Cephalometric Evaluation of Correlation Between Full Facial Balance and Pharyngeal Airway Dimensions in Orthodontic Subjects

Abstract:

Objective: To evaluate the cephalometric correlation between full facial balance parameters, derived from Arnett's soft-tissue analysis, and pharyngeal airway dimensions among orthodontic subjects from Western Uttar Pradesh, India, and to compare these with established Arnett's Caucasian norms.

Material & Methods: This cross-sectional cephalometric correlation study utilized 62 pre-treatment lateral cephalograms (M=F) aged 17–25 years, obtained from the archives of the Department of Orthodontics and Dentofacial Orthopedics, KDC. The study was approved by the Institutional Ethical Committee. Arnett's soft-tissue harmony parameters were traced manually, with all projections measured perpendicular to the True Vertical Line (TVL). Pharyngeal airway widths were measured at upper, middle, and lower levels. Statistical analysis included independent t-tests and Pearson's correlation coefficients (SPSSv25.0). The significance level was set at $p<0.05$.

Results: In western Uttar Pradesh population, soft-tissue projections exhibited significant deviations from Arnett's Caucasian norms across multiple landmarks. Notably, the orbital rim, cheekbone, alar base, and pogonion measurements demonstrated statistically significant differences ($p<0.05$). Among airway parameters, the lower pharyngeal width showed a significant gender difference ($p=0.03$). Correlation analysis revealed that facial angle negatively correlated with Gl' –A' distance ($r=-0.269$, $p=0.038$), and a significant positive correlation existed between upper and middle pharyngeal widths ($r=0.368$, $p=0.004$), and between middle and lower pharyngeal widths ($r=0.529$, $p<0.001$).

Conclusion: Subjects from Western Uttar Pradesh exhibited distinct soft-tissue harmony profiles compared with Caucasian norms. Facial balance parameters demonstrated measurable associations with pharyngeal airway morphology, particularly at the lower airway level, indicating possible interdependence between facial soft-tissue projection and airway space dimensions.

Keywords: Cephalometry, Arnett analysis, full facial balance, pharyngeal airway, orthodontics, soft tissue profile.

Introduction:

Facial esthetics and airway adequacy are crucial determinants in orthodontic diagnosis and treatment planning. The growing emphasis on soft-tissue–based diagnosis has shifted focus from skeletal hard- tissue norms to individualized soft-tissue harmony. Arnett et al. introduced the *soft-tissue cephalometric analysis for orthognathic planning (STCA)* to establish balance and harmony relative to a True Vertical Line (TVL) drawn through subnasale.[1−3,4] This method quantifies facial projection in millimeters from the TVL, offering a comprehensive understanding of sagittal soft-tissue balance.

Parallelly, the evaluation of the pharyngeal airway has become integral to orthodontic and orthognathic assessments.[5-7] Airway morphology has been associated with craniofacial growth pattern, skeletal discrepancy, and even the success of

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Received : 5 June, 2026, **Published :** 30 June, 2026

Access this article online

Website:
www.ujds.in

DOI:
https://doi.org/10.21276/ujds.2026.12.2.14

How to cite this article: Dr. Shipra yadav, Dr. Ashish kumar, Pandey, D. S., & Dr. Sonu Pradhan. (2026). Cephalometric Evaluation of Correlation Between Full Facial Balance and Pharyngeal Airway Dimensions in Orthodontic Subjects. UNIVERSITY JOURNAL OF DENTAL SCIENCES, 12(2).

orthodontic mechanics.[8,9] Given the ethnic diversity of facial forms, population-specific data are essential for establishing normative references.

While several studies have assessed either soft-tissue harmony or airway dimensions independently, few have explored the relationship between full facial balance and pharyngeal airway space within a specific ethnic Indian population.[10-12] Hence, this study aims to cephalometrically evaluate the correlation between Arnett′s full facial balance parameters and pharyngeal airway widths among orthodontic subjects in Western Uttar Pradesh, India, and compare them to established Caucasian norms.

