calamities. Hence, teeth play a vital role in individual identification for medicolegal circumstances and unknown identification from skeletal remains during mass causalities.[1,2]

Dental morphometrics helps in the quantitative analysis of form of the tooth that includes both size and shape of teeth. Estimation of physical profile using dental morphometrics is a subject of great significance in forensic studies.

Previous studies have been attempted in physical height prediction using dentition and by correlation of different dimensions of the tooth and body dimensions. A varied conclusion has being drawn in all these studies.

Raghavendra *et al*. in their study on the comparative evaluation of permanent maxillary central incisor crown length (CL) with facial height and body height of 100 subjects concluded that there is no statistical correlation present between these parameters.[3] Jayawardena *et al*. conducted a study in Sri Lankan Sinhalese subjects to determine relationship between tooth length of permanent maxillary central and lateral incisors with the stature and concluded that tooth morphometrics does not determine body height of the subjects.[4] Sterrett *et al*. in their study among Caucasians, width, length, and width/length ratios of maxillary anterior sextant permanent dentition to the height of the individual could not find any statistically significant correlation between tooth dimensions and subject height.[5] However, Prabhu *et al*. in contrary to the above studies observed a small statistically significant correlation to the body height during evaluation of multiple dimensional parameters of the maxillary central incisor tooth.[6]

A literature review surprisingly reveals no studies on the determination of physical height using CL using both deciduous and permanent dentition. The present study is designed to identify the relationship between the two parameters by measuring the erupted deciduous and permanent vertical CL and height of child and adult. Linear stepwise forward regression analysis is used to derive a mathematical equation to predict the subject height from tooth CL.

Materials and Methods

The protocol of this study was approved by the Local Institutional Ethics Research Committee. One hundred and twenty subjects were selected for this study; sixty children (30 males and 30 females) in the age group 3–6 years and sixty adults (30 males and 30 females) in the age group of 18–26 years. The age range was selected based on the evidence of minimal disruption to tooth morphology due to oral excursions, for example, attrition.

The inclusion criteria for children and adult sample selection are as follows:

- Presence of healthy teeth, gingiva, and periodontium
- Presence of fully erupted deciduous dentition (51, 52, 53, 54, 55) and permanent dentition (11, 12, 13, 16, 17)
- Presence of normal overjet and overbite
- Presence of normal molar and canine relationship
- Absence of interdental spacing or crowding between teeth.

The exclusion criteria for children and adult sample selection

- Presence of mobile deciduous and permanent teeth
- Incomplete eruption of deciduous and permanent teeth
- Presence of any dental irregularities
- Physical alterations of tooth structure due to caries or restorations, fracture, attrition.

Informed consent from adults and parents of children was obtained for the study, and the basic measurements such as age, height and erupted tooth CL were obtained. A standard measuring tape was used in height (H) determination of the subject (H was converted into mm while recording). With the help of standardized digital Vernier calipers (Aerospace Ltd., Bengaluru), clinical vertical CL was measured on cast models of the dentition prepared using irreversible hydrocolloid (alginate) material and dental stone. The clinical vertical CL was recorded in millimeters and entered into MS EXCEL sheet. Ratios of CL/H in adults and children were determined.

Statistical methods

T-test independent was used to compare the ratios of CL/H among children and adults.

Linear stepwise forward regression analysis was used to determine the statistically significant teeth whose CL was most likely to be predictive of the individuals' height. A mathematical equation for each tooth that would assist in determining the probable physical height from tooth CL was also arrived at. This equation was randomly tested on the various subjects and verification derived.

Results

The following results are obtained from the correlation of data recordings.

General characteristics: Height (H)

Adults: The mean height of the adults among females is 1550.72 mm with a standard deviation of 173.95 and among males is 1741.72 mm with a standard deviation 81.80. The average height is more among males than in females.

Children: The mean height of the child among females is 972.65 mm with a standard deviation of 158.49 and among males is 1086.41 mm with a standard deviation 106.27. The average height is more among males than in females.

Crown lengths of the sample

Adults: The mean CL of tooth numbers 11, 12, 13, 16, 17 among males was 10.64 mm, 8.89 mm, 10.16 mm, 7.21 mm, 6.62 mm and among females was 10.11 mm, 8.27 mm, 9.34 mm, 7.02 mm, 6.34 mm, respectively. The mean CL of all the selected teeth in this study among males was more compared to females.

