Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2023; 23:e210180
https://doi.org/10.1590/pboci.2023.016
ISSN 1519-0501 / eISSN 1983-4632

ORIGINAL ARTICLE

Establishing Cephalometric Norms in Primary Dentition Using Comprehensive Craniofacial Growth Analysis – A Digital Cephalometric Study

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Academic Editor: Alessandro Leite Cavalcanti

Received: 28 September 2021 / **Review:** 17 March 2022 / **Accepted:** 13 May 2022

How to cite: Deshmukh S, Nandlal B. Establishing cephalometric norms in primary dentition using comprehensive craniofacial growth analysis – a digital cephalometric study. Pesqui Bras Odontopediatria Clín Integr. 2023; 23:e210180. https://doi.org/10.1590/pboci.2023.016

ABSTRACT

Objective: To establish cephalometric norms in primary dentition among males and females using novel customized Comprehensive Cephalometric Growth (CCG) Analysis. **Material and Methods:** The study was conducted on 67 subjects with a mean age of 5.5 yrs. Digital lateral cephalometric radiographs were obtained using Planmeca Pro One. The digital images were then transferred to Nemoceph software. Craniofacial Growth (CCG) Analysis was configured in the software with five sub-groups. This sub-grouping was done such that related components were grouped together and comprehensively; it would provide an assessment of every component of the craniofacial region that could be affected either by treatment maneuver or growth process. The same was used for the cephalometric analysis and to determine the cephalometric norms in the primary dentition. **Results:** Certain linear measurements were higher among males when compared to females. However, most measurements remained similar among males and females during this age group. The CCG analysis provided a comprehensive knowledge of the craniofacial parameters during the growth process. **Conclusion:** The cephalometric norms during primary dentition thus established using Comprehensive Craniofacial Growth analysis would provide the data for early diagnosis and treatment planning in interceptive orthodontic treatment procedures.

Keywords: Tooth, Deciduous; Dentofacial Deformities; Software.

Introduction

Post-natal growth covers the period from infancy through adolescence, and it is assumed that during this span, almost 100% of adult dimensions are achieved [1]. However, the growth occurring during this period is not continuous and exponential. Different parts of the body grow at different times and at different rates. The rate of growth tends to increase from the cephalic to the caudal end. The same dynamic trend is applicable in the craniofacial region as well. According to Scammon's growth curve, the growth and development of cranial structures follow the neural curve, with the cranial vault achieving 95% of adult size by 5 years of age, followed by which there is a deceleration in the growth rate. In children, these changes can be well appreciated from the facial profile as a large forehead, smaller nasal part due to the correspondingly less respiratory demand and more growth changes occurring in the mandible compared to maxilla leading to the final facial type after growth completion [2].

The transition from primary to mixed dentition and from mixed to permanent dentition has a significant effect on the facial profile [3], and this transition remains a continuous process. Studies have indicated that their significant changes in the craniofacial growth pattern can be appreciated in two phases. The first period was during the 5 to 7 years of age, corresponding with the transition from primary to early mixed dentition period. The second period was during 10 to 13 years of age corresponding with the transition from late mixed to permanent dentition period [4]. Many cephalometric studies have been reported for the mixed dentition period [5-8]; however, the studies emphasizing the craniofacial norms on primary dentition are meager.

With more emphasis on early diagnosis and treatment planning, there is a need to identify the developing malocclusion at the earliest. To identify the developing malocclusion, it is essential to have the norms well defined so that any deviation from the norms can be diagnosed and considered for treatment. Not only for treatment planning, but these norms are also required to predict growth changes as well. Hence this study was conducted to establish cephalometric norms in primary dentition with the use of novel integrated, comprehensive, customized cephalometric growth analysis.

This study utilized this integrated growth analysis as this focused on all aspects of the craniofacial growth comprehensively compiled in the single analysis, which can be further utilized in the follow-up of the craniofacial growth.

