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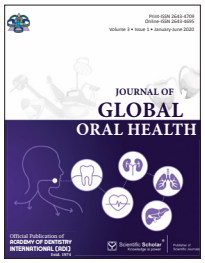

Research Article

A novel model of age estimation in mixed dentition population in Western India – A retrospective study

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ABSTRACT

Objectives: Age estimation is an integral part of legal investigations for forensic purposes. When the chronological age of the individual is not documented or he/she is under the conflict of the law, age estimation comes into play. The need for age estimation may arise in various legal incidences involving children, and juveniles, for civil aspects such as adoption, child labor, or other criminal proceedings such as rape, kidnapping, and illegal immigration. An accurate and dependable method, that can estimate age with high probability, can aid in narrowing down the list of possible victims or even play a decisive role in such cases. The reliability of the method and the probability of correct age estimation play a decisive role in the court of law. Bedek *et al*'s model (2019) was recently developed and tested in Croatian and South Indian populations with satisfactory results. As there is no evidence of study in the Western Indian population, looking into the accessibility of the population group, the present study aims to evaluate the validity and reliability of the Bedek method in the Western Indian population. **Materials and Methods:** Approval was sought from the Institutional Ethical Committee. Five hundred and twenty-five orthopantomographs (OPG) of patients aged 5–15 were obtained. A double-blinded study was done, where the radiographs were analyzed using ImageJ software, independently by two investigators. The data were tabulated and subjected to statistical analysis for accuracy of age estimation and intra- as well as inter-observer reliability. **Results:** There was an underestimation by a range of −1.3038 to −0.74536. There was underestimation in all the models of Bedek with $P < 0.005$, for all the teeth models except, the three- and two-teeth model ($P > 0.005$). **Conclusion:** In our study, we found that the accuracy of age estimation increases significantly with the number of teeth used. Seven four-teeth models were the most suitable for age estimation on OPG. All models except the three-teeth model and two-teeth model were found to be more accurate.

Keywords: Bedek method, Age estimation, Mixed dentition, Orthopantomograph

INTRODUCTION

Age estimation is crucial in forensic anthropology, applicable to both deceased individuals (cadavers and skeletons) and living persons. It plays a pivotal role in various scenarios such as adoption, illegal migration, sexual exploitation cases involving children, and establishing criminal liability. Dental remains are particularly valuable due to the durability of teeth, which resist environmental and genetic factors and degrade slowly compared to other body parts.[1]

Teeth are essential for age estimation, especially in children and adolescents, due to well-defined developmental stages. They are sometimes the only body part available for study and this makes teeth very suitable for dental age estimation.[2] Various methods such as morphological, biochemical, and radiological approaches are used, each with its limitations but significant

utility in forensic investigations.[3] However, all these methods have one or the other limitation restricting their usage on a mass scale. Radiography, being non-destructive, is particularly useful for comparing antemortem and post-mortem dental records. Dental examination and comparison between antemortem and post-mortem dental records and radiographs produce results with a high degree of reliability and relative simplicity.[4,5]

Recently, Bedek *et al.*,[6] from Croatia proposed new models for age estimation based on combinations of mandibular teeth, addressing scenarios with missing teeth (hypodontia) or incomplete remains. Bedek *et al.* emphasized the critical need for age estimation methods, especially in scenarios involving missing teeth, such as hypodontia, or incomplete human remains where multiple teeth are missing. Despite its potential, the accuracy of Bedek *et al*'s models has not been extensively tested outside specific populations like South India. They developed and tested new models for dental age estimation based on a combination of one to seven mandibular arch teeth using univariate regression and regression with forward and backward elimination.[6,7]

To the best of our knowledge, no studies are available in the dental literature that tested the accuracy of Bedek *et al*'s[6] new models of age estimation, except for one study conducted in the South Indian population. Thus, the aim of our study was to evaluate the accuracy of age estimation in Western India on radiographs by Bedek *et al*'s method.[6]

MATERIALS AND METHODS

Five hundred and twenty-five orthopantomographs (OPGs) of children (265 boys and 260 girls) aged between 5 and 15 years were collected retrospectively (2000–2021) from the Department of Oral Medicine and Radiology, Government Dental College and Hospital, Mumbai. All the OPGs were obtained from the archives and taken for radiological diagnosis. No OPG was taken for the sole purpose of this investigation. Ethical approval to undertake this investigation was granted by the Institutional Ethics Committee. OPGs from individuals of Western India, aged between 5 and 15 years, with no apparent dental pathology on the left side of the mandible, and permanent teeth present in the lower left quadrant (except third molars) were included in the study. Exclusion criteria were OPGs with incomplete details, dental pathology of permanent teeth, low-quality radiographs, history of systemic diseases, and congenital anomalies. All OPGs were digitalized and each OPG was coded with unique identification, with relevant information about date of birth (DOB) and date of exposure (DOE). The chronological age (CA) for each individual was then calculated by subtracting DOB from DOE of the radiograph, which was then converted into decimal points (years and months) as a fraction of 12 months.

