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Age estimation in children of Ahmedabad population by measurement of open apices of teeth

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Abstract
Background/Objective: *To estimate the age by radiographic prediction method and to validate the equation of Cameriere in 5-15 years of children of Ahmedabad city population. To compare observed age with estimated age and to formulate new regression equation for children if Cameriere equation is not validated.*
Method:*Orthopantomographs taken from 300 children of Ahmedabad city aged between 5-15 years were analyzed. Following the Cameriere equation, subjects' age was modeled as a function of gender(g),region of the country© and morphological variable:x5(the distance between the inner sided of the open apex of second premolar divided by the tooth length), s(x1+x2+x3+x4+x5+x6+x7)sum of normalized open apices,N0(the number of teeth with root development complete).*
Result: *Second premolar variable was not significant while gender and the variables S, N0 and the firsts order interaction between S and N0 contributed significantly to the fit. Thus, only these variables were included in the regression model yielding the following linear regression formula:*
Age=10.019-0.277g+0.635N0-0.758S+0.082N0
Where g is gender equal to 1 for male and 2 for female. The above equation with the variables considered explained 99.3% of total variance. The median of residual s(=observed age minus predicted age) was -0.032 years with an interquaritile range (IQR)=0.880 years.
Conclusion: *Cameriere's equation does not fit to the children of Ahmedabad city population and thus needs to be modified for different regions. The second premolar variable was not significant and thus had to be removed and the equation then generated by the considering city specific variables estimated the age to better accuracy than Cameriere's equation.*

Keywords: *Forensic Odontology, Age estimation, Open apices, Regression equation.*

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I. Introduction

Age determination plays a key role in forensic medicine, human anthropology, pediatricendocrinology and orthodontic treatments.[1]Teeth are extremely useful in the estimation overskeletal methods as they are durable in archaeological contexts, have mineral remodellingand the growth of permanent and deciduous teeth continues over the entire juvenile period.[2] Inpediatric dentistry age estimation can be used as a crucial indicator to determine theabnormal eruption sequence so that preventive measures can be implemented. Also,thetreatment planning and the prognosis of certain orthodontic treatment greatly depends on thedental age.[3]

There are various methods for dental age determination such as morphological, biochemical and radiographical methods.[4] The present study deals with the dental implications in human age determination using radiological methods. In 2006, Cameriere et al. published a new concept of estimating chronological age in children by measuring the open apices in seven mandibular teeth on radiographs, which gave reliable estimates of age in 455 Italian Caucasian children.[5] Cameriere's method has been found to be more accurate than Demerjian and Willem's methods.[6] The reliability of Cameriere's method was evaluated on several sample groups from different nationalities, to reveal the fact that the original regression model formulated by Cameriere is not always suitable for other countries as tooth development differed among populations and exhibited variation among ethnic groups and regional locations.[7] They were further influence by dietary practice, socioeconomic status, nutritional habits and lifestyle.[8] Few authors therefore modified Cameriere's regression model with newer samples to suit their population and suggested Cameriere's method to be the most accurate method for the population of currentdecade.[9,10]

Although these studies validated the method, they also highlighted the need to develop a discreet regression model for the study samples of each country. A study was conducted by using the aforementioned method and a Cameriere's formula specific for Indian children was established.[11] However, India being a large

country with diverse lifeforms and a population of mixed ethnicity, it is imperative to derive region-specific formula. Hence the present study was designed to evaluate the viability of Cameriere's specific formula for Ahmedabad city, India population.

The purpose of this study is to assess the applicabilty of Cameriere's method as a method for assessing chronological age in children based on the relationship between age and the measurement of the open apices in teeth of Ahmedabad children.

II. Materials and Methods

This retrospective study was carried out in the Department of Pedodontics and Preventive Dentistry, Karnavati School of Dentistry, Gujarat. Ethical approval for the study was obtained from the ethics committee of Karnavati School of Dentistry. Orthopantomographs were taken from the inception of Department of Pedodontics and Preventive Dentistry, Karnavati School of Dentistry.

A sample of 300 good quality orthopantomographs were selected of children aged between 5 and 15 years from Department of Pedodontics and Preventive dentistry in Karnavati School of Dentistry, Gandhinagar.

