Evaluation of dental and skeletal age among unilateral cleft lip and palate patients in an eastern Indian population

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The authors declare that they have no conflict of interest.

KEYWORDS

Unilateral cleft lip and palate,
Dental age,
Skeletal age,
Demirjian method,
G-P atlas technique,
Forensic age assessment.

J Forensic Odontostomatol
2025. Aug;(43): 2 -32:42
ISSN :2219-6749
DOI: doi.org/10.5281/zenodo.16486024

ABSTRACT

Background: Unilateral cleft lip and palate affects dental and skeletal maturation, leading to delays that impact treatment planning and forensic age estimation. Understanding the correlation between dental age, skeletal age, and chronological age is essential for clinical and medico-legal applications.

Aim: To evaluate and compare dental and skeletal age in non-syndromic unilateral cleft lip and palate patients with an age- and gender-matched non-cleft control group.

Materials and Methods:

This cross-sectional study included 216 individuals (108 unilateral cleft lip and palate cases and 108 controls), aged 7 to 18 years. Dental age was assessed using Acharya's modified Demirjian method on panoramic radiographs, while skeletal age was estimated using the Greulich and Pyle Atlas from left hand-wrist radiographs. Statistical analyses were conducted to compare dental age, skeletal age, and chronological age.

Results: Skeletal age was more delayed than dental age, with males experiencing greater delays than females. Males had a mean skeletal delay of 0.92 years ($p < 0.001$), and females had a delay of 0.90 years ($p < 0.001$). Dental age delay was 0.28 years in males ($p = 0.016$) and 0.21 years in females ($p = 0.150$, not significant). The most significant delays were observed between ages 10 to 14 years, with a peak skeletal delay of 1.04 years at age 10 in females ($p < 0.001$).

Conclusion: Skeletal age is more delayed than dental age, with males experiencing greater delays. These findings highlight the need for individualized treatment planning and reinforce the importance of cleft-specific age estimation methods in forensic and legal contexts.

Clinical Significance: Accurate assessment of skeletal and dental age is essential for timely orthodontic and surgical interventions and for preventing age misclassification in forensic applications.

INTRODUCTION

Cleft lip and palate (CL/P) represent one of the most common congenital anomalies, affecting approximately 1 in 700 live births globally, with prevalence varying across populations.[1] It is reportedly more frequent in Asian (1 in 500) than in European (1 in 1,000) and African (1 in 2,500) populations.[2] The prevalence of CL/P within Southeast Asia demonstrates significant variation across ethnic groups, with incidence rates per 10,000 live births documented as 16.63 among Chinese,[3] 18.5 among Malays,[4] 13.0 among Indians,[5] and 21.73 in individuals of mixed ethnic heritage.[6] India reports 50,000–60,000 new cases annually,[7] with regional variations, including 1.09 per 1,000 in Andhra Pradesh,[8] 1 in 700 in Karnataka and Kerala,[9] and 0.73 per 1,000 in rural Gujarat.[10]

Children with CL/P may experience feeding, breathing, dental and skeletal abnormalities with delayed maturation, speech, hearing, and psychological challenges.[11,12] Previous studies have reported delayed dental and skeletal maturation in cleft patients compared to individuals without clefts.[2] Understanding a cleft patient's dental age (DA) and skeletal age (SA) which designate the biological age, is crucial as their growth pattern often does not align with chronological age (CA). This knowledge has significant applications in treatment planning, orthodontic interventions and cosmetic surgeries as it helps determine the optimal timing for corrective procedures that synchronize with the patient's growth and developmental stages. It is also crucial in forensic investigations to ensure they are not erroneously classified as minors when applying standard age reference models developed for non-cleft populations which holds importance in medico-legal contexts, where accurate age determination has serious implications.[13]

The Study Group on Forensic Age Diagnostics (AGFAD) recommends a comprehensive forensic age assessment, including physical examination, a hand X-ray, and dental evaluations using orthopantomograms (OPG).[14] SA estimation determines CA based on skeletal maturation, primarily assessed through hand-wrist ossification patterns.[12] The Greulich and Pyle (G-P) Atlas, a widely recognized methodology, evaluates left hand-wrist radiographs by referencing standardized age-specific radiographic templates.[15] Dental age estimation (DAE) utilizes various methods including Demirjian's,[16] Willems',[17] Cameriere's open apices [18] with selection based on age, dental status, radiographic quality, and precision needs. Demirjian's method, the most widely used, evaluated seven mandibular teeth across eight developmental stages, later incorporating third molars.[16] However, inaccuracies have been reported when employing the original method in other populations.[19,20] To address this, Acharya et al. modified the Demirjian's method, introducing Indian-specific formulae, that provided improved accuracy and reliability with a mean absolute error (MAE) of 1.29 years in the Indian population.[21]

Dental maturity may be impacted at various levels by the etiological factors associated with different cleft severities and types of CL/P each of which can have distinct effects on the cleft-affected region.[13] A subset of these cleft conditions is unilateral cleft lip and palate (UCLP) which stands out from other cleft types due to its higher prevalence of dental anomalies.[22] To the best of our knowledge, biological age assessment by investigation of skeletal development and dental development in a group of non-syndromic subjects with complete UCLP and its comparison with CA has hitherto not been performed in the Indian population. Therefore, the present study aimed to evaluate the same and to also compare the findings with an age and gender matched non-cleft control group. The current study solely involves patients with complete UCLP in order to minimize potential bias integration and to enable fair comparisons in future research. These insights are expected to improve clinical treatment strategies and enhance forensic age estimation for UCLP patients in this population.