Material and Methods

Study Design and Sample

In this observational study, the craniofacial parameters were assessed on 67 subjects of the regional Indian population (38 males and 29 females) with a mean age of 5.5 years. Since the outcome measure was quantitative, the sample size was determined based on a comparison of means (a comparison of means was done here as this data is part of a longitudinal study comparing primary and mixed dentition). A pilot study was conducted to determine the means.

At 95% confidence and 80% power of study, the sample size was determined using the formula for comparison of means. Children less than 6yrs of age with complete primary dentition, no gross facial asymmetry and balanced facial profile as observed on extraoral examination were included in the study. The anthropometric measurements (height and weight) were considered and subjects belonging to extreme measurements as per the growth chart were excluded from the study. Subjects with a history of previous orthodontics treatment, rampant caries, syndromes and defects involving craniofacial region were also excluded from the study.

Data Collection

Before the examination, ethical clearance was obtained from the Institutional Ethical Board. Then, an initial clinical examination was done and children satisfying the above-mentioned inclusion criteria were selected. The parents were explained about the study and procedures to be performed during the study. The possible advantages and effects were also explained. Only the children whose parents had provided informed consent and children providing informed assent were included.

Standardized Digital lateral cephalometric radiographs were obtained from the participants with Planmeca Pro One (Planmeca OY, Helsinki, Finland). The Planmeca imaging was provided with Romexis software. This software was used for image enhancement and the thus obtained image was converted into Jpeg format and imported into the Nemoceph Software version 10.4.2 for further analysis (NemoTec, Madrid, Spain). After calibration, anatomic landmarks were located in the Nemoceph software (Figure 1), and cephalometric analysis was done with a novel customized analysis for craniofacial growth – Comprehensive Craniofacial growth (CCG) analysis. All the measurements were performed only in the software; no manual measurements were made. This analysis was customized and comprehensive the analysis was grouped as follows: A. Upper Craniofacial Measurements; B. Lower Craniofacial Measurements; C. Upper/Lower Craniofacial Measurements; D. Dental Measurements; and E. Cephalometric Soft tissue measurements. The above-mentioned measurements and their significance have been described in Tables 2 to 6.

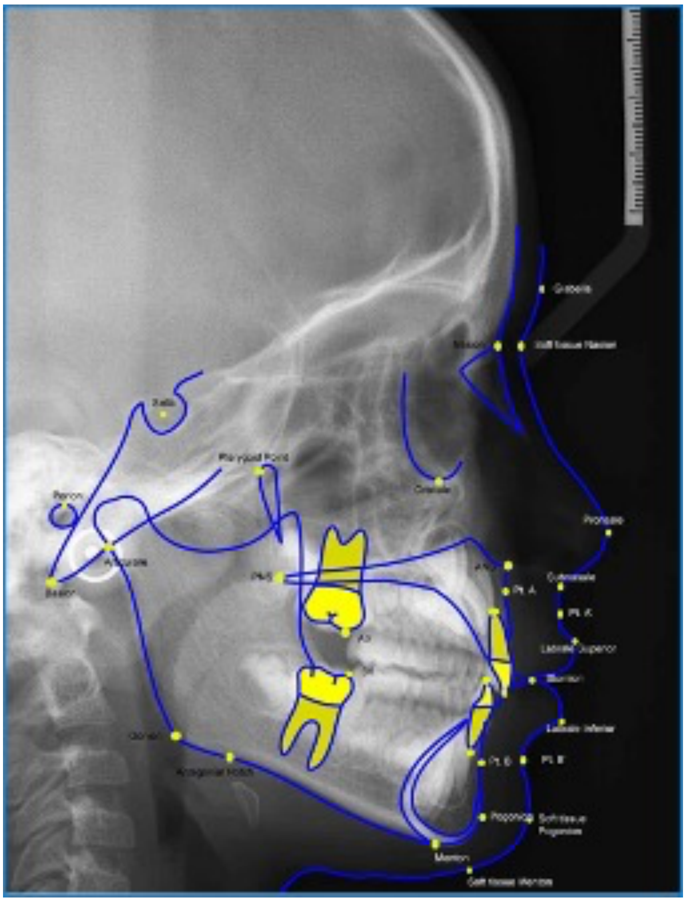

Figure 1. Anatomic landmarks.