The orthopantomographs were taken using Satellite 8000 C Digital Panoramicoperating at 60-90Kvp(maximum) with exposure time 8-18 seconds(maximum)at 2-15 mA (maximum) in a standardized manner with an inbuilt magnification factor as specified by the manufacturers.

All subjects were divided into 5 groups 5-6(60-83 months); 7-8 (84-107 months); 9-10(108-131 months); 11-12 (132-155 months); 13-14(156-180 months) according to chronological age and males and females gender wise. A sample size of 300 was determined using the

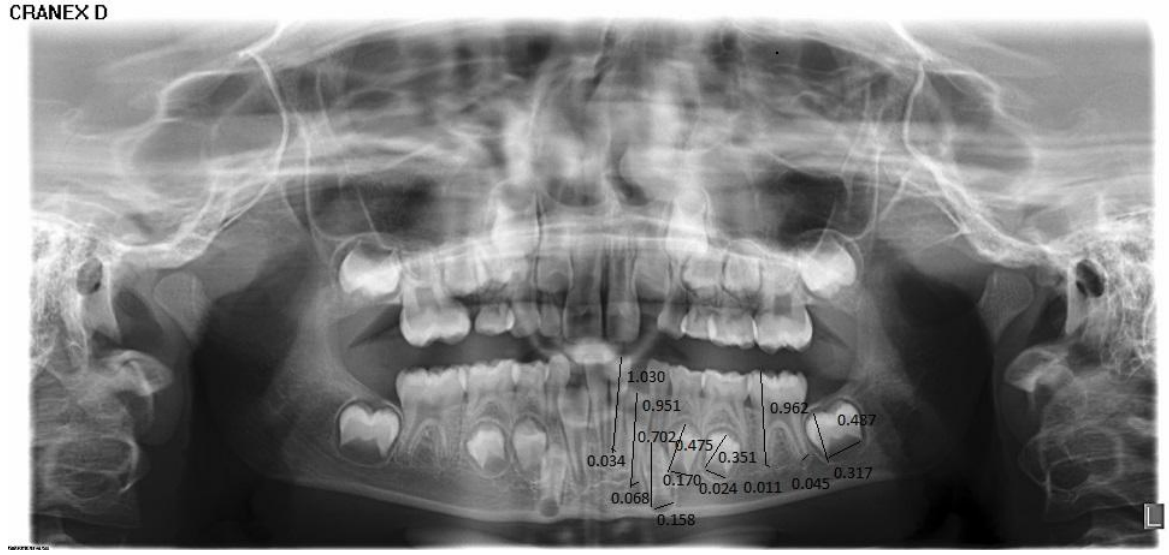
formula: (zalpha +zbeta)^2×sqrt(n×delta^2/2ks^2).

The inclusion criteria for the opg was age between 5 and 15 years at the time of orthopantomogram as assessed by birthdate on case paper,good quality radiographs, healthy left lower quadrant,children residing in Ahmedabad city confirmed by residual address.While, poor quality opg,opg with agenesis or extractions in the left lower quadrant, congenital anomalies, patients with syndromes ,tooth missing due to trauma in lower left quadrant, gross pathology were excluded out of the study.

Assessment of radiographs:

Orthopantogram of 300 children from Ahmedabad city aged between 5 and 15 years were analysed, which were processed using a computer-aided drafting program Adobe photoshop cs (version 8).Theseven left permanent mandibular teeth were assessed(Figure 1).

Figure 1: Measurement of li and ai with adobe photoshop



Calculation of n_o:

The number of teeth with root development complete, apical ends of the roots completely closed (N_0) were calculated.

Calculation of a_i/l_i:

Furthermore, the teeth with root development incomplete, and therefore with open apices, were considered. For teeth with one root, the distance (a_i, i=1,….,5) between the inner sides of the open apex was

measured. For teeth with two roots (a_i, i=6,7),the sum of the distances between the inner sides of the two open apices was evaluated.
Finally, dental maturity was evaluated using the normalized measurements of the seven left permanent mandibular teeth ($x_i=a_i/l_i$, i =1,….,7),the sum of the normalized open apices and the number (n_0) of teeth with root development complete.

Calculation of chronological age:
Chronological age was calculated by subtracting date of birth from the date of radiograph and was also recorded in the table.