MATERIALS AND METHODS

Ethical approval:

The study was conducted following ethical guidelines, with Institutional Ethical Committee approval from SCB Dental College and Hospital, Cuttack (Ref. No: IEC/SCBDCH/155/2022).

Study Sample:

This cross-sectional comparative study (June 2022–October 2024) included 216 children and adolescents (7–18 years), comprising 108 UCLP cases and 108 age- and gender- matched non-cleft controls, with a maximum CA difference of 60 days per pair. Standardized OPGs and hand-wrist radiographs were obtained for all participants, and both imaging procedures were performed on the same day.

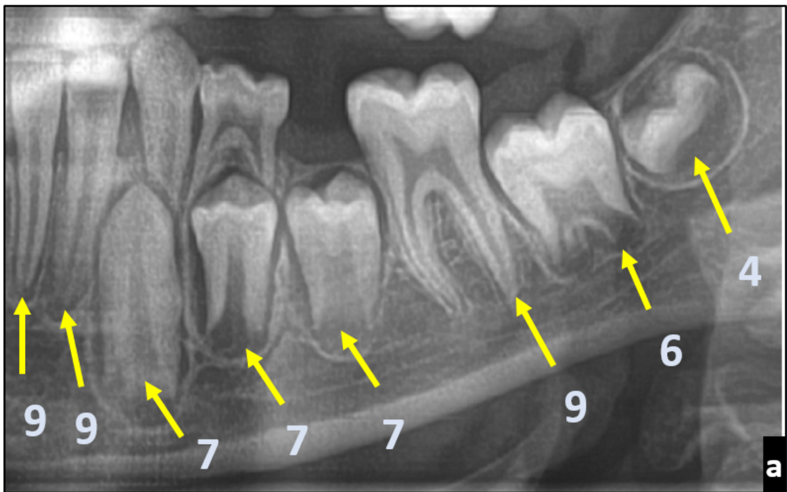
Sample selection:

The demographic, clinic and radiographic data related to forensic age estimation of the UCLP group were obtained from a specialized treatment center for cleft patients - Ashwini

Trauma Centre & Hospital, Cuttack - during the period from June 2022 to October 2024 following screening of all the cleft cases. The similar corresponding data for the age- and gender-matched non cleft control group was obtained from SCB Dental College & Hospital, Cuttack, comprising individuals in the pre-orthodontic phase of treatment. Data extracted from the patient's records included date of birth, gender, side affected by cleft, date of OPG taken and the presence of tooth agenesis. The study included individuals with complete non-syndromic UCLP (cleft group) who provided informed consent, had a full complement of mandibular left-side teeth, and possessed high-quality radiographs. Individuals were excluded if they had other cleft types, syndromic conditions, congenital anomalies, insufficient tooth mineralization, prior orthodontic or orthognathic treatment, grossly carious teeth in the lower left quadrant, systemic or metabolic disorders affecting growth, bilateral tooth agenesis, extractions outside the cleft area, dental crowding, or hand-wrist trauma impacting bone development. The subjects, selected as per inclusion and exclusion criteria, underwent a comprehensive intraoral clinical examination.
Standardized left hand-wrist radiographs were obtained and assessed for SA assessment. The G-P Atlas method was employed by two calibrated, blinded, independent observers, who had no prior knowledge of the subject's CA, or clinical condition.
DA assessments were performed using standardized OPGs, digitized with a Scanjet G4050 scanner and HP software, and anonymized to minimize bias. The maxillary region was excluded to obscure cleft areas, ensuring objective measurements. Two blinded, forensic-trained oral pathologists independently assessed these images using Acharya's modification of Demirjian's method which evaluates the developmental stages of the eight left mandibular permanent teeth and assigns each tooth a stage, from initial calcification to apex closure. These stages correspond to gender-specific numerical scores. The scores of all eight teeth are summated to obtain a total maturity score, which is then applied to a gender-specific Indian formula (cubic functions) to calculate the DA (figure 1). To ensure reliability, intra-observer variation was evaluated by re-assessing 30 randomly selected samples by the same observer, from the UCLP and control groups after a period of 30 days, while inter-observer variation was also assessed to further validate the consistency of observations.