A single examiner performed all the cephalometric analyses. The images were calibrated before the location of the cephalometric landmarks. The intra-operator reliability coefficient was obtained for each parameter to assess the intra-observer reliability. A set of five subjects were assessed on different parameters at three different times. Most of the parameters measured had intra-observer reliability above 95% (Table 1). Following this, the tracing was performed. The analysis measurements thus obtained were exported from the software in txt format and tabulated in an Microsoft Excel spreadsheet.

Table 1. Intra-rater reliability coefficient (γ) for different measured parameters.

Parameters	γ	IR (%)
Inter Incisor Angle	0.9986	99.86
Cervico Facial Angle	0.9978	99.78
Lower Facial Height	0.9974	99.74
Sti - Me	0.9968	99.68
Sn - Me	0.9961	99.61
Sts - Me	0.9944	99.44
Li - Me	0.9943	99.43
IMPA	0.9927	99.27
Upper Incisor to SN Plane	0.9915	99.15
Saddle Sella Angle N S Ar	0.9905	99.05
SNA	0.9810	98.10
Facial Convexity	0.9788	97.88
Articular Angle S Ar Go	0.9786	97.86
Maxillary Inclination	0.9767	97.67
Maxillary Dental Height	0.9766	97.66
Facial Angle	0.9726	97.26
SNB	0.9690	96.90
Upper Lip Angle	0.9654	96.54
Gonial Angle Ar Go Me	0.9648	96.48
Posterior Facial Height	0.9640	96.40
MP-ANS PNS	0.9559	95.59
Upper Facial Height	0.9507	95.07
Maxillary Height	0.9507	95.07
Position of Mandibular Molar	0.9368	93.68
Mandibular Posterior Dental Height	0.9241	92.41
Mandibular Anterior Dental Height	0.9228	92.28
FMIA	0.9227	92.27

Table 2. Definitions of the linear and angular measurements: upper craniofacial measurements.

Upper Craniofacial Measurements				
S.No	Measurement	Landmarks Used	Significance	Analysis
	Linear			
1	Upper Anterior Facial Height	N–ANS	Describes the skeletal upper facial height.	COGS Analysis – Burstone et al. [9]
2	Sagittal Growth at Nasion	Pt Point–N	Signifies the Sagittal growth at Nasion with respect to stable reference point.	Nanda and Ghosh [10]
3	Sagittal Growth at Anterior Nasal Spine	Pt Point–ANS	Signifies the sagittal growth at Anterior Nasal spine with respect to stable reference point	Nanda and Ghosh [10]
4	Sagittal Growth at Point A	Pt Point–Pt A	Signifies the sagittal growth at point A with respect to stable reference point.	Nanda and Ghosh [10]
	Angular			
5	SNA	S-N-Pt A	This angle indicates the horizontal position of the maxilla relative to the cranial base.	Steiner and Hills Analysis [11]
6	Maxillary Inclination	Palatal Plane–SN Plane	Provides assessment of the inclination maxillary base with reference to the cranial base	Bjork and Skieller [12]

Table 3. Definitions of the linear and angular measurements: lower craniofacial measurements.