Children: The mean CL of tooth numbers 51, 52, 53, 54, 55 among males was 6.72 mm, 6.05 mm, 7.09 mm, 6.07 mm, 5.84 mm and among females was 6.59 mm, 5.96 mm, 6.87 mm, 5.90 mm, 5.75 mm, respectively. The mean CL of

Table 1: Mean height and crown length of male and female adults and children

	Gender	*n*	Mean	SD	*t*	df	*P*
Adult							
Height (mm)	Female	30	1550.72	173.9509	−5.443	41.228	<0.001*
	Male	30	1741.727	81.80161			
11 CL	Female	30	10.119	0.72715	−2.461	58	0.017*
	Male	30	10.64833	0.926968			
12 CL	Female	30	8.271667	0.715976	−2.933	58	0.005*
	Male	30	8.891333	0.908936			
13 CL	Female	30	9.344	0.82692	−3.512	58	0.001*
	Male	30	10.16033	0.968196			
16 CL	Female	30	7.022667	0.709298	−0.987	58	0.328
	Male	30	7.212667	0.780512			
17 CL	Female	30	6.341667	0.649111	−1.498	58	0.14
	Male	30	6.619333	0.780967			
Children							
Height (mm)	Female	30	972.6533	158.4848	−3.265	58	0.002*
	Male	30	1086.408	106.2683			
51 CL	Female	30	6.582333	0.439441	−1.163	58	0.249
	Male	30	6.719667	0.474382			
52 CL	Female	30	5.957333	0.437287	−0.714	58	0.478
	Male	30	6.048667	0.547431			
53 CL	Female	30	6.873667	0.532026	−1.659	58	0.103
	Male	30	7.091	0.481466			
54 CL	Female	30	5.903333	0.553106	−1.299	58	0.199
	Male	30	6.072667	0.451556			
55 CL	Female	30	5.749667	0.593084	−0.62	58	0.537
	Male	30	5.839667	0.528632			

*Statistical significance at $P<0.05$. CL: Crown length, SD: Standard deviation

all the selected teeth in this study among males was more compared to females [Table 1].

Crown length/height results

Adults: CL/H ratios of the #11CL/H, #16CL/H, and #17CL/H were found to be statistically significant at $P < 0.1$ levels [Graph 1].

Children: CL/H ratios of the all the five group of teeth #51CL/H, #52CL/H, #53CL/H, #54CL/H, and #55CL/H were found to be statistically significant at $P < 0.1$ levels [Table 2 and Graph 2].

Statistically significant teeth

A linear stepwise forward regression analysis identifies the following teeth to be statistically significant and forms the strong basis for mathematical equation derivation that assists in predicting the individual's height using the tooth vertical CL.

Adults: Among five groups of teeth (#s 11, 12, 13, 16, 17) evaluated in the study, #12 among the combined group (male + female data) was found to be statistically significant from the analysis with standard error of estimate 194.71 [Table 3a and 3b].

The remaining set of teeth: Teeth numbers 11, 13, 16, 17 were found to be statistically nonsignificant [Table 4].

Children: Among five groups of teeth (#s 51, 52, 53, 54, 55) evaluated in the study, #s 52, 53, 55 were statistically significant from the analysis [Table 3a].

a. Maxillary right canine (#53) among the combined data (male + female tooth measurements) with standard error of estimate of 135.91
b. Maxillary right lateral incisor (#52) among female tooth measurements with standard error of estimate of 136.0062055
c. Maxillary right second molar (#55) among male tooth measurements with standard error of estimate of 100.7729203.

The following sets of teeth: #s 51, 52, 54, 55 (in combined data); #s 51, 52, 53, 54 (in male data); and #s 51, 53, 54, 55 (in female data) were statistically nonsignificant [Table 4].