Figure 1. illustrates the estimation of DA using Acharya's modification of Demirjian's method

a) A male patient OPG demonstrating each of the eight left mandibular teeth being assigned a developmental stage as per Demirjian's tooth development chart
b) Table depicts individual tooth score allocation for each of the 8 teeth, in reference to Demirjian's maturity scoring tables and summating the scores to generate the total maturity score (TMS). TMS is substituted in Acharya's Indian specific formula to estimate DA.
c) The box depicts the Acharya Indian specific cubic function formulae used to estimate the dental age.



Tooth	Score (Male)	Total maturity score
31	10.68	
32	10.91	
33	7.59	
34	8.18	75.04
35	8.68	
36	11.22	
37	7.89	
38	9.89	

b

Acharya's modification of Demirjian's method

Males, Age = 27.4351 – (0.0097*S2) + (0.000089*S3)
Females, Age = 23.7288 – (0.0088*S2) + (0.000085*S3)

The estimated Dental age = 10.42 years.
Lower limit: 9.25 years
Upper limit: 11.59 years

c

Statistical analysis:
Data were entered into Microsoft Excel 2021 and analyzed using SPSS (IBM Corp., Version 27.0). Descriptive statistics were performed, with categorical variables presented as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation. Paired t-tests and Wilcoxon tests were used for variable comparisons. Intra-class correlation coefficients (ICCs) assessed inter- and intra-observer reliability. A p-value <0.05 was considered statistically significant.

RESULTS

The study sample of 216 individuals comprised 112 (51.9 %) males and 104 (48.1 %) females. Table 1 shows distribution of CA categorized into three age groups of <10y, 10-15y, 16-18y for both males and females. Among the cases, majority had cleft lip/palate on the left side (67.6%, n=73), while 32.4% (n=35) had it on the right.

The UCLP group demonstrated a significantly lower mean DA than the corresponding matched controls (Table 2), with a more pronounced delay in males (0.28 years) (Table 3, Figures 2 and 3). Although dental maturation lagged across most age groups, statistical significance varied. (Table 4).

SA was lower in the UCLP group (Table 2) compared to controls, though the overall difference was not statistically significant. However, both males and females exhibited significant skeletal delays (Table 5, Figures 4 and 5). Age-specific analyses revealed a marked delay in females at ages 10, 11, and 12, while no significant differences were observed at other ages. In males, skeletal maturation remained comparable to controls across all age groups except at age 11, where a statistically significant difference was observed (p= 0.015) (Table 6).

Table 1. Distribution of study sample according to chronological age (CA)

Age group	Female	Male	Total
<10	24(11.1%)	4(1.9%)	28(13 %)
10-15	76(35.2%)	108(50%)	184(85.6%)
16-18	4(1.9%)	0(0.0%)	4(1.9%)
TOTAL	104	112	216

Table 2. Comparison of dental and skeletal Age Between UCLP Cases and Controls

	Case		**Control**					
	Mean	**SD**	**Mean**	**SD**	**Mean difference**	**95%CI**	***t-value***	***p-value***
Dental Age	11.45	1.59	12.03	1.82	0.58	0.12, 1.04	2.498	0.013
Skeletal Age	10.78	1.9	11.24	1.97	0.46	-0.06, 0.98	1.793	0.083

Table 3. Comparison of Dental Age with Chronological Age for Male and Female Cases Using MDA Method

Case	**CA (Mean±SD)**	**DA (Mean±SD)**	**Mean Difference (M.D)**	***t-value***	**95% CI of Mean Difference**	***p-value***
Male	12.04±1.75	11.77±1.38	-0.28	2.493	-0.54 to -0.015	0.016
Female	11.33±2.27	11.13±1.68	-0.21	1.390	-0.015 to 0.47	0.150

Figure 2. Box plot comparing Chronological Age (Blue), Dental Age (Red), and Skeletal Age (Green) in male control subjects. In male controls, the alignment of the median values for chronological age, dental age, skeletal age suggests generally synchronized development across parameters