Lower Craniofacial Measurements				
S.No	Measurement	Landmarks Used	Significance	Analysis
	Linear			
1	Lower Anterior Facial Height	ANS-Me	Describes the skeletal lower facial height.	COGS Analysis – Burstone et al. [9]
2	Sagittal Growth at Point B	Pt Point–Pt B	Signifies the sagittal growth at point B with respect to stable reference point.	Nanda and Ghosh [10]
3	Sagittal Growth at Pogonion	Pt Point–Pg	Signifies the sagittal growth at Pogonion with respect to stable reference point	Nanda and Ghosh [10]
4	Mandibular Body Length	Go–Me	Signifies length of mandibular base.	COGS Analysis – Burstone et al. [9]
5	Ramus Height	Ar–Go	Ramus height, as measured on lateral cephalogram, is the distance from the articulare to gonion.	COGS Analysis – Burstone et al. [9]
	Angular			
6	Gonial Angle	Ar–Go–Me	Expression for the form of the mandible describes the relation between body and ramus.	COGS Analysis – Burstone et al. [9]
7	SNB	S-N-Pt B	This angle expresses the horizontal position of the mandible relative to the cranial base using B-point as a cephalometric landmark.	Steiner and Hills Analysis [11]

Table 4. Definitions of the linear and angular measurements: upper/lower craniofacial measurements.

Upper/Lower Craniofacial Measurements				
S.No	Measurement	Landmarks Used	Significance	Analysis
	Linear			
1	Total Anterior Facial Height	N–Me	Describes the skeletal total facial height.	COGS Analysis – Burstone et al. [9]
2	Total Posterior Facial Height	S–Go	Influences facial form, both vertically and horizontally	Tweed's Analysis [13]
	Angular			
3	Angle of Convexity	N Pt A–Pt A Pg'	It reveals the convexity or concavity of the skeletal profile	Downs Analysis [14]
4	Mandibular Inclination	SN–Mandibular Plane	Excessively high or low mandibular plane angles suggest unfavourable growth patterns	Bjork and Skieller [12]
5	Articular Angle	S–Ar–Go	Larger angle indicates retrognathic mandible and smaller angle indicates prognathic mandible.	Bjork and Skieller [12]
6	ANB	Point A–N–Point B	ANB angle measures the relative position of the maxilla to the mandible.	Steiner and Hills Analysis [11]

Table 5. Definitions of the linear and angular measurements: Dental measurements.

Dental Measurements				
S.No	Measurement	Landmarks Used	Significance	Analysis
	Linear			
1	Maxillary Anterior Dental Height	Upper Incisor to Palatal Plane	Determines the position of maxillary incisor with respect to the palatal plane.	COGS Analysis – Burstone et al. [9]
2	Mandibular Anterior Dental Height	Lower Incisor to Mandibular Plane	Determines the position of mandibular incisor with respect to the mandibular plane.	COGS Analysis – Burstone et al. [9]
	Angular			
3	Frankfurt's Mandibular Incisor Angle (FMIA)	FH Plane–Lower Incisor	Determines the degree of balance and harmony between the lower face and anterior limit of the dentition	Tweed's Analysis [13]
4	Incisor Mandibular Plane Angle (IMPA)	Lower Incisor-Mandibular Plane	Determines the balance and harmony in the lower facial profile. Due to the effect of lower incisors on facial esthetics and stability, it is considered a determinant of balance in lower facial harmony.	Tweed's Analysis [13]

5	U1 Inclination	Upper Incisor–SN Plane	This angular measurement determines the inclination of the upper central incisor relative to the anterior cranial base.	Tweed's Analysis [13]
6	Interincisal Angle	$\overline{1}$-$\underline{1}$	The interincisal angulation relates the relative position of the maxillary incisor to that of the mandibular incisor.	Downs Analysis [14]

Table 6. Definitions of the linear and angular measurements: soft tissue measurements.

