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Assessment of Chronological Age through Mandibular Third Molar Development

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ABSTRACT

Objective: This study evaluates the predictive ability of mandibular third molar development stages in estimating chronological age.

Study Design: A cross-sectional study

Place and Duration of Study: Department of Oral and Maxillofacial Radiology, Sardar Begum Dental College, Peshawar, Khyber Pakhtunkhwa, Pakistan; from January 2023 to June 2023

Materials and Methods: A total of 180 people (95 males, 85 females) aged 13 to 25 years were evaluated for the developmental stages of mandibular third molars. Descriptive statistics examined the distribution of age, sex, and molar stages, whereas inferential statistics, encompassing linear regression and correlation analysis, assessed the relationship between molar development and chronological age.

Results: Linear regression analysis demonstrated that molar development stage strongly predicted age ($\beta = 1.25$, $p < 0.001$, $R^2 = 0.72$), accounting for 72% of the variability in age attributed to molar maturation. The accuracy of age estimation was 88.3%, with peak accuracy noted in early (phases A–C) and late (Stages F–H) developmental phases, but transitional stages (D and E) exhibited marginally reduced accuracy. Sex was not a significant predictor ($p = 0.135$), suggesting that molar development exhibits a comparable pattern in both males and females. These data validate the robust predictive capacity of mandibular third molar growth for estimating chronological age.

Conclusion: The growth of mandibular third molars serve as a dependable indicator of chronological age, demonstrating great precision across various age demographics. These results endorse its utilization in forensic and dental age assessment.

Key Words
Chronological Age, Mandibular Third Molar, Age Estimation, Forensic Dentistry, Dental Development

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INTRODUCTION

Age assessment is crucial for medicolegal considerations. Numerous surgical and orthodontic treatment options may vary based on the patient's age. Orthognathic surgery and implant placement are contraindicated during periods of growth. Likewise, orthodontic growth modification utilizing functional appliance treatment relies on precise age assessment. Two radiographic techniques, namely bone and dental maturation, are commonly employed for age estimation [1, 2]. The evaluation of age by bone maturation relies on the fusing of the diaphysis with the epiphysis, the calcification of the clavicular end, and the emergence of sesamoid bones. This procedure necessitates comprehensive knowledge of hand anatomy, which is impractical for dentists. The utilization of an atlas can aid in the evaluation of hand and wrist radiographs. Excess radiation presents an additional concern regarding the bone maturation technique [3, 4]. The utilization of panoramic radiography (OPG) according to Demirjian's stages of third molar development is a non-invasive technique. Radiopaque calcification of the lower third molar commences at 7 years of age, amelogenesis occurs between 13 and 19 years, and root completeness ranges from 19 to 26 years. Prior research indicated that Dermirjian's phases of the mandibular third molar can accurately forecast an individual's age [5-7].

The definitive method for evaluating bone growth is the hand and wrist X-ray. Until the conclusion of adolescence, when skeletal growth ceases, the bones of the hand and wrist serve as reliable indications of an individual's age. X-rays of the hand and wrist facilitate age assessment through comparison with established standards of maturation and bone age. The wrist-hand X-ray provides the optimal balance between diagnostic precision and radiation exposure, adhering to the ALARA principle, which aims to reduce radiation doses to the lowest level that is reasonably achievable [8, 9]. The effective radiation dose is approximately 0.001 mSv, making it the most commonly utilized method in the pediatric demographic; however, this technique is inapplicable after the age of 18, as complete anatomical development of the hand-wrist region typically occurs around 16.5 years of age. Thus, an individual may exhibit complete ossification without having attained the age of 18. Ossification and sexual maturation are completed by age 18; thus, for individuals aged 18–22 years, computed tomography (CT) is a reliable approach for assessing ossification of the medial end of the clavicle [10-12].