Normalization of the magnification error:
To take into account the effect of possible differences in magnification and angulation among x-rays, the measurements were normalized by dividing by the tooth length (l_i,i=1,…,7).

Test for intraobserver reproducibility:
All measurements were carried out by the same observer. To test intraobserver reproducibility a random sample of 40 opgs were re-examined after an interval of 15 days.
The collected data was entered in excel 2013. Inferential statistics was done using: SPSS18.0.Following statistical test were applied: kappa coefficient used to assess intraobserver reproducibility and linear regression model test to assess the data for regression equation.P value less than 0.05 was considered to be significant.

III. Results

The total number of samplewas 300 of which 150 were male and 150 were female. The samples were then grouped according to age and group 5 to 6 years had 57 subject of which were 28 female and 29 male, age group 7 to 8 year had 61 subjects of which 31were females and 30 males, age group 9 to 10 had 72 subjects of which were 38 male and 34 were female, age group 11 to 12 had 50 subject of which were 26 male and 24 were female and age group 13-14 had 60 subject of which were 27 males and 33 were female.
The statistical tests that were applied were linear regression test and kappa coefficient test.
Cameriere (2006)[9] gave the regression equation
8:971+0:375 g+1.631 x 5+0.674 N0+1.034 s+0.176 s N0
Where g is variable equal to 1 for boys and 0 for girls. Subjects' ages were modeled as a function of gender (g), region of country (C), and morphological variables: x5 (second premolar), s, N0, and the first-order interaction between s and N0.
According to this equation the age was estimated and the observed and estimated ages were compared. Age of 25 samples could not be determined due to missing value of x5. The p value of sex, N0, S (x1+…x7), SN0 were significant and X1,X2,X3,X4,X5,X6,X7 were partially significant. Statistical analysis showed that not all the variables used for the European model were significant predictors of age in the Indian sample. In particular second premolar variable was not significant (Table 1).

Table1: Regression analysis with selected morphological variables (predictors) and age as the dependent variable in the total study sample

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	P VALUE
	(Constant)	10.019	.164		61.116	.000
	SEX	-.277	.075	-.055	-3.703	.000
	NO	.635	.028	.529	22.526	.000
	S	-.758	.034	-.497	-22.084	.000
	SNO	.082	.019	.060	4.221	.000
	X1	-.204	.358	-.012	-.571	.568
	X2	.232	.244	.021	.952	.342
	X3	-.093	.185	-.010	-.503	.616
	X4	-.169	.195	-.022	-.866	.387
	X5	-.408	.233	-.056	-1.751	.081
	X6	.360	.237	.035	1.521	.129
	X7	.163	.168	.029	.967	.334

The results show that gender and the variables S, N0 and the first order interaction between S and N0 contributed significantly to the fit. Thus, only these variables were included in the regression model, yielding the following linear regression formula:
10.019-0.277g+0.635N0-0.758S+0.082SN0
Where g is gender, N0 is number of teeth with closed apex, S is sum of x1+…, +x7.

For g, 2 is for female and 1 is for male.
The R^2 of the equation was 0.948 and the standard error of estimate was 0.5783(Table 2)

TABLE2: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.974[a]	.948	.947	.5783

The full model explained 99.3% of total variance, whereas Eq. 1, with the selected variables, explained 94.8% (R2=0.948). The median of the residuals (=observed age minus predicted age) was −0.032 years, with interquartile range (IQR) =0.880 years.
The observed vs predicted plot shows that the regression model fits the trend of the data reasonably well. Hence, the diagnostic plots support our chosen model. (Chart1, 2)

Chart 1: Correlation between ages estimated by regression equation fit for the data and chronological age in total sample**.**