MATERIALS AND METHODS:

Study Design and Sample

This was a **cross-sectional observational correlation study** utilizing archived pre-treatment lateral cephalograms and demographic data of orthodontic patients aged 17–25 years. The study was conducted in the Department of Orthodontics & Dentofacial Orthopedics, KDC, after approval from the Institutional Ethics Committee (IEC No: KDC/LTR/22/093, dated 17/05/20**).

A total of **62 cephalograms** (31 males and 31 females) were included. Sample size estimation was performed using **G*Power software** (version 3.1.9.4, Düsseldorf, Germany) for 95% power, $\alpha = 0.05$, $\beta = 0.05$, and an effect size of 0.91, yielding 31 per group.

Inclusion Criteria:

1. Subjects aged 17–25 years with Class I skeletal base.
2. Balanced facial proportions without prior orthodontic or surgical treatment.
3. Availability of good-quality lateral cephalograms taken in natural head position with lips relaxed and teeth in centric occlusion.

Exclusion Criteria:

1. Craniofacial syndromes or facial asymmetry.
2. History of airway pathology, adenoidectomy, or tonsillectomy.
3. Gross dental malocclusion altering facial balance.

Cephalometric Analysis:

All cephalograms were traced manually on 0.003-inch acetate sheets using a sharp 0.5-mm pencil under standardized illumination. The **True Vertical Line (TVL)** was constructed through *subnasale (Sn)* and used as the reference line for all anteroposterior soft-tissue measurements **(Figure 1)**, as per **Arnett et al. (1999)**.[1]

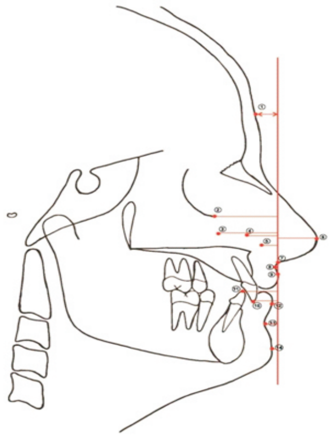

Fig. 1 Landmarks related to projections to TVL

CODE	PROJECTIONS TO TVL
1	Glabella (G) to TVL
2	Orbital rim (OR) to TVL
3	Cheek bone (CB) to TVL
4	Subpupil (SP) to TVL
5	Alar base (Ab) to TVL
6	Nasal projection (Pn) to TVL
7	Subnasale (Sn) to TVL
8	Soft tissue point A' (A') to TVL
9	Upper lip anterior (Ls) to TVL
10	Maxillary central incisor tip (Mx1) to TVL
11	Mandibular central incisor tip (Md1) to TVL
12	Lower lip anterior (Li) to TVL
13	Soft tissue point B' (B') to TVL
14	Pogonion' (Pog') to TVL

Soft-Tissue (Full Facial Balance) Parameters:

Measurements included projection distances (in mm) from TVL to soft-tissue landmarks **(Figure 2):** Glabella′, Orbital rim, Cheekbone, Subpupil, Alar base, Nasal tip, Subnasale, A′ point, Upper lip anterior, Mx1, Md1, Lower lip anterior, B′ point, and Pogonion′.

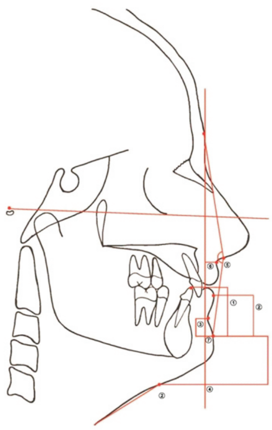

Fig. 2 Facial harmony showing intramandibular relations & full facial balance.