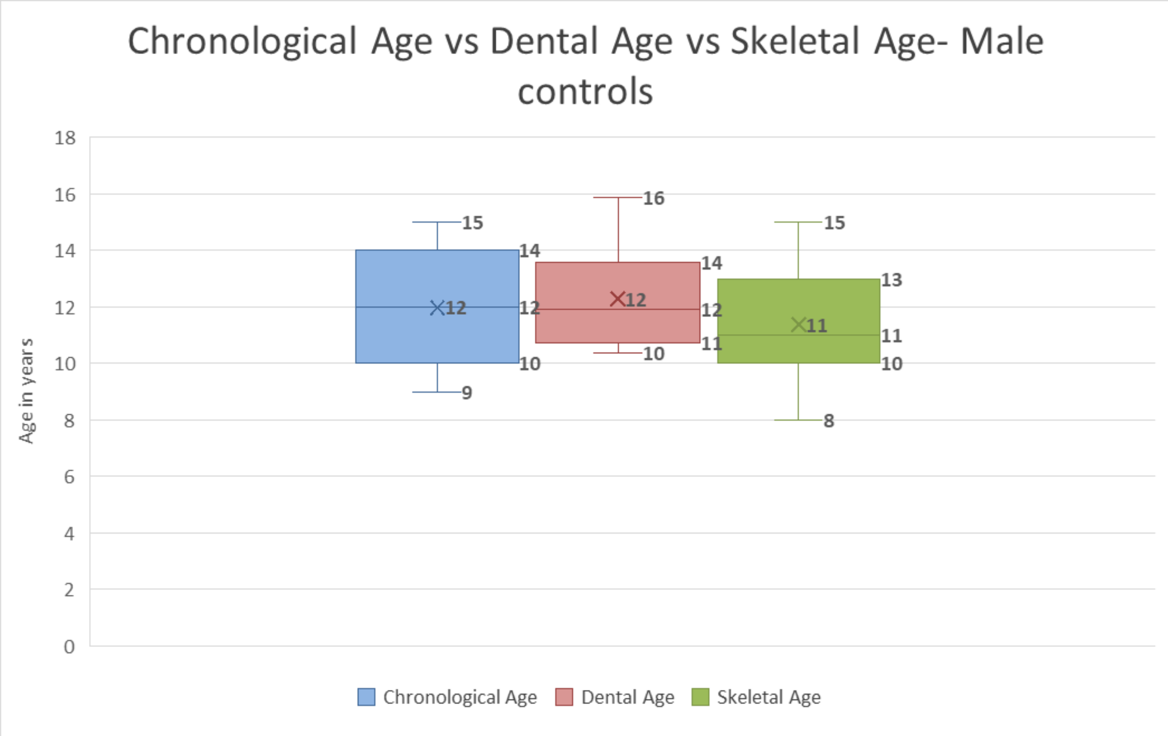


Figure 3. Box plot comparing Chronological Age, Dental Age, and Skeletal Age in female control subjects. In female controls, the alignment of the median values for chronological age, dental age, skeletal age suggests generally synchronized development across parameters

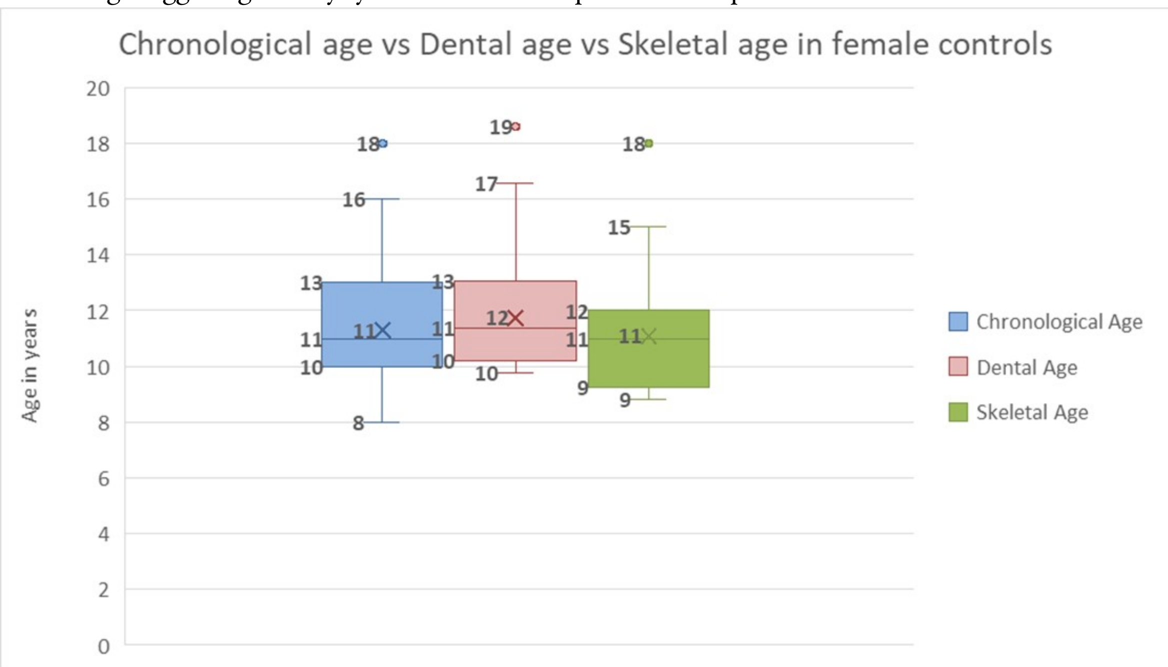


Table 4. Mean difference in dental age between control and UCLP patients at different ages