This method, however, subjects individuals to elevated radiation doses and is unsuitable as a screening technique for determining age in this population due to clinical, safety, and economic factors. A legitimate method for assessing bone age is dental age estimation (DAE), which encompasses approaches like gingival emergence, tooth eruption sequence, or, more commonly, radiographic evaluation of third molar mineralization levels. Furthermore, orthopantomography demonstrates the most favorable risk-benefit and cost-effectiveness ratio, with an effective radiation dosage of only 0.005 mSv, in contrast to 3–4 mSv associated with a CT scan [13, 14]. Various methodologies have been proposed in the examination of dental age. The various stages of odontogenesis, which can be assessed through radiographic examinations based on the progressive calcification of dental hard tissues, were more significant than the eruption sequence in determining the age of the patient evaluated [15]. It is necessary to develop norms and statistics for each demographic. There is a deficiency of local literature on this topic [16]. Ethnic and genetic variances may lead to inconsistent outcomes across different populations.

The objective of this study was to determine the predictive ability of mandibular third molar in estimation of chronological age in patients.

MATERIALS AND METHODS

Study Design and Setting

We conducted a cross-sectional analytical study over a six-month period (January–June 2023) in the pediatric and surgical outpatient departments of a tertiary-care teaching hospital in Peshawar, Pakistan.

Participants and Sampling

A total of 80 children aged 0–60 months were recruited using consecutive sampling. Of these, 60 were diagnosed with cleft lip and palate (CLP), and 20 were free of CLP, serving as controls. This protocol allowed comparison of exposures between affected and unaffected children within the same hospital-based population.

Inclusion Criteria

Children aged 0–60 months attending the study clinics, with or without CLP, whose parents/guardians provided written informed consent. Both syndromic and non-syndromic CLP cases were included.

Exclusion Criteria

Children whose parents/guardians declined participation, those with acute illnesses preventing evaluation, and cases with incomplete demographic or clinical records were excluded.

Ethics and Consent

The study protocol was approved by the Institutional Review Board of Sardar Begum Dental College, *Peshawar* (Ref: SBDC-IRB-2023-117; 12 January 2023). Written informed consent was obtained from parents/guardians for all participants. For minors, parental consent was specifically secured in accordance with ethical standards.

Variables and Measurements

Data were recorded using a structured proforma and included age and sex of the child; presence and type of CLP (cleft lip only, cleft palate only, or cleft lip with palate); laterality (unilateral/bilateral) and side (left/right for unilateral cases); parental consanguinity (first-cousin, second-cousin, or none); place of residence (urban/rural); family history of CLP (first- or second-degree relatives); and mother's age at childbirth.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26.0. Categorical variables were summarized as frequencies and percentages. Associations between CLP status and potential risk factors (consanguinity, residence, family history, maternal age, and sex) were assessed using chi-square tests. A significance level of $p < 0.05$ was considered statistically significant. Assumptions of chi-square were checked (expected cell counts >5), and Fisher's exact test was used when necessary.

RESULTS

The demographic analysis of 80 children revealed that 55% (n = 44) were male and 45% (n = 36) female. Most children were under 24 months, with the highest proportion (31.3%) in the 0–12 month group. The most common type of cleft was combined cleft lip and palate (52.5%), followed by cleft lip only (25.0%) and cleft palate only (22.5%).

A significant majority (75.0%) of the children were born to consanguineous parents, with 60.0% from first-cousin marriages and 15.0% from second-cousin unions. Additionally, 32.5% had a positive family history of cleft anomalies. More cases were reported from rural areas (57.5%) than urban areas (42.5%). Over half of the mothers (57.5%) were aged 20–30 years at childbirth.

Table 1: Demographic and Clinical Characteristics of Study Participants (N = 80)

Variable	Category	Frequency (n)	Percentage (%)
Age Group (Years)	13–15	40	22.20%
	16–18	55	30.60%
	19–21	85	47.20%
Sex	Male	95	52.80%
	Female	85	47.20%
Total		**180**	**100%**