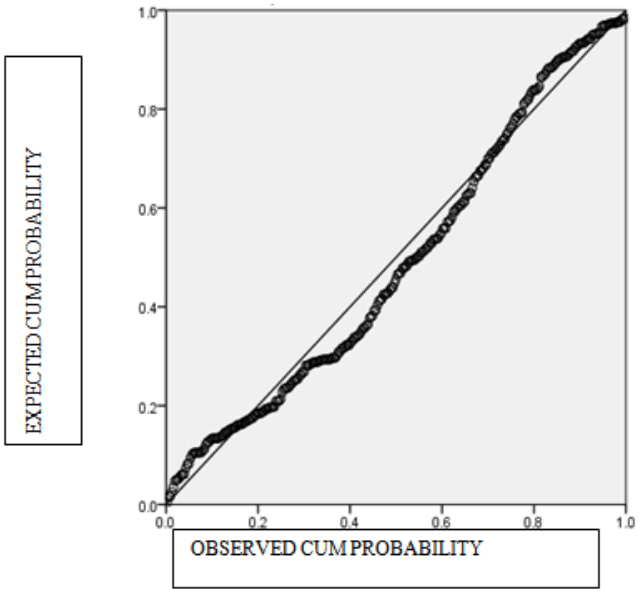
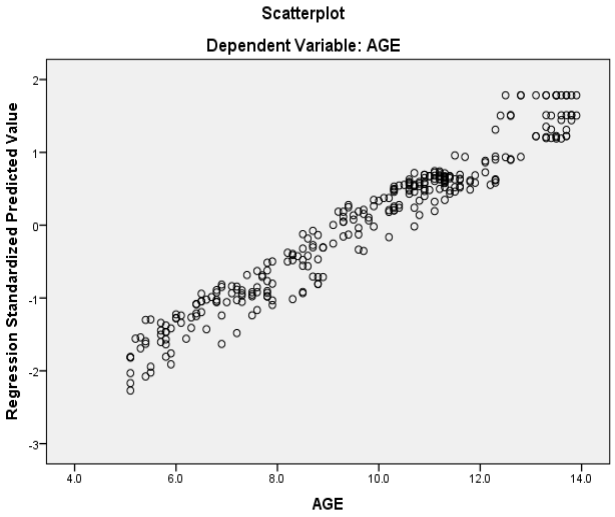


Chart 2: Plot of the residuals against the fitted values (left panel) and plot of the observed against predicted values (right panel) by using the regression model



Intra observer reliability:

There were no statistically significant intraobserver differences between the paired sets of measurements carried out on the re-examined panoramic radiographs. In fact, in the seven right permanent mandibular teeth with root development complete (N0), no misfit was observed between the two measurements made by the observers, i.e., κ=1.

Comparison of differences in observed and estimated values of regression equation fit for the data and Cameriere's equation:

By applying the regression model fit for the data, there was a mean overestimation of 0.20 months in males with a maximum of underestimation of 12 months and overestimation of 15 months and for females there was an under estimation of 0.007 months with a maximum of 17 months underestimation and maximum of 15 months overestimation. While with Cameriere's equation the mean underestimation noted was 0.647months, with maximum of 27 months underestimation and 18 months for male and for females mean under estimation of 5.5 months with maximum underestimation of 28 months and overestimation of 16 months. (Chart 3)

Chart 3: Genderwisecomparison of observed versus estimated ages determined by Cameriere's equation and regression equation fit for data