Age	Mean Difference (MD) Females	95% CI	SE of MD	*t-value*	*p-value*	Mean difference Males	95%CI	SE of MD	*t-value*	*p-value*
8	0.02	-0.10, 0.15	0.05	0.460	0.659	-	-	-	-	-
9	0.06	-0.18, 0.31	0.11	0.545	0.595	-0.10	-6.81, 6.61	0.53	-0.190	0.881
10	0.27	-0.00, 0.54	0.13	2.067	0.053	0.17	-0.047, 0.38	0.10	1.592	0.123
11	0.61	0.09, 1.12	0.24	2.534	**0.022**	0.48	-0.13, 1.09	0.28	1.701	0.115
12	0.89	0.11,1.67	0.34	2.549	**0.029**	0.79	0.36, 1.21	0.20	3.848	**0.001**
13	1.30	0.39, 2.20	0.37	3.505	**0.013**	0.64	0.2,1.09	0.20	3.153	**0.008**
14	1.48	0.98,1.98	0.23	6.417	**<0.001**	0.81	0.24,1.37	0.27	2.973	**0.008**
15	0.93	-0.18, 2.04	0.26	3.593	0.069	0.90	0.3,1.45	0.24	3.714	**0.006**
16	1.35	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-

Table 5. Comparison of skeletal age with chronological age for Male and Female Cases Using G-P atlas Method

Case	CA (Mean±SD)	SA (Mean±SD)	SE of Mean Difference	Mean Difference (M.D)	*t-value*	95% CI of Mean Difference	*p-value*
Male Case	12.04±1.75	11.13±1.82	0.07	-0.92	12.064	0.75-1.05	<0.001
Female Case	11.33±2.27	10.43±2.07	0.09	-0.90	10.154	0.72-1.07	<0.001

Figure 4. Box plot comparing Chronological Age, Dental Age, and Skeletal Age in male UCLP cases. In male UCLP cases, both skeletal and dental ages were lower than the chronological age, indicating delayed biological development. The median skeletal age was 11 years, compared to 12 years for both chronological and dental ages. The lower quartile of skeletal age extended to 8 years, further highlighting a trend toward delayed skeletal maturation

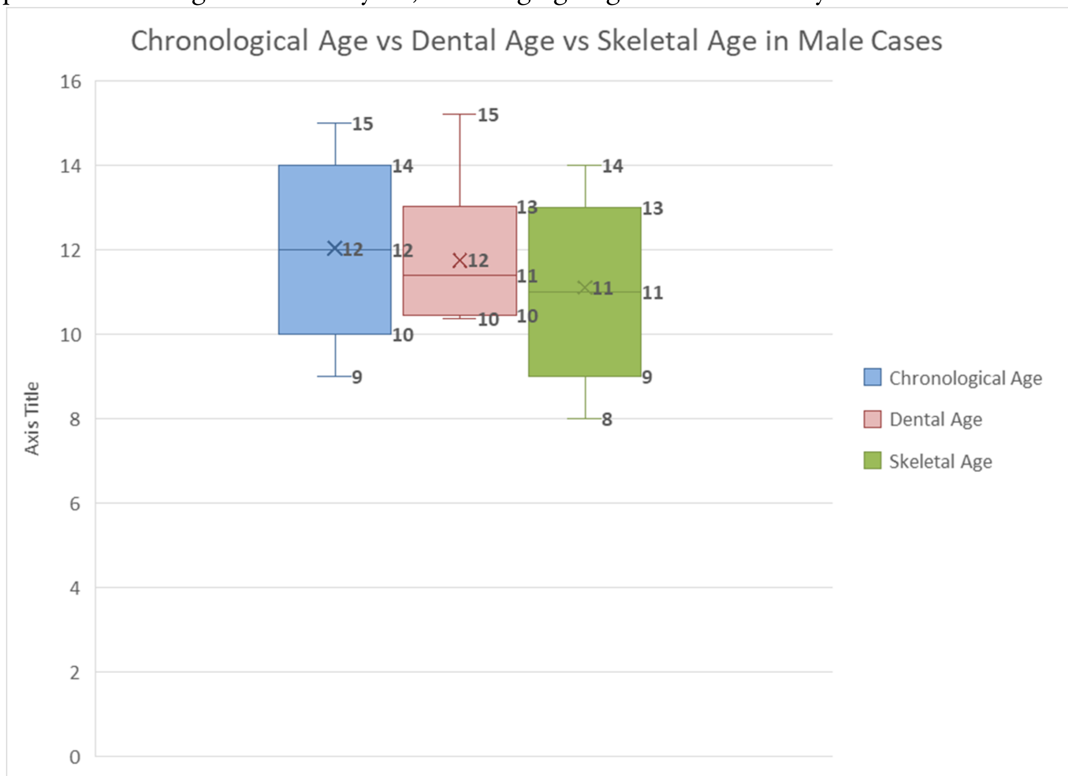


Figure 5. Box plot comparing Chronological Age, Dental Age, and Skeletal Age in female UCLP cases. Female UCLP cases exhibited the most pronounced developmental discrepancy, with median skeletal and dental ages (10 and 11 years, respectively) falling below the chronological age median of 11 years. The skeletal age range extended to a low of 8 years, reinforcing the presence of developmental delay in skeletal maturation