CODE	FACIAL HARMONY
	A)INTRAMANDIBULAR RELATIONS
1	Mandibular central incisor tip-pogonion' (Mx1-Pog')
2	Labrale inferius- pogonion' (Ls-Pog')
3	Soft tissue point B'- pogonion' (Point B'-Pog')
4	Throat length-pogonion' (neck throat point-Pog') **B) FULL FACIAL BALANCE**
5	Facial angle (N-Sn-Pog')
6	Glabella to point A' (G-point A')
7	Glabella to pogonion' (G-Pog')

Pharyngeal Airway Measurements

Airway widths were measured as **(Figure 3):**

- **Upper pharynx:** Distance between the posterior outline of soft palate and posterior pharyngeal wall.
- **Middle pharynx:** Space between tongue base and posterior pharyngeal wall.
- **Lower pharynx:** Distance from the intersection of epiglottis base to the posterior pharyngeal wall.

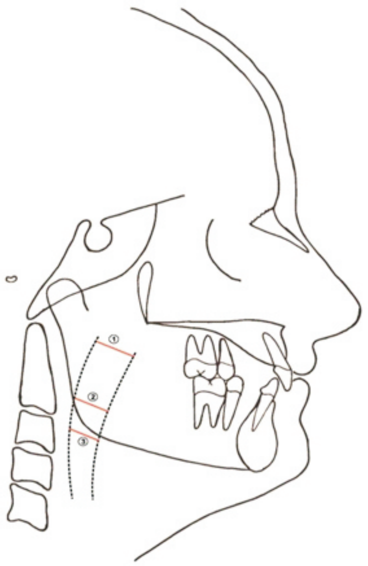

Fig. 3 Pharyngeal Airways

CODE	PHARYNGEAL AIRWAYS
1	Upper pharyngeal width (UPW)
2	Middle pharyngeal width (MPW)
3	Lower pharyngeal width (LPW)

Statistical Analysis:

All data were analyzed using SPSS v25.0 (IBM Corp., Armonk, NY).

- Mean ± SD values were calculated separately for males and females.
- Intergroup differences were analyzed using independent *t*-tests.
- Correlations between facial balance parameters and airway widths were evaluated using Pearson's correlation coefficient.
- Statistical significance was set at $p < 0.05$.

Reliability of Measurements:

To assess intra-examiner reliability, 10 randomly selected cephalograms were retraced and remeasured after a 2-week interval by the same examiner. Intraclass correlation coefficients (ICC) were calculated for all linear and angular parameters, which showed excellent reliability (ICC = 0.91–0.97). Measurement error was assessed using Dahlberg's formula and found to be less than 0.5 mm for all variables.

Results:

Comparison with Arnett's Caucasian Norms:

Soft-tissue projection differences between the Western U.P. sample and Arnett's Caucasian data showed significant deviations in several parameters **(Table 1):**

- **Orbital rim**, **Cheekbone**, **Alar base**, **Nasal projection**, **A′ point**, **Upper lip**, and **Pogonion′** all displayed $p < 0.05$.
- Females showed lesser midface projection than males.
- The **mean difference** ranged from 1.35 mm (A′ point) to 12.55 mm (Orbital rim).

Table 1. Comparison of Arnett's Soft-Tissue Harmony Parameters (Caucasian norms) with Western Uttar Pradesh Norms (Indian Population)