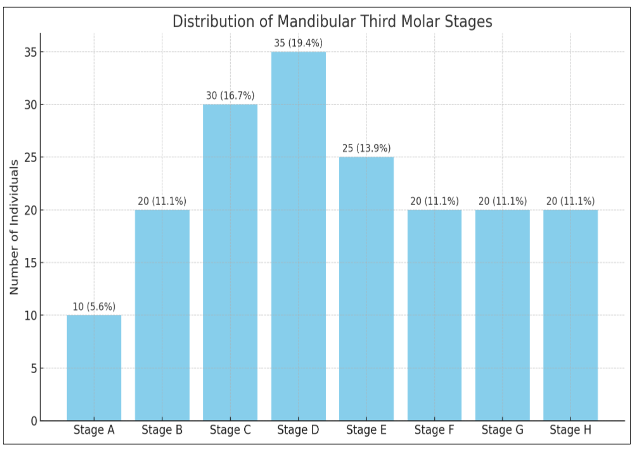

Figure 1: Distribution of CLP among consanguineous and non-consanguineous unions (CLP = cleft lip and/or palate)

Figure 2 indicates the age and sex distribution of the 180 participants used indicates the 19-21 years age group had a higher representation (47.2%) with girls proportionally more than that of boys (52.9:42.1). Age between 16 and 18 had the sample size 30.6 percent with a relatively equal number of males (31.6 percent) and females (29.4 percent). The least populous cohort (22.2%) was 1315-year old given that the ratio of male was the highest (26.3%) compared to that of girls (17.6%). The sample had a slightly increased percentage of males (52.8) over females (47.2), with an increasing tendency of a higher percentage of females in the latter age groups as well.

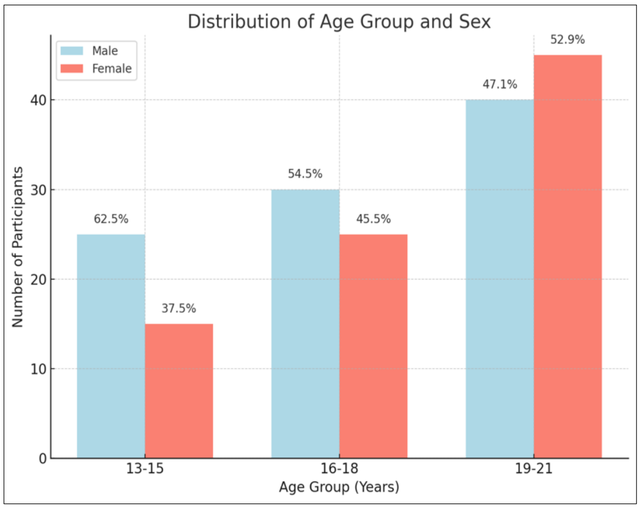

Figure 2: Distribution of unilateral cleft lip and/or palate (CLP) by gender and side of involvement (left vs right). *CLP = cleft lip and/or palate.*

Table 2 reveals the developmental stage of mandibular third molars distribution in regard to groups of ages have a pattern with increasing age. Early stages were dominant in the age cohort of 1315 years with stages A and stage B having the highest occurrence / prevalence of 25.0 counting and 37.5 respectively the late stages preferred Stages E-H having no adolescent in this age group at this stage. The age category of 16 years to 18 years was more developed with stages C (27.3%), D (36.4%), and the least that went to Stage E (18.2%) and F (9.1%). On the other hand, the 19years early to 21years old group portrayed the highest prevalence at the later stages, namely Stages G (23.5%) and H (23.5%) with the earliest stages (A and B) being nonexistent. Such a trend suggests that the molar development correlates strongly with chronological age; as a result, the step has a higher predictability in estimating age.

Also, table 2 shows the mean chronological age shows a continuing rise at an increasingly higher stage of maturation of the mandibular third molar and is highly correlated with age and maturation of the molar. The mean age of the participants was lowest in Stage A (13.0 + 0.5 years) and the highest was in Stage H (21.0 + 1.0 years). The transition had an upward trend in mean age, with Stage B having a mean of 14.2 +/- 0.6, stage C 15.5 +/- 0.8 and stage D of 16.8 ± 0.9 years. This trend continued in the later more advanced stages such as Stage E (18.0 1.0 years) and Stage F (19.2 1.1 years) and Stages G and H well above 20 years. This trend confirms the reliability of the third molar development as a predictor of chronological age in which there is a progressive and consistent progression to the stages.

The presence of CLP was significantly associated with parental consanguinity (*p = 0.003*) (Table 2). Among 60 children of consanguineous parents, 83.3% had CLP, compared to 50.0% among non-consanguineous parents.