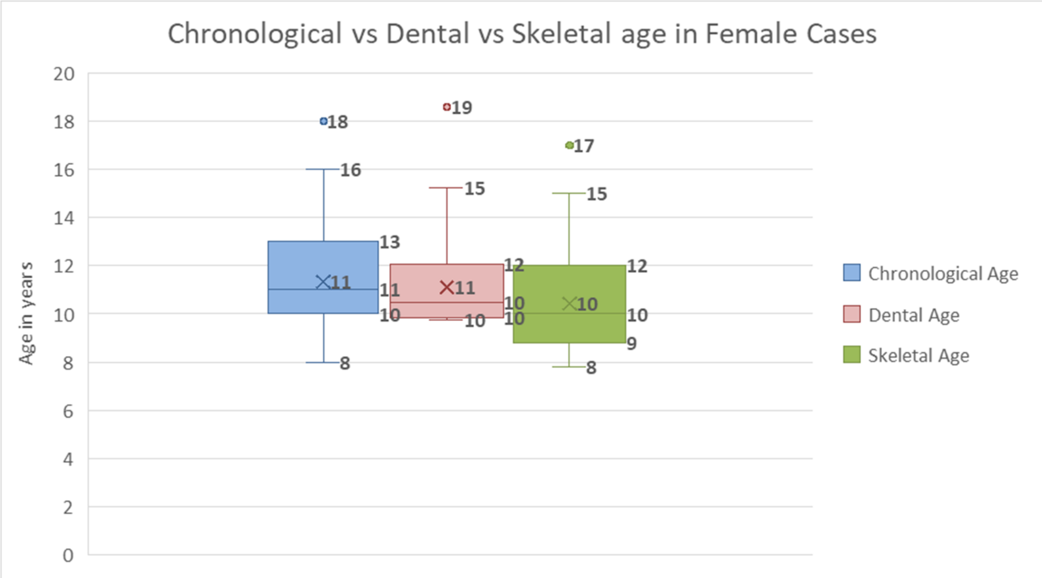


Table 6. Mean difference in skeletal age between control and UCLP patients at the different ages

Age	MD Females	95% CI	SE of MD	*t-value*	*p- value*	MD Males	95% CI	SE of MD	*t-value*	*p- value*
8	0.5000	-0.09,1.09	0.2535	1.972	0.089	-	-	-	-	-
9	0.4036	-0.02,0.83	0.1983	2.035	0.063	-	-	-	-	-
10	1.0400	0.61,1.46	0.2033	5.115	**<0.001**	0.3333	-0.05,0.71	0.1886	1.768	0.088
11	0.5556	0.11,0.99	0.2079	2.673	**0.017**	0.5714	0.13, 1.01	0.2020	2.828	**0.015**
12	0.8333	0.14,1.51	0.3073	2.712	**0.022**	0.6682	-0.21, 1.54	0.4213	1.586	0.129
13	0.5000	-0.36,1.36	0.3536	1.414	0.207	0.0714	-0.38,0.52	0.2103	0.340	0.740
14	0.5714	-0.15,1.30	0.3350	1.706	0.114	0.1000	-0.48,0.68	0.2789	0.359	0.724
15	1.0000	-1.15,3.15	0.5000	2.000	0.184	-0.1000	-0.33, 0.13	0.1000	-1.000	0.347
16	0.0000	-	-	-	-	-	-	-	-	-
18	1.0000	-	-	-	-	-	-	-	-	-

In right-sided cleft patients, no statistically significant differences were observed between CA and either DA or SA (Table 7). The mean differences for both comparisons remained minimal across genders. In the left-sided cleft subgroup, a statistically significant delay in dental maturation was observed in both sexes, with CA exceeding DA ($p = 0.048$ in males; $p = 0.005$ in females, Table 8).

CA correlated strongly with DA and SA in both groups ($p < 0.001$). In controls, CA correlates more strongly with DA ($r = 0.965$) and SA ($r = 0.949$) than in cases ($r = 0.902$ and $r = 0.957$, respectively). In UCLP cases, SA exhibits a higher correlation. The reliability between the two observers for DA and SA assessment was excellent, as reflected by a high Intraclass Correlation Coefficient (ICC > 0.9, $p < 0.001$). Excellent intra-observer reliability for both dental and skeletal age assessments was demonstrated as indicated by intraclass correlation coefficient (ICCs) between 0.995 to 1.00, $p < 0.001$.

Table 7. Comparison of chronological age with dental and skeletal age in right-sided cleft patients

Group	MD (DA)	SD (DA)	95% CI (DA)	*p-value*	MD (SA)	SD (SA)	95% CI (SA)	*p-value*
Male	0.28	0.85	-0.15 to 0.70	0.184	0.35	0.82	-0.20 to 0.90	0.160
Female	0.017	1.14	-0.57 to 0.60	0.950	0.12	1.05	-0.50 to 0.74	0.660
Overall	0.15	0.995	-0.19 to 0.49	0.374	0.24	0.94	-0.30 to 0.78	0.330

Table 8. Comparison of chronological age with dental and skeletal age in left sided cleft patients

Group	MD (DA)	SD (DA)	95% CI (DA)	*p-value*	MD (SA)	SD (SA)	95% CI (SA)	*p-value*
Male	0.26	0.78	0.0026 to 0.52	0.048	1.00	0.62	0.79 to 1.20	<0.001
Female	0.38	0.84	-0.05 to 0.81	0.005	0.93	0.55	0.74 to 1.12	<0.001
Overall	0.27	0.86	0.07 to 0.47	0.009	0.96	0.59	0.83 to 1.10	<0.001

DISCUSSION

CL/P is one of the most prevalent craniofacial anomalies, presenting profound challenges in terms of aesthetics, function, and overall growth and development.[23] These conditions arise from failure of fusion among the structures that form the upper lip or palate during prenatal development which is influenced by a complex interplay of genetic and environmental factors.[23] Among the various subtypes, UCLP is particularly notable for its impact on craniofacial structures, often resulting in aesthetic challenges, asymmetry and developmental delays.[22] These delays can affect both dental and skeletal maturation, adding complexity to orthodontic and surgical planning.[11]

Dental and skeletal maturity assessments are crucial in effectively managing UCLP patients, especially in forensic investigations.[13] Demirjian's method, a widely used radiographic age estimation technique, evaluates seven or eight left mandibular teeth using panoramic radiographs, offering a comprehensive view of development and eruption.[16] Extensively studied worldwide, it provides a precise, objective approach with standardized criteria, schematic illustrations, and gender-specific maturity scores, eliminating the need for detailed tooth measurements.[16] However, the original Demirjian 8-teeth method, incorporating Chaillet's modification, has been found to underestimate age in various non-Canadian populations.[24] To improve accuracy, Acharya et al. developed an Indian-specific modification using cubic functions, which performed better across Indian subsets.[21] Therefore, the present study adopted Acharya's method for precise DA estimation.

For SA assessment, radiographs of the hand-wrist, elbow joint, pelvis, and shoulder joint are commonly utilized, with left-hand radiographs preferred for their strong correlation with pubertal growth.[25] The preference for left-hand and wrist radiographs in bone age assessment is based on practical and historical considerations, as the dominant right hand is more prone to injuries, potentially affecting skeletal evaluation accuracy.[15] The G-P method is the most widely accepted reference standard, demonstrating strong correlation with chronological age in modern populations.[12] Therefore, the present study adopted the G-P method despite the lack of Indian normative data.

202 UCLP cases were initially included in the study. Of these, 94 cases were excluded for not meeting the inclusion criteria, namely the absence of bony crypts (37/94), prior orthodontic treatment (19/94), poor-quality radiographs (17/94), non-UCLP clefts (12/94), and gross dental caries (9/94). Similar criteria have been applied in previous studies to ensure sample integrity.[2,11,26] Thus, the final case sample totaled 108 subjects following which 108 age- and gender-matched controls were included, resulting in a total sample of 216.

CA in the current study ranged from 7 to 18 years, with most subjects (185/216) between 10 and 15 years, and 12.5% (27/216) under 10 years. Literature highlights challenges in evaluating younger cohorts (<10 years) due to delayed third molar mineralization and absence of bony crypts, restricting their inclusion in this study. Tan et al. reported delayed dental mineralization in cleft children aged 5–9 years,[27] while Ribeiro et al. demonstrated significantly retarded third molar mineralization in cleft populations.[28] These constraints necessitate the selection of the 7–18-year age range, ensuring the presence of well-defined dental and skeletal maturation markers for robust comparative analyses between cleft and non-cleft groups.

In the UCLP cases, males (51.9%) outnumbered females (48.1%), aligning with existing literature reporting a male predominance in UCLP cases.[1] The cleft defect mostly affected the left side (67.6%), aligning with prior studies reinforcing the left-side predominance.[1,2,13]

The UCLP patients exhibited a significant delay of 0.58 years in dental development compared to age- and gender-matched controls ($p = 0.013$). This delay may stem from shared genetic pathways between cleft formation and odontogenesis, with genes such as TGFβ, TGFβ3, and MSX1 playing critical roles.[29] Beyond genetic influences, craniofacial growth disruptions associated with clefts may contribute to this delay. Van Dyck et al. systematically reviewed CL/P children (6–20 years) and reported a significant dental delay of 0.56 years ($p < 0.0001$), ranging from 0.2 to 0.9 years, compared to controls.[30] Similarly, Tan et al. found a significant delay of 0.55 years ($p < 0.001$) in 5–9-year-olds, while delays in older age groups (9–13 years) were not significant ($p = 0.744$). This suggests potential catch-up growth over time.[27] Ying Guo et al. observed a significant underestimation of DA (0.319 years, $p = 0.013$) in UCLP patients.[11] A greater delay in DA was noted among UCLP males (0.28 years, $p = 0.016$) than females (0.21 years, $p = 0.150$), though the difference was not statistically significant across all age groups. This aligns with previous studies indicating greater delays in males, likely due to their slower somatic and dental development. Hyuskens et al. reported significant delays in UCLP males at ages 5 (1.31 years, $p < 0.001$) and 14 (1.74 years, $p < 0.001$), while females showed smaller but significant delays (0.73 years, $p < 0.001$; 0.67 years, $p = 0.02$).[31] Conversely, Van Dyck et al. found greater delays in females, particularly at age 13 (1.411 years, $p < 0.0001$).[13]

SA assessment provides a complementary perspective on maturation alongside DA. While controls exhibited minimal SA differences (Males: MD = -0.03, $p = 0.09$; Females: MD = -0.02, $p = 0.112$), UCLP patients showed significant delays (Males: 0.92 years, $p < 0.001$; Females: 0.90 years, $p < 0.001$). Notably, SA delays in females were significant at ages 10–12 ($p < 0.05$), whereas males displayed a more consistent delay across all ages. Akcam et al. reported an overall mean SA delay of 0.9 years in UCLP cases, with males showing greater delays (2.4 years) than females (1.7 years).[12] MS Ravi et al. found significant delays in males aged 10–13 years ($p = 0.019$), but not in older groups ($p = 0.277$)[32] suggesting that factors such as genetic predisposition, cohort characteristics, and methodological variations may influence skeletal maturation.

Since DAE was conducted using the left mandibular dentition as per Demirjian's method, a subgroup analysis for both left- and right-sided clefts was performed to assess the effect of laterality on dental and skeletal development. However, substitution of right mandibular teeth for any missing left mandibular teeth was not done in the present study, as the inclusion criteria mandated the presence of all eight left mandibular teeth. In the left-sided cleft subgroup, a statistically significant delay in dental maturation was observed in both sexes, with CA exceeding DA ($p = 0.048$ in males; $p = 0.005$ in females, Table 8). Similarly, SA lagged significantly behind CA in both males and females ($p < 0.001$, Table 9), indicating overall developmental delay. These findings highlight a consistent pattern of developmental delay in both dental and skeletal parameters on the cleft-affected (left) side. In contrast, no significant difference was found between DA and CA in right-sided clefts ($p = 0.374$), suggesting that developmental delays may be localized to the cleft-affected side despite clefts being maxillary anomalies. These delays may result from malnourishment, limited eruption space, impaired vascularization due to surgical fibrosis, and mandibular adaptation to maxillary deficiency.[33] Previous studies report conflicting findings with most exhibiting no significant differences. Tan et al.[27] reported delayed development on the cleft side. These findings challenge Demirjian's method's substitution approach for UCLP cases, as developmental asymmetry may affect age estimation accuracy. Similarly, SA comparisons in right-sided clefts (left hand-wrist analysis) showed no significant differences ($p = 0.330$), further supporting the notion that growth disturbances are cleft-side specific. Future studies should directly compare dental and skeletal development bilaterally in larger cohorts to refine age estimation protocols.

CA revealed strong positive correlations with both DA ($r = 0.902$, $r = 0.965$) and SA ($r = 0.957$, $r = 0.949$) in cases, and controls respectively ($p < 0.001$). SA exhibited a slightly stronger association in cases, whereas DA had a marginally higher correlation in controls. Similar findings by Ying Guo et al. reinforce that developmental patterns differ between UCLP and non-UCLP individuals, underscoring the need for group-specific considerations in age estimation.[11]

The study has limitations, including the lack of comparison between dental and skeletal development on the cleft and non-cleft sides within individual UCLP patients, which could have provided insights into intra-individual variations. The exclusion of patients with unerupted third molars lacking bony crypts or insufficient mineralization may have influenced the assessment of late-stage dental development. Additionally, since the cleft is a maxillary anomaly, evaluating only mandibular teeth may not fully capture its impact. The study also focused solely on UCLP cases, and the findings may not be applicable to other cleft types, necessitating further research.

Future studies should explore intra-individual variations between cleft and non-cleft sides to clarify asymmetric growth and its impact on treatment. Research should also extend to Bilateral Cleft Lip and Palate and isolated clefts to evaluate differences in biological maturation across cleft types. Additionally, maxillary assessment for age estimation could further elucidate growth variations and their effects on dental development.

CONCLUSION

UCLP cases exhibited developmental delays, with both dental and skeletal maturation lagging behind CA as compared to matched controls. Our study demonstrated that SA showed a more pronounced delay compared to DA, with males experiencing greater delays. Given these delays, skeletal assessments should take precedence over CA for treatment planning, refining orthodontic and secondary bone grafting strategies. Beyond clinical applications, standard age estimation methods may misclassify UCLP patients in forensic, legal, and sports contexts, leading to inaccurate legal decisions and administrative discrepancies. This underscores the need for condition-specific reference tables to enhance accuracy across clinical, forensic, and regulatory domains. Until further research clarifies the influence of cleft laterality on dental and skeletal maturation delays in this population, substitution of missing teeth using the contralateral side, as per Demirjian's method should be approached with caution or potentially avoided, to preserve accuracy in age estimation.

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