Parameter		Gender	Arnett norms (Caucasian population) Mean ± SD	Western U.P. norms (Indian population) Mean ± SD	Mean difference	p-value
Projections to TVL	Glabella (mm)	Female	-8.50 ± 2.40	7.65±3.30	0.85	.23
		Male	-8.00 2.50	6.03±2.85	1.97	.02?
	Orbital Rims (mm)	Female	-18.70 2.00	31.25±3.75	12.55	.01?
		Male	-22.40±2.70	27±2.80	-4.6	.01?
	Cheek Bone (mm)	Female	-20.60±2.40	22.66±4.39	2.0	.01?
		Male	-25.20±4.00	17.80±4.77	7.4	.01?
	Subpupil (mm)	Female	-14.80±2.10	13.36±3.34	1.44	.01?
		Male	-18.40±1.90	10.55±3.95	7.85	.01?
	Alar Base (mm)	Female	-12.90 1.10	8.88±1.96	4.07	.01?
		Male	-15.00±1.70	6.68±1.70	8.32	.01?
	Nasal Projections (mm)	Female	16.00 ± 1.40	12.33±1.24	3.69	.02?
		Male	17.40 + 1.70	12.45+2.36	4.9	.02?
	Subnasale (mm)	Female	0	0	0	-
		Male	0	0	0	-
	A point' (mm)	Female	0.10 ± 1.00	1.85±1.02	1.84	.02?
		Male	-0.30 1.00	1.65±0.84	-1.35	.02?
	Upper Lip Anterior (mm)	Female	3.70 ± 1.20	1.37±1.18	2.33	.01?
		Male	3.30 ± 1.70	1.50±1.32	2.13	.01?
	Mx1 (mm)	Female	9.20 ± 2.20	11.93±3.07	-2.73	.02?
		Male	12.10±1.80	9.51±2.50	2.59	.02?
	Md1 (mm)	Female	-9.20 ± 2.20	15.15±3.16	-5.95	.06
		Male	-15.40 1.90	12.83±2.56	2.57	.08
	Lower Lip Anterior (mm)	Female	1.90 ± 1.40	3.54±2.91	-1.648	.05
		Male	1.00± 2.20	2.90±1.83	-1.9	.07
	B point' (mm)	Female	-5.30 ± 1.50	9.50±3.74	-4.2	.02?
		Male	-7.10 ± 1.60	7.93+2.78	-0.8	.04?
	Pogonion (mm)	Female	-2.60 ± 1.90	8.20±3.95	-5.6	<.001?
		Male	-3.50± 1.80	6.50±3.49	-3	.01?

TVL = True Vertical Line; p < 0.05 considered statistically significant.

Pharyngeal Airway Widths:

- The **lower pharyngeal width** was significantly higher in females (p = 0.03), whereas upper and middle pharyngeal widths did not differ significantly between genders **(Table 2).**

Table 2. Comparison of Oro-pharyngeal Airway Dimensions between Male and Female Subjects.

Oropharyngeal airway space	Gender	Mean width	Std. Deviation	Mean difference	p-value
Upper Pharynx	Female	15.73	2.43	0.45	.41
	Male	16.18	1.74		
Middle pharynx	Female	9.38	2.48	0.07	.93
	Male	9.31	2.83		
Lower pharynx	Female	12.23	2.76	1.52	**.03***
	Male	10.71	2.75		

* Statistically significant difference.

Correlation Analysis:

Pearson's correlation results revealed:

- Facial angle and Gl′–A′: $r = -0.269, p = 0.038$
- Upper and middle pharynx widths: $r = 0.368, p = 0.004$
- Middle and lower pharynx widths: $r = 0.529, p < 0.001$

These suggest that facial projection parameters influence the pattern of pharyngeal width distribution, especially in the lower airway **(Table 3).**

Table 3. Correlation Coefficients between Full Facial Balance Parameters and Pharyngeal Airway Widths

Correlations between Full Facial Balance & Pharyngeal Widths							
PARAMETERS		Facial angle	Glabella'- A point'	Glabella'- Pogonion'	Width of upper pharynx	Width of middle pharynx	Width of lower pharynx
Facial angle	Pearson Correlation	1	**-.269***	-.071	.094	-.035	-.014
	Sig. (2-tailed)		**.038***	.590	.474	.789	.916
Glabella'-A point'	Pearson Correlation	**-.269***	1	-.224	.172	.151	.251
	Sig. (2-tailed)	**.038***		.086	.188	.248	.053
Glabella'-Pogonion'	Pearson Correlation	-.071	-.224	1	.046	.068	-.117
	Sig. (2-tailed)	.590	.086		.725	.604	.372
Width of upper pharynx	Pearson Correlation	.094	.172	.046	1	**.368***	.193
	Sig. (2-tailed)	.474	.188	.725		**.004***	.139
	Pearson Correlation	-.035	.151	.068	**.368***	1	**.529***
Width of middle pharynx	Sig. (2-tailed)	.789	.248	.604	**.004***		**.000***
Width of lower pharynx	Pearson Correlation	-.014	.251	-.117	.193	**.529****	1
	Sig. (2-tailed)	.916	.053	.372	.139	**.000**	