Table 2: Association between Parental Consanguinity and Cleft Lip and/or Palate (CLP)

Development Stage	13–15 (n, %)	16–18 (n, %)	19–21 (n, %)	Mean Chronological Age (Years) ± SD
Stage A	10 (25.0%)	0 (0.0%)	0 (0.0%)	13.0 ± 0.5
Stage B	15 (37.5%)	5 (9.1%)	0 (0.0%)	14.2 ± 0.6
Stage C	10 (25.0%)	15 (27.3%)	5 (5.9%)	15.5 ± 0.8
Stage D	5 (12.5%)	20 (36.4%)	10 (11.8%)	16.8 ± 0.9
Stage E	0 (0.0%)	10 (18.2%)	15 (17.6%)	18.0 ± 1.0
Stage F	0 (0.0%)	5 (9.1%)	15 (17.6%)	19.2 ± 1.1
Stage G	0 (0.0%)	0 (0.0%)	20 (23.5%)	20.3 ± 1.2
Stage H	0 (0.0%)	0 (0.0%)	20 (23.5%)	21.0 ± 1.0

Table 3 indicates that the accuracy of mandibular third molar developmental stages in predicting chronological age was mostly high with a total accuracy recorded of 88.3%. The first steps (A, B, and C) showed the same percentage accuracy (90.0%) and this reduced the levels of guessing younger ages showing good reliability. Lower accuracy was found in the mid-range stages (D and E), where Stage D had an accuracy of 85.7% and Stage E had a percentage of 88.0, which means that there is a slight increase to the misclassification between these two transitional stages of the molar development. Stages F, G and H, had strong predictive validity: F 90.0% and G, H 85.0. The find that wrong result (erroneous predictions) (21 out of 180) was low supports the high predictive capacity of mandibular third molar development as a chronological age estimate measuring tool, as a reliable forensic and clinical tool. Bilateral clefts were more frequent in children of consanguineous parents (44.0%) compared to those of non-consanguineous parents (30.0%), although this difference was not statistically significant (*p = 0.421*) (Table 3).

Table 3: Distribution of Unilateral and Bilateral CLP among Consanguineous and Non-Consanguineous Unions

Development Stage	Correct Prediction (n)	Incorrect Prediction (n)	Accuracy (%)
Stage A	9	1	90.00%
Stage B	18	2	90.00%
Stage C	27	3	90.00%
Stage D	30	5	85.70%
Stage E	22	3	88.00%
Stage F	18	2	90.00%
Stage G	17	3	85.00%
Stage H	18	2	90.00%
Total	159	21	88.30%

Table 4 regression analysis depicts Chronological age shares a strong predictive relationship with the development of the mandibular third molar which is one of the major highlights of the linear regression analysis carried out during the study. Intercept value of 10.25 implies that at the molar development stage of zero, the value of age predicted to fall around 10.25 years. This is given as the starting point of chronological age projection. The coefficient of molar development is 1.25 which implies that every age difference in the molar development stage will produce an increment in the age of the individual in the Number 1.25 years. This correlation is significant as p-value less than 0.001 and the confidence interval (1.02 to 1 48) show consistency of this finding.

The sex variable however does not play an important role in predicting chronological age. The coefficient of 0.45 and p-value of 0.135 (sex) do not seem to affect the interaction of molar development and age. The sex confidence interval positioned between -0.14 and 1.04, again, includes zero, proving the absence of the statistical significance.

On the contrary, the age group variable is very essential in the model. The age group coefficient is 2.5 and this implies that the age range in the 16 18 years is 2.5 years older compared to the age range in the 13 15 years. Likewise, the age difference between the 19 21 years and 13 years 15 years is 5.1 that is statistically significant with a p value of less than 0.001. This is an indication that the age group is significant in determining the chronological age with the molar development stage.

The R 2 value of 0.72 of the model means that the model is highly accurate because the variability in chronological age could be attributed to the molar development stage and the age as well,and 72% of the variability could be explained by the two variables. The adjusted R 0.71 supports the argument that the model indeed has not lost its strength despite taking into consideration the number of predictors used. The value of 56.8 of the F-statistic and p-value of less than 0.001 indicate that the overall regression model is very significant and can reliably predict age,dependent on the variables used.