Mathematical equations for height determination derived from statistically significant teeth crown length

Adults: Equation derived from combined (males + females) data for adult height prediction using #12 CL is:

$$\text{Adult height} = 941.28 + 82.14 \times (\#12\ \text{CL})$$

Children: Equation derived from male data for male child height prediction using #55 CL is:

$$\text{Male child height} = 660.290 + 72.970 \times (\#55\ \text{CL})$$

Equation derived from female data for female child height prediction using #52 CL is:

Table 2: Differences in male and female height, crown length/height ratios between adults and children

	t-test independent						
	Gender	*n*	Mean	SD	*t*	df	*P*
Adult							
Height (mm)	Female	30	1550.72	173.9509	−5.443	41.228	<0.001*
	Male	30	1741.727	81.80161			
11 CL/height	Female	30	0.006557	0.000909	2.436	49.305	0.018*
	Male	30	0.006077	0.000581			
12CL/height	Female	30	0.005343	0.00072	1.793	58	0.078
	Male	30	0.005057	0.000498			
13CL/height	Female	30	0.006057	0.00085	1.301	58	0.198
	Male	30	0.005803	0.000644			
16CL/height	Female	30	0.004547	0.000819	2.544	47.415	0.014*
	Male	30	0.004103	0.00049			
17CL/height	Female	30	0.004083	0.00061	2.236	58	0.029*
	Male	30	0.003763	0.000492			
Children							
Height (mm)	Female	30	972.6533	158.4848	−3.265	58	0.002*
	Male	30	1086.408	106.2683			
51 CL/height	Female	30	0.006913	0.001363	2.312	58	0.024*
	Male	30	0.006217	0.00093			
52 CL/height	Female	30	0.006223	0.001134	2.429	58	0.018*
	Male	30	0.005587	0.000881			
53 CL/height	Female	30	0.007213	0.001349	2.19	58	0.033*
	Male	30	0.006567	0.000892			
54 CL/height	Female	30	0.00621	0.00143	2.107	41.694	0.041*
	Male	30	0.0056	0.000686			
55 CL/height	Female	30	0.006043	0.001298	2.496	43.014	0.016*
	Male	30	0.00538	0.000659			

*Statistical significance at *P*<0.1. CL: Crown length, SD: Standard deviation

Table 3a: Statistically significant group of teeth among adults and children - model summary table

Model summary						
Group	Sex	Model	*R*	R^2	Adjusted R^2	SE of the estimate
Adult	Combined	1	0.431[a]	0.186	0.172	150.7429882
Children	Combined	1	0.378[b]	0.143	0.128	135.9173726
	Female	1	0.538[a]	0.289	0.264	136.0062055
	Male	1	0.363[c]	0.132	0.101	100.7729203

[a]Predictors: (Constant), 12 CL, 52 CL, [b]Predictors: (Constant), 53 CL, [c]Predictors: (Constant), 55 CL. SE: Standard error, CL: Crown length

Female child height = −187.942 + 194.818 × (#52CL)

Equation derived from combined (males + females) data for child height prediction using #53 CL is:

Child height = 400.558 + 90.264 × (#53 CL).

Discussion

In previous anthropological studies, tooth CL has being used to determine the total body length with varying results. Wood[7] in his study on the primate taxa of Homo, Gorilla, Pan, Colobus, and Papio studied the variations between tooth size and body size. In this study, allometric coefficients in each variable between the taxa were different, and hence, results obtained between the nonhuman taxa samples were different from the human taxa. Hence, there were no specific correlations derived between tooth size and body size. Shimada[8] in her study analyzed the relationship of tooth crown height and body length of great white sharks and proposed the existence of linear relationship between the two parameters. The linear relationship derived was given as: Total length (in centimeters) = a + bx (where a - constant; b - slope of the line; x - CL of the labial surface of the tooth). This linear relationship later became a regular formula for anthropologists and paleontologists in measuring body length of sharks. However, the relevance of this linear relationship to human height determination is yet to be established.

Previously, no studies have been attempted in height estimation using CLs in deciduous and permanent dentition. In the present study, there exists a predictive correlation between the clinical CL of erupted teeth and height of the subject. This relationship also varies between the two sets of dentition.

Based on linear stepwise forward regression analysis: (a) In permanent dentition tooth, # 12, i.e., permanent upper right lateral incisor, among the combined group of males and females was statistically significant in the prediction of the adult height. (b) In deciduous dentition tooth, # 53, i.e. maxillary right canine among the combined data (male + female measurements), #52, i.e., maxillary right lateral incisor, among

Table 3b: Statistically significant group of teeth among adults and children - coefficients table