Soft Tissue Vertical Measurements				
S.No	Measurement	Landmarks Used	Significance	Analysis
	Linear			
1	Upper Facial Height	G-Sn	Signifies the vertical upper facial height.	Legan and Burstone Analysis [15]
2	Lower Facial Height	Sn-Me	Signifies the vertical lower facial height.	Legan and Burstone Analysis [15]
3	Height of the Upper Lip	Sn-St	Signifies the vertical height of the upper lip.	Soft Tissue Cephalometric Analysis - Arnett et al. [16]
4	Height of the Lower Lip, including Chin	St-Me	Signifies the vertical height of the lower lip, including chin.	Soft Tissue Cephalometric Analysis - Arnett et al. [16]
5	Maxillary Prognathism	Vertical Plane Dropped from Glabella–Sn	Measured by drawing a perpendicular towards subnasale to the vertical plane dropped from glabella. Determines the position of soft tissue maxillary base with reference to the glabella.	Legan and Burstone Analysis [15]
6	Mandibular Prognathism	Vertical Plane Dropped from Glabella–Pg'	Measured by drawing a perpendicular towards soft tissue pogonion to the vertical plane dropped from glabella. Determines the position of soft tissue chin with reference to the glabella.	Legan and Burstone Analysis [15]
7	Upper Lip Position	Sn–Pg' Line to Ls	It determines the amount of upper lip protrusion or retrusion	Legan and Burstone Analysis [15]
8	Lower Lip Position	Sn–Pg' Line to Li	It determines the amount of lower lip protrusion or retrusion	Legan and Burstone Analysis [15]
	Angular			
9	Cervicofacial Angle	Sn–Gn'-C	Determines the position of the mandible with respect to the maxilla	Soft Tissue Cephalometric Analysis - Arnett et al. [16]
10	Facial Angle	G–Sn–Pg'	Describes the convexity/ concavity of the soft tissue profile thereby determining the interjaw harmony.	Legan and Burstone Analysis [15]

Data Analysis

The data obtained from the cephalometric analysis was then exported and tabulated in an Excel sheet. Finally, an independent sample t-test was applied to compare boys and girls. The level of significance was set at p=0.05.

Results

Table 7 describes upper craniofacial measurements during primary dentition among males and females. Among the parameters assessed in the upper craniofacial region, the sagittal growth at ANS showed a significant difference among males and females, with females having higher sagittal growth. However, the other linear and angular measurements remained almost similar among males and females for the age group under assessment.

Table 8 describes lower craniofacial measurements during primary dentition among males and females. Among the lower craniofacial measurements, the ramus height was significantly different in males and females, with males having a mean value of 38.74 mm compared to females, which was 35.79 mm. Among the angular measurements, SNB was statistically higher among females.

Table 7. Comparison of upper craniofacial measurements during primary dentition among males and females.

Upper Craniofacial Measurements	Gender	Primary Dentition Mean (SD)	p-value
Linear			
Upper Anterior Facial Height (UAFH)	Male	40.91±3.13	0.311
	Female	40.09±2.27	
Sagittal Growth at Nasion	Male	41.52±2.66	0.436
	Female	40.94±2.35	
Sagittal Growth at ANS	Male	46.08±2.32	0.007*
	Female	48.37±2.84	
Sagittal Growth at point A	Male	43.49±2.31	0.647
	Female	43.09±1.94	
Maxillary Length	Male	46.41±3.81	0.756
	Female	46.69±2.29	
Angular	Male		
Maxillary Inclination	Female	6.93±1.21	0.292
	Male	6.16±2.93	
SNA	Female	80.26±3.74	0.776
	Male	80.95±3.57	

*Statistically Significant.

Table 8. Comparison of lower craniofacial measurements during primary dentition among males and females.

Lower Craniofacial Measurements	Gender	Primary Dentition Stage Mean (SD)	p-value
Linear			
Lower Anterior Facial Height (LAFH)	Male	50.11±4.25	0.349
	Female	49.02±3.59	
Sagittal Growth at Point B	Male	39.56±2.87	0.991
	Female	39.57±2.35	
Sagittal Growth at – Pg	Male	40.72±2.98	0.862
	Female	40.85±2.23	
Mandibular Length	Male	62.49±3.66	0.146
	Female	60.95±3.34	
Ramus Height	Male	38.74±5.68	0.028*
	Female	35.79±3.02	
Angular			
Gonial Angle	Male	128.96±4.00	0.957
	Female	128.89±4.31	
SNB	Male	74.11±2.95	0.008*
	Female	76.74±3.23	

*Statistically Significant.