Discussion:

Soft-Tissue Facial Balance and Ethnic Variations:

The present study supports the notion that soft-tissue facial balance exhibits population-specific characteristics. The Western U.P. population showed reduced anterior projection compared with Arnett's Caucasian norms. Such findings align with previous Indian studies by Kalha et al.[12] and Nanda et al.[13], who highlighted ethnic distinctions in facial convexity and lip posture.

Facial esthetics are strongly governed by soft-tissue adaptation rather than skeletal configuration alone. Arnett's system emphasizes *facial harmony*—the balanced projection of soft-tissue landmarks to the TVL—providing a more realistic representation of facial beauty.[1-3,4]

Airway Dimensions and Craniofacial Pattern:

The pharyngeal airway space serves as a critical functional component influencing craniofacial growth and orthodontic stability. Studies by McNamara[5], Schwab[7], and Ceylan[9] have underscored the relationship between airway dimensions and facial morphology. In the present study, the lower pharyngeal width displayed sexual dimorphism, consistent with reports by Martin et al.[14]

A significant positive correlation among upper, middle, and lower pharyngeal segments suggests regional interdependence within the airway. These results concur with findings by Grauer et al.[15], who reported proportional relationships between oropharyngeal compartments in balanced facial profiles.

Correlation between Facial Harmony and Airway Space:

The negative correlation between facial angle and Gl′–A′ implies that as the facial convexity increases, the anterior maxillary projection decreases, possibly reflecting retrusive midface patterns associated with narrower pharyngeal space. This supports findings by Hellsing[16] and El & Palomo[17] who linked retrognathic skeletal bases with diminished airway dimensions.

The present findings underscore the necessity for individualized diagnostic approaches that integrate both esthetic and functional dimensions. With the increasing use of digital cephalometric and CBCT, future studies can incorporate volumetric airway assessment to strengthen the soft-tissue–airway correlation framework.

Clinical Implications:

Understanding the interplay between facial harmony and airway dimensions aids in:

1. Predicting functional outcomes of orthodontic and orthognathic interventions.
2. Identifying patients predisposed to compromised airway function.
3. Customizing treatment mechanics to optimize both esthetics and respiratory efficiency.

The Western U.P. data provide a valuable regional reference for orthodontic diagnosis, emphasizing the need for population-specific norms rather than reliance on Caucasian standards.

Limitations:

- Two-dimensional cephalograms may not fully capture airway volume; CBCT-based studies could enhance accuracy.
- Age range limited to 17–25 years; growth-phase variations not considered.
- Functional aspects such as tongue posture or nasal resistance were not evaluated.

Future research incorporating **3D imaging** and **dynamic airway assessment** can further elucidate the relationship between facial harmony and airway adequacy.

Conclusion:

1. Western U.P. orthodontic subjects exhibited distinct soft-tissue projection profiles compared with Arnett's Caucasian norms, with reduced midface and pogonion projections.
2. Lower pharyngeal airway width showed significant gender variation, being greater in females.
3. Positive correlations between pharyngeal compartments and selected facial balance parameters indicate a structural-functional relationship between facial esthetics and airway space
4. Population-specific soft-tissue and airway norms should be used in orthodontic diagnosis and treatment planning for enhanced esthetic and functional outcomes.

Declarations:

Ethical Approval: The study protocol was reviewed and approved by the Institutional Ethics Committee, KDC (IEC No: KDC/LTR/22/093, dated 17/05/20**). As this was a retrospective radiographic study, individual informed consent was waived.

Conflict of Interest: The authors declare that they have no conflicts of interest related to this study.

Funding Source: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions: All authors contributed equally to study design, data analysis, manuscript preparation, and final approval of the submitted version.

Acknowledgments:

The authors acknowledge the support of the Department of Orthodontics and