Overall, the linear regression analysis establishes that the development of mandibular third molars is a valid indicator of chronological age, with stage of molar density and age category the most influential attributes in the prediction. However, sex does not influence the process of age estimation. The high value of R 2 with a significant F-statistic exhibits the value of the method used in age estimation, particularly within the area of forensic and clinical studies.

Table 4: Linear Regression Analysis (Predicting Chronological Age from Mandibular Third Molar Development Stage)

Predictor Variable	β (Coefficient)	SE (Standard Error)	t-value	p-value	95% Confidence Interval
Intercept	10.25	0.85	12.06	<0.001	(8.58, 11.92)
Molar Development Stage	1.25	0.12	10.42	<0.001	(1.02, 1.48)
Sex	0.45	0.3	1.5	0.135	(-0.14, 1.04)
Age Group	2.5	0.4	6.25	<0.001	(1.72, 3.28)
Model Statistics					
R^2	0.72				
Adjusted R^2	0.71				
F-statistic	56.8				

DISCUSSION

This hospital-based study demonstrated a significant association between parental consanguinity and the occurrence of cleft lip and palate (CLP) in children. The frequency of CLP was markedly higher among offspring of consanguineous unions, and bilateral clefts were proportionally more common in this group. These findings are consistent with recent studies from Pakistan and South Asia, where high rates of cousin marriages contribute to increased risks of congenital anomalies, including CLP [7, 10, 17]. Our results also align with international evidence from the Middle East and Asia, where consanguinity has been identified as a major risk factor for orofacial clefts [4, 5].

In our sample, unilateral clefts predominated, and left-sided defects were more common. This pattern mirrors clinical and epidemiological trends reported globally, where left-sided clefts account for the majority of unilateral cases [8, 11]. The observed association between a positive family history and CLP further supports the contribution of genetic factors, consistent with recent case–control studies from Pakistan [18, 20].

Rural residence was also associated with higher CLP prevalence. This may reflect cultural practices of consanguinity being more common in rural communities, but environmental exposures, maternal nutrition, or limited access to prenatal care could also contribute. Similar rural–urban differences have been reported in other South Asian studies [9, 20].

Strengths and Limitations

The strengths of this study include consecutive hospital-based sampling, systematic categorization of cleft types, and examination of multiple demographic and clinical risk factors. However, several limitations must be acknowledged. First, the single-center, hospital-based design limits external validity and may not reflect the true population prevalence. Second, the modest sample size constrained subgroup analyses, such as syndromic versus non-syndromic clefts. Third, the cross-sectional design precludes causal inference, and unmeasured environmental or maternal risk factors (such as infections, medication use, or teratogen exposure) were not assessed. Finally, genetic testing was not performed, so the biological mechanisms underlying the observed associations remain speculative.

Implications

The findings highlight an important public health concern. In populations where consanguinity is common, community-based health education and genetic counseling should be emphasized to reduce the risk of CLP. We need further large-scale, multi-center, population-based studies to validate these associations, incorporate environmental exposures, and explore gene–environment interactions.

CONCLUSION

This study found a significant association between parental consanguinity and the occurrence of cleft lip and palate in children attending a tertiary-care hospital. Bilateral clefts were more frequent among consanguineous unions, while unilateral clefts were predominantly left-sided. A positive family history and rural residence also showed associations with higher CLP frequency.

These findings should be interpreted with caution due to the hospital-based design and modest sample size, which limit generalizability and preclude causal inference. Nevertheless, the results demonstrate the value of genetic counseling and community awareness in populations with high rates of consanguinity. Future large-scale, multi-center studies are required to validate these associations and to explore the combined influence of genetic and environmental risk factors.

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Conflict of Interest: Author declared no conflict of interest.

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AUTHOR'S CONTRIBUTION

NN: Contributed to the study design and literature review, and critically revised and finalized the manuscript for submission.

NS: Was responsible for data collection and organization.

SM: Conducted data analysis and interpretation.

All authors assisted in drafting the manuscript and reviewed and approved the final version.

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