Table 9 describes upper/lower craniofacial measurements during the primary dentition stage among males and females. The facial height, both total and posterior facial height was higher among males when compared to females. This difference was statistically significant. The mandibular inclination was also found to be higher among males.

Table 9. Comparison of upper/lower craniofacial measurements during primary dentition stage among males and females.

Upper/Lower Craniofacial Measurements	Gender	Primary Dentition Stage Mean (SD)	p-value
Linear			
Total Anterior Facial Height (TAFH)	Male	94.06±3.93	0.014*

	Female	91.1±3.81	
Total Posterior Facial Height	Male	61.89±2.52	0.001*
	Female	58.09±2.25	
Angular			
Facial Convexity	Male	11.19±4.44	0.249
	Female	9.84±3.35	
Jaw Relationship	Male	28.26±4.23	0.566
	Female	27.63±3.13	
Mandibular Inclination	Male	37.07±3.94	0.001*
	Female	33.63±2.69	
Saddle Sella Angle	Male	124.15±5.21	0.403
	Female	125.47±5.25	
Articular Angle	Male	143.41±6.29	0.108
	Female	140.37±6.08	
ANB	Male	5.3±1.71	0.065
	Female	4.26±1.88	

*Statistically Significant.

Table 10 describes dental measurements during primary dentition among males and females. The incisor mandibular plane angle (IMPA) was found to be significantly higher among males.

Table 10. Comparison of dental measurements during primary dentition among males and females.

Variables	Gender	Primary Dentition Stage Mean (SD)	p-value
Dental Measurements			
Upper Incisor to Palatal Plane (mm)	Male	21.94±1.87	0.564
	Female	22.23±1.46	
Lower incisor to Mandibular Plane (mm)	Male	31.02±1.79	0.702
	Female	31.23±1.8	
Angular Measurement			
FMIA	Male	61.7±7.81	0.133
	Female	64.95±6.49	
IMPA	Male	90.81±5.96	0.017*
	Female	89.53±5.58	
Upper Incisor to SN	Male	86.44±6.06	0.521
	Female	85.37±5.18	
Interincisal Angle	Male	147.11±5.14	0.416
	Female	149.42±4.83	

*Statistically Significant.

Table 11 describes soft tissue measurements during primary dentition among males and females. The differences in soft tissue parameters among males and females, although existed were not statistically significant.

Table 11. Comparison of soft tissue measurements during primary dentition among males and females.

Soft Tissue Vertical Measurements	Gender	Primary Dentition Stage Mean (SD)	p-value
Upper Facial Height	Male	51.14±3.17	0.767
	Female	50.89±2.35	
Lower Facial Height	Male	51.00±3.72	0.708
	Female	51.34±2.36	
Height of Upper Lip	Male	16.2±1.77	0.062
	Female	15.37±1.18	
Height of Lower Lip Including Chin	Male	34.64±2.87	0.708
	Female	34.90±1.71	
Maxillary Prognathism	Male	5.27±1.64	0.497
	Female	4.79±2.70	
Mandibular Prognathism	Male	-0.69±0.30	0.716

	Female	-0.80±0.31	
Upper Lip Position	Male	3.23±0.26	0.815
	Female	3.38±0.98	
Lower Lip Position	Male	1.69±1.17	0.734
	Female	1.98±2.74	
Cervicofacial Angle	Male	108.67±6.69	0.607
	Female	103.79±8.56	
Facial Angle	Male	164.78±4.68	0.076
	Female	163.11±3.97	

Discussion

The craniofacial growth and development is a complex interplay of events that may not follow a uniform line and is rather a time and magnitude based. There are various milestones in craniofacial growth. The primary dentition stage is a stable phase of dentition expressing well-defined growth parameters [17].