The developmental stages of seven permanent mandibular teeth on the left side of the jaw were evaluated using Demirjian's method. Coefficients were assigned gender-wise based on the developmental stages of the teeth. The coefficients of individual teeth were summed up. The age of each individual was calculated by the formula:

Dental age = Intercept + coefficients assigned to the tooth stages in the model.

Table 1 shows the details of the formulae for different tooth models for boys and girls separately. All the OPGs were examined for staging by two different examiners. To test intra- and inter-examiner agreement, 100 OPGs were selected randomly and re-assessed after 1 month.

All the data were entered into a computer by giving coding system, proofed for entry errors. Data obtained were compiled on an Microsoft Office Excel Sheet (2019, Microsoft Redmond Campus, Redmond, Washington, United States). Data were subjected to statistical analysis using the Statistical Package for the Social Sciences v 26.0, IBM. Descriptive statistics such as mean and standard deviation for numerical data have been depicted. Inter-group comparison (two groups) was done using the test. For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

* - Statistically significant difference ($P < 0.05$)

** - Statistically highly significant difference ($P < 0.01$)

- Non-significant difference ($P > 0.05$) for all tables

RESULTS

After the statistical analysis, we found out that there was an underestimation by a range of −0.74536 (seven-teeth model) to −1.3038 (one-tooth model), as shown in Table 2. There was no significant difference observed between the variables among the males and the females, indicating gender did not influence the estimation of CA. Tables 3 and 4 depict the Pearson correlation value, and r value for the female and male subjects, respectively, for all the seven models. A comparison of the readings of the two observers did not reveal any statistical significance [Table 5]. There was underestimation in all the models with $P < 0.005$, for all the teeth models except, the three- and two-teeth model ($P > 0.005$). For the three- and two-teeth model, a statistically non-significant difference was seen.

Regarding test of significance, there was underestimation in all the models with $P < 0.005$, for all the teeth models except, the three- and two-teeth model ($P > 0.005$).

For the three and two-teeth model, a statistically non-significant difference was seen.

Table 1: Discrepancy in calculated age using various models and the chronological age.

Models	CA	7-Teeth	6-Teeth	5-Teeth	4-Teeth	3-Teeth	2-Teeth	1-Teeth
Mean	9.26	8.51464	8.44906	8.19988	8.32556	8.24314	8.16078	8.9562
Std Dev	2.183519	2.055604	1.941515	1.929218	1.941515	2.037189	2.090974	2.215518
Upper value of range	14	15.316	14.182	14.315	15.414	15.351	15.299	16.923
Lower value of range	6	4.631	4.42	4.42	5.417	5.35	5.35	5.771
Discrepancy		-0.74536	-0.81094	-1.06012	-0.93444	-1.01686	-1.09922	-1.3038

Std Dev: Standard deviation, CA: Chronological age

Table 2: Pearson corelation value for females.

Model	Female	Chronological age
Seven-Teeth	Pearson Correlation r value	0.896**
	P-value	0.000
	N	260
Six-Teeth	Pearson Correlation r value	0.900**
	P-value	0.000
	N	260
Five-Teeth	Pearson Correlation r value	0.893**
	P-value	0.000
	N	260
Four-Teeth	Pearson Correlation r value	0.897**
	P-value	0.000
	N	260
Three-Teeth	Pearson Correlation r value	0.877**
	P-value	0.000
	N	260
Two-Teeth	Pearson Correlation r value	0.873**
	P-value	0.000
	N	260
One-Teeth	Pearson Correlation r value	0.844**
	P-value	0.000
	N	260

**: Significant, N: Numerical

Table 3: Pearson corelation value for males.

Model	Male	Chronological age
Seven-Teeth	Pearson Correlation r value	0.810**
	P-value	0.000
	N	264
Six-Teeth	Pearson Correlation r value	0.771**
	P-value	0.000
	N	264
Five-Teeth	Pearson Correlation r value	0.921**
	P-value	0.000
	N	264
Four-Teeth	Pearson Correlation r value	0.927**
	P-value	0.000
	N	264
Three-Teeth	Pearson Correlation r value	0.905**
	P-value	0.000
	N	264
Two-Teeth	Pearson Correlation r value	0.859**
	P-value	0.000
	N	264
One-Teeth	Pearson Correlation r value	0.868**
	P-value	0.000
	N	264

**: Significant, N: Numerical

DISCUSSION

This study investigates the applicability of the Bedek and Cameriere method in determining the dental age of the patient using orthopantomographs (OPG). Due to the same geographical location of the sample, it can be considered an accurate representation of Western India. In addition, all the OPGs were taken on the same device, ensuring high-quality standardized images.

In 2019, Bedek *et al.*,[6] developed new models for age estimation based on a combination of one to seven mandibular teeth using univariate regression and regression with forward and backward elimination. To date, no method in the literature has been put forward to assess age in living individuals or incomplete human remains with multiple missing mandibular teeth.[7,8] Bedek *et al.*, highlighted the absolute necessity of age estimation methods, particularly in cases of hypodontia or incomplete human remains with multiple missing teeth. In the same study, Bedek *et al.*, also tested new age estimation models by comparing their performance in parallel with Willems models. Results showed that the newly developed models significantly surpass the accuracy of Willems models. This method has not been tested on the Indian population except study conducted on the South Indian population.