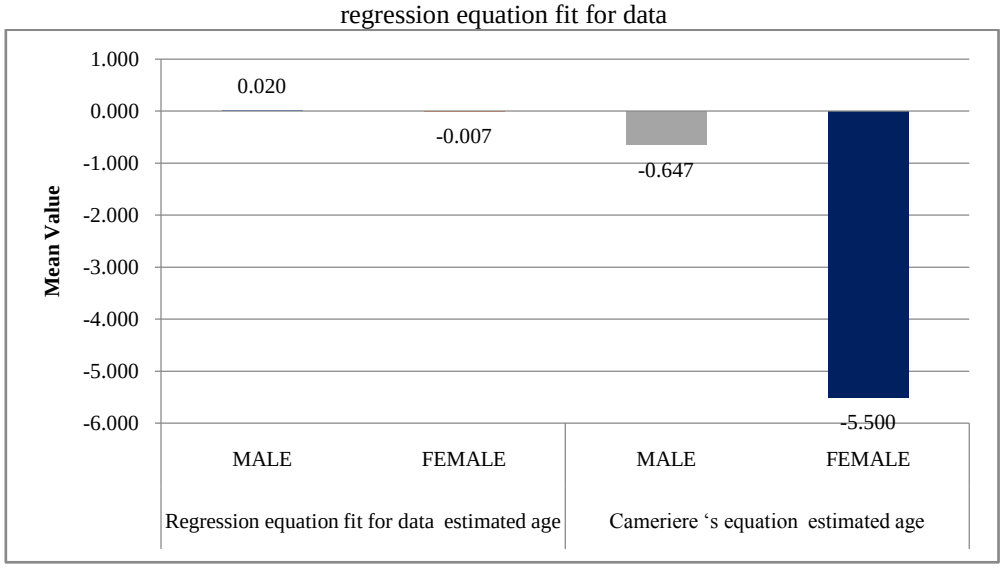
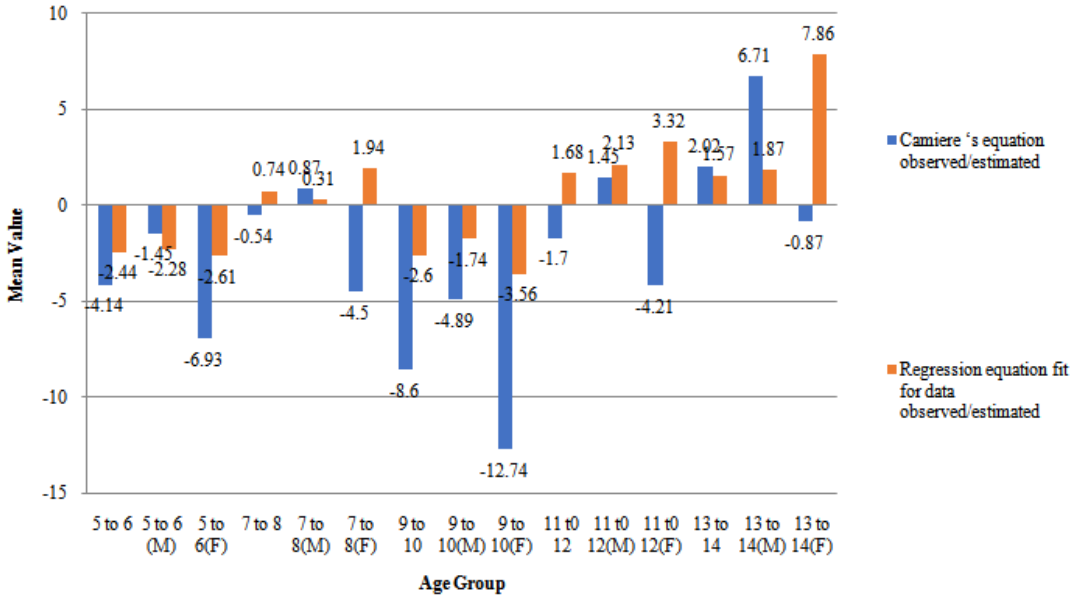


Chart 4: Age group wise comparison of difference in observed versus estimated age by Cameriere's equation and regression equation fit for thedata



For age group 5-6 years there was a mean underestimation of 4.14 months by Cameriere's equation, with highest underestimation being 18 months and overestimation being 16 months and by applying regression

model fit for the data the mean underestimation was 2.44 months, there was maximum underestimation of 13 months and maximum overestimation was also 13 months.

For age group 7-8 years there was a mean underestimation of 0.54 months by Cameriere's equation, with maximum underestimation of 25 months and overestimation of 18 months and when regression model fit for the data was applied the mean overestimation was 0.74 months with maximum underestimation of 11 months and overestimation of 13 months.

When Cameriere's equation was applied for age group 9-10 years, there was a mean underestimation of 8.60 months, the maximum underestimation was 28 months and overestimation was 13 months and when the regression model fit for the data was applied for the same age group, the mean underestimation was 2.60 months, there was maximum underestimation of 12 months and also an overestimation of 12 months was recorded.

A mean underestimation of 1.70 months was recorded for age group 11-12 years, the maximum underestimation of 16 months and overestimation of 13 months was found out when Cameriere's equation was applied while when the regression model fit for the data was used then a mean over estimation of 1.68 months was found out with a maximum underestimation of 6 months and overestimation of 12 months.

There was a mean overestimation of 2.02 months with maximum underestimation of 23 months and overestimation of 14 months by applying Cameriere's equation for age group 13-14 years and when the regression model fit for the data was applied for the same age group the mean overestimation was 1.57 months, with an underestimation 17 months and overestimation of 15 months.