Group	Sex	Model		Unstandardized coefficients		Standardized coefficients	*t*	Significant
				B	SE	β		
Adult	Combined	1	Constant	941.286	194.710	0.431	4.834	0.000
			12 CL	82.146	22.576		3.639	0.001
Children	Combined	1	Constant	400.558	202.944	0.378	1.974	0.053
			53 CL	90.264	29.022		3.110	0.003
	Female	1	Constant	−187.942	344.963	0.538	−0.545	0.590
			52 CL	194.818	57.755		3.373	0.002
	Male	1	Constant	660.290	207.536	0.363	3.182	0.004
			55 CL	72.970	35.399		2.061	0.049

Coefficients[a]

[a]Dependent variable: Height (mm). CL: Crown length, SE: Standard error

Table 4: Statistically insignificant group of teeth among adults and children - excluded variables table

Excluded variables[a]

Group	Sex	Model		β	*t*	Significant	Partial correlation	Collinearity statistics Tolerance
Adult	Combined	1	11 CL	0.079[b]	0.553	0.582	0.073	0.695
			13 CL	0.001[b]	0.003	0.997	0.000	0.484
			16 CL	−0.105[b]	−0.840	0.404	−0.111	0.894
			17 CL	0.116[b]	0.945	0.349	0.124	0.934
Children	Combined	1	51 CL	−0.031[c]	−0.217	0.829	−0.029	0.731
			54 CL	0.162[c]	1.295	0.200	0.169	0.937
			55 CL	0.201[c]	1.603	0.114	0.208	0.920
			52 CL	−0.009[c]	−0.065	0.948	−0.009	0.749
	Female	1	51 CL	0.211[b]	1.213	0.236	0.227	0.823
			53 CL	0.239[b]	1.310	0.201	0.244	0.745
			54 CL	0.128[b]	0.789	0.437	0.150	0.986
			55 CL	0.109[b]	0.641	0.527	0.122	0.899
	Male	1	51 CL	−0.069[d]	−0.382	0.705	−0.073	0.990
			53 CL	0.000[d]	−0.001	0.999	0.000	0.767
			54 CL	−0.052[d]	−0.200	0.843	−0.038	0.469
			52 CL	−0.091[d]	−0.480	0.635	−0.092	0.897

[a]Dependent variable: Height (mm), [b]Predictors in the model: (Constant), 52 CL, 12 CL, [c]Predictors in the model: (Constant), 53 CL, [d]Predictors in the model: (Constant), 55 CL. CL: Crown length

Table 5a: Example of 12 crown length, 52 crown length model summary table derived from linear stepwise forward regression analysis

Model summary

Group	Sex	Model	*R*	R^2	Adjusted R^2	SE of the estimate
Adult	Combined	1	0.431[a]	0.186	0.172	150.7429882
	Female	1	0.320[a]	0.102	0.070	167.7301245
	Male	1	0.339[a]	0.115	0.084	78.3081862
Children	Combined	1	0.182[a]	0.033	0.017	144.3513134
	Female	1	0.538[a]	0.289	0.264	136.0062055
	Male	1	0.035[a]	0.001	−0.034	108.0814194

[a]Predictors: (Constant), 12 CL, 52 CL, SE: Standard error, CL: Crown length

female measurements, and #55, i.e., maxillary right second molar among male measurements, are statistically significant in the prediction of the child height.

Mathematical equation derivation for height prediction using CLs as an example is shown in Table 5a and 5b. Here, height of the adult is equal to (unstandardized coefficient of constant of combined data) 941.286 plus (unstandardized coefficient of #12 CL) 82.146 multiplied by CL of upper right lateral incisor (#12 CL) and is based on combined (male + female) data.

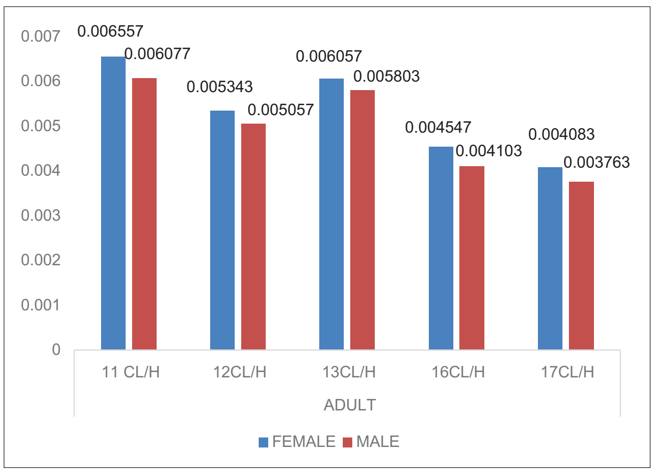
Similarly, height of the female child is equal to −187.942 (unstandardized coefficient of constant) plus 194.818 (unstandardized coefficients of #52 CL) multiplied by the CL of upper right lateral incisor (#52 CL) and is based on female data.