Table 4: Standard error of the estimate for the Bedek model.

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.916[a]	0.839	0.835	0.989

[a]Predictors: (Constant), One-Teeth Model, Seven-Teeth Model, Three-Teeth Model, Two-Teeth Model, Five-Teeth Model, Four-Teeth Model, Six-Teeth Model, R: Standard error

Table 5: Standardized and unstandardized coefficients for the Bedek models.

Coefficients						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		A	**Std. Error**	**Beta**		
1	(Constant)	-0.557	0.229		-2.432	0.015
	7-Teeth	0.330	0.082	0.253	4.046	0.000
	6-Teeth	-0.291	0.077	-0.229	-3.783	0.000
	5-Teeth	0.578	0.103	0.476	5.616	0.000
	4-Teeth	0.354	0.161	0.266	2.193	0.029
	3-Teeth	-0.014	0.101	-0.011	-0.135	0.893
	2-Teeth	-0.036	0.079	-0.031	-0.451	0.652
	1-Tooth	0.215	0.047	0.210	4.604	0.000

A: Dependent variable; t: Test of significance; Sig.: Significance

For this purpose, we conducted a study to evaluate the accuracy of age estimation on radiographs by the Bedek method in Western India. New models developed by univariate regression and regression with forward and backward elimination, proved to be precise, even when using fewer teeth for dental age estimation. This is the major advantage and contribution of our study.[9] The most precise age estimation was achieved using the teeth model. An important advantage of these models is the possibility to estimate dental age in cases with hypodontia while maintaining or even surpassing the accuracy of other radiographic methods. These new models can also be used in cases of human remains where some teeth or part of the jaw are missing.

A possible weakness of our study was the small number of OPGs, being an institutional study. All the OPGs were taken for diagnostic purposes and not for this investigation. As there is no ethical justification for taking OPGs merely for scientific research with no clinical relevance for the child, we were not in a position to boost the number of OPGs in age groups 5–6 and 6–7 years. This was both an ethical and professional decision. Due to our selected statistical methods, we are nonetheless confident that the small number of OPGs in the two youngest age groups did not compromise age estimation for the other age groups (7–16 years).

In Turkish children, Gulsahi *et al.*, (2022)[10] found underestimated CA by 0.2–0.1 years, whereas in our study underestimation of range, −0.745 to −1.3038 was observed. In a previous sample of 1868 Croatian children, Bedek *et al.*,[6] found underestimation within a range of 0.41–0.22. Whereas, in our study, the Bedek method underestimates by a range of −0.745 to −1.06012. Similar results were obtained in a study conducted on the South Indian population by Sheriff *et al.*[7] Recently, a study was done in a Turkish population of 1118 children, wherein all Bedek models underestimated CA by 0.2–0.1 years, which coincides with our results.

In our newly developed models, the accuracy of age estimation increases significantly with the number of teeth used. Predictably, the difference in the percentage of correct estimations within a specific interval between models with three or four teeth and the model with seven teeth does not exceed 3%. Due to their simplicity and accuracy, these models can be recommended for dental age estimation in clinical practice. The reduced number of teeth required for age estimation of almost equal value offers the possibility for age assessment in different forensic contexts in which even several teeth are missing. This method will prove particularly effective in the analysis of incomplete human remains and hypodontia. Its future application represents the greatest contribution to our study. In cases of age estimation when all the teeth are present, maximal accuracy can be obtained using the seven-teeth model. One study by De Donno *et al.*,[11] modified the Demirjian method based on a Belgian Caucasian population and simplified the age estimation by directly converting maturity scores into age. The modified technique resulted in smaller overestimation of 0.0 years in males and 0.2 years in females.[11]

Merits

Only one study was conducted in Western India to assess the accuracy of Bedek models, where the sample size was considerably high compared to the other available literature. In case of missing teeth, we have got satisfactory results. All the OPGs were digital, standardized, and taken from the same machine.

Demerits

Less literature is available regarding the Bedek models and lesser number of OPGs were studied, being Institutional level study.

CONCLUSION

In our study, we found that the accuracy of age estimation increases significantly with the number of teeth used. Seven-

four teeth models were the most suitable for age estimation. All models except the three-teeth model and two-teeth model were found to be more accurate. Bedek models for both sexes with two to seven teeth proved to be significantly accurate and thus represent a simple, reliable, and accurate approach to dental age estimation. Due to their simplicity and applicability in cases of missing teeth, they can be used for clinical purposes as well as for complex forensic scenarios, particularly in cases that present incomplete human remains or hypodontia. For result comparison, it is to be hoped that these models will be tested among other populations, particularly those of a similar geographical origin. Furthermore, a study is to be done with a larger group of the population.

Ethical approval

The research/study was approved by the Institutional Review Board at Government Dental College and Hospital, Mumbai, number 4090/2023, dated October 12, 2023.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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