IV. Discussion

Various age estimation methods are widely used to estimate the chronological age of children of unknown birth records for medicolegal purposes. The treatment planning and prognosis of certain orthodontic treatment greatly depends on the dental age. It can be used as a crucial indicator to determine the abnormal eruption sequence so that preventive measures can be implemented. Dental development is more reliable as an indicator of biological maturity in children.[12] There are two concepts in dental age assessment. One is by assessing the age of tooth eruption in the oral cavity and the other is by recording the stages of root and crown mineralization in primary and permanent dentition. The former possesses the disadvantage of being affected by local factors during the process of tooth eruption which includes premature deciduous tooth loss, ankylosis etc. while the latter is a progressive phenomenon and easily definable by the staging of calcification and therefore is the most reliable indicator.[13]

The radiological method is among the most reliable method available for age estimation which is widely used for both dental and skeletal methods.[14] In our study dental age has been assessed by using Panoramic radiograph, following the method described by Cameriere, which is widely used and has been studied extensively on different population by many authors.

Studies comparing various dental age estimation method showed that Cameriere's method showed minimum errors and is highly applicable in various population.[15]Since Cameriere method is better than the other methods of dental age estimation so it was applied in the present study.

The age range from 5 to 14 years remains the most critical with regard to estimating a child's dental age and consequently to determine the proper timing for orthodontic therapy. This age group is commonly accepted for dental age estimation in children as teeth development passes through various stages during these age groups.[16]

A study was done by Cameriere L et al on Italian population of children aged between 5-15 years. Study was based on seven mandibular left healthy permanent teeth for assessing dental age by measurement of open apices in teeth. Statistical analysis showed 83.6% significant correlation with chronological age.[17]The European model states that the developmental stage of second premolar had a significant correlation with age estimation, and hence was included as a variable in the regression equation.[9]

When the same formula was applied on the study population of Ahmedabad city the statistical analysis showed that not all the variables used for the European model were significant predictors of age in the Indian sample. In particular, second premolar variable was not significant. All normalized open apices showed a significant correlation with age, hence, they entered the model equation through the sum of normalized open apices (*s*) and number (*N0*) of teeth with complete root development. The second premolar(x5) proved to be insignificant in the present study as age of 25 samples could not be estimated.

Another study was carried out by Rai B et al on a large sample of Indian children aged between 3-15 years. Results showed that all these variables except gender and second premolar contributed significantly to the fit.[11] In the present study the gender did have an influence and more underestimation of age with the derived regression formula was observed in females. It is possible that the poor nutritional status of Indian adolescents, especially girls, has important implications in terms of their capacity for physical work and adverse reproductive outcomes, as was in fact observed in study done by Koshy S(1998)[14] but contrary to the results found in another

study done by E Cunha (2009) .[18] Hence the gender in India has an influence on maturation because the early maturation of girls, when compared with boys, may be offset by malnutrition and the greater amount of physical work required of them. In fact, as Cunha et al. noted, the best method is sometimes the one which has been tested by many researchers on several different populations, and which is also suitable for a specific forensic context, practical, quick and inexpensive.[19]

The median of residual obtained was 0.269 when Cameriere's equation was applied while the median of residual was -0.032 when the linear regression obtained which was fit for the data was applied. So, the accuracy achieved by this evaluation was higher than the Cameriere's equation.

The results found in this work, like those of others, indicate that more attention should be focused on the possible differences between children of different origins. In fact, all differing factors may be important for age estimation and could make the European formula inappropriate.

V. Conclusion

The present study has been done to estimate age in children of Ahmedabad city using Cameriere's method as no study has been done to estimate age in this region and Cameriere's equation has shown variability in region specific population. When Cameriere's equation was applied on children of Ahmedabad city population, the maximum underestimation was 28 months and maximum overestimation was 18 months. The second premolar (X5) did not show significant correlation.

So, a linear regression equation fit for data was deduced in which gender, sum of normalized open apices(s) and number of teeth (N0) showed significant correlation. Using this linear regression equation the ages were estimated and the maximum underestimation found out was 17 months and maximum overestimation was 15 months.Themedian of residual obtained was 0.269 when Cameriere's equation was applied while when the linear regression obtained which was fit for the data was applied the median of residual was -0.032.

Further research should be done to compare the reliability of our method with other methods for age estimation for city specific population.

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