Interestingly, height prediction equations from our study have similarities to Shimada's study of linear relationship of tooth crown height and body length in sharks; i.e., total length in centimeters = a + bx (where a - constant; b - slope of the line; x - CL of the labial surface of the tooth). Here, "a" constant resembles nonstandardized coefficient of constant, and "b"

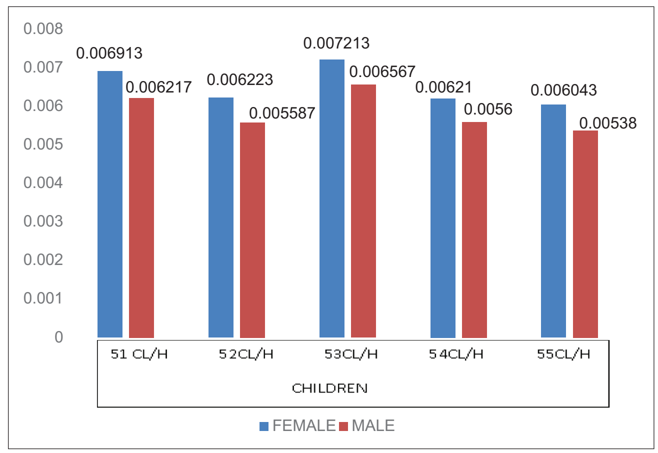
Table 5b: Example of 12 crown length, 52 crown length coefficients summary table derived from linear stepwise forward regression analysis

Group	Sex	Model		Unstandardized coefficients		Standardized coefficients	*t*	Significant
				B	SE	β		
Adult	Combined	1	Constant	941.286	194.710	0.431	4.834	0.000
			12 CL	82.146	22.576		3.639	0.001
	Female	1	Constant	907.931	361.139	0.320	2.514	0.018
			12 CL	77.710	43.502		1.786	0.085
	Male	1	Constant	1470.146	142.963	0.339	10.283	0.000
			12 CL	30.545	15.998		1.909	0.067
Children	Combined	1	Constant	742.002	204.238	0.182	3.633	0.001
			52 CL	48.167	34.087		1.413	0.163
	Female	1	Constant	−187.942	344.963	0.538	−0.545	0.590
			52 CL	194.818	57.755		3.373	0.002
	Male	1	Constant	1044.804	222.636	0.035	4.693	0.000
			52 CL	6.878	36.663		0.188	0.853

[a]Dependent variable: Height (mm). SE: Standard error, CL: Crown length



Graph 1: Comparative representation of male and female mean crown length/height among adults



Graph 2: Comparative representation of male and female mean crown length/height among children

constant resembles nonstandardized coefficient of CL multiplied by mean CL of the tooth. An important observation to be noted from the analysis is that the constants derived from a sample size will fluctuate between different sample sizes in different studies.

Similar equations can be obtained for all the teeth separately for combined group, male group, female group using deciduous and permanent dentition by following the above example and using the constants derived from linear stepwise forward regression analysis. Here, the height prediction equations derived of statistically significant teeth give a more approximate prediction with less error than the nonsignificant teeth. The three groups of data (combined, male, female) are used separately during different situations such as male data equation derived would be used in male height prediction, female data equation derived would be used in female height prediction, and combined group data equation derived would be used when the sex of the individual is unknown.

The findings of the present study are significant in many aspects. The establishment of a definitive relation between tooth CL and individual height has been statistically justified. The predictive relation between the two parameters has been created and mathematically explained. This adds a new dimension in the creation or establishing the profile of a missing individual from tooth data. The obvious advantages of the tooth structure in cases of environmental disasters as a forensic tool can hardly be understated and the availability of the additional parameter of height determination strengthens the armamentarium of the forensic odontologist. The standardized tooth CLs to height ratios would also help assess the growth and development of an individual.

Conclusion

Considering the statistically significant correlation between the tooth CLs and individual height, an application of this concept to all the deciduous and permanent dentition in all the quadrants in a larger population, using different races over different geographical area, better significant results can be obtained minimizing the errors in the final results.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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