It is essential to define these parameters comprehensively during this phase to identify the deviation from normal at the earliest. These should also necessarily include the soft tissue parameters, as the assessment of the facial balance would be incomplete if facial soft tissue characteristics are not considered, as overlying soft tissue drapes may not always follow the underlying skeletal framework. Furthermore, facial treatment outcomes may not be satisfactory if the approach is based only on dental and skeletal parameters [18]. Hence this article describes a comprehensive analysis that would define the growth parameters during the initial stage of craniofacial growth and development.

Though the norms discussed in this study cannot be generalized to all the population as the study was conducted on the Indian regional population, the availability of such data can be considered for the purposes of comparison as the studies describing the cephalometric norms of regional populations are very meagre. Therefore, the analysis emphasizes the growth-related parameters that have been identified and grouped. This provides a platform for the craniofacial biologist to gather related information easily using this tool. In this analysis, the linear and angular measurements are grouped such that individual groups themselves can be used as an analysis.

This study was conducted to establish cephalometric norms of primary dentition for the regional population and to introduce the comprehensive cephalometric analysis, which can be used effectively to determine the cephalometric parameters, particularly among growing children.

Sixty-seven subjects satisfying the previously mentioned inclusion and exclusion criteria were included in the study. Standardized lateral cephalometric radiographs were obtained with Planmeca Pro One. Nemoceph software (version 10.4.2) was used for the cephalometric analysis, which provided accurate and quicker measurements. However, this process required calibration of the images before performing the analysis.

On each cephalometric radiograph, 25 skeletal and 12 soft tissue landmarks were identified. From the cephalometric landmarks and reference lines, 16 angular and 34 linear measurements were analyzed. All the landmarks selected were configured in a separate analysis named Comprehensive Craniofacial Growth Analysis. This was a customized, comprehensive configuration performed in the Nemoceph Software. The analysis had the related components of the craniofacial region grouped together to derive effective outcomes. This analysis is comprehensive as it describes not only the hard tissues but also the soft tissues parameters to accurately identify the discrepancy. Although this study does not compare the growth changes, this analysis was named "Comprehensive Craniofacial Growth Analysis" because this tool can effectively be used for research and assessments related to craniofacial growth.

Literature reports only a few studies describing the cephalometric norms for primary dentition [19-21]. However, the measured variables showed variation in facial dimensions compared to the present study. These differences are attributed to the racial differences present in the population studied. Moreover, a difference existed in the reference points as well.

Hence this demands a need for a systematic, comprehensive cephalometric analysis. This article emphasizes this analysis and also describes the cephalometric norm of primary dentition for the regional population. This analysis would provide the standardized baseline for diagnosing the malocclusion at the earliest and treating them accordingly as a treatment performed during the growth is considered more stable. It has been reported that more than 50% of malocclusion appears during the transition from primary to mixed dentition, which emphasizes the need for early orthodontic intervention [22].

This study further compares the dimensional differences in primary dentition among males and females. Most parameters were similar among males and females in this age group. However, certain variables like total facial height, posterior facial height, ramus height and mandibular inclination were higher among males. Similar observations were also reported by Suh et al. [21].

Conclusion

This paper describes the Comprehensive Craniofacial Growth (CCG) Analysis as a novel unique analysis method that can be incorporated for cephalometric analysis, particularly for interceptive orthodontic procedures to be performed during the primary and transitional dentition period. In addition, this analysis has further subgroups which can be used individually if the area of interest remains specific. Most craniofacial parameters assessed in primary dentition were similar among males and females except for certain linear measurements, which were higher among males.

Authors' Contributions

SD	https://orcid.org/0000-0001-5169-7811	Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation and Writing - Original Draft.
BN	https://orcid.org/0000-0002-4983-9742	Writing - Review and Editing, Visualization, Supervision and Project Administration.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

Financial Support

The study has been funded by Vision Group of Science and Technology (VGST) – Project No. GRD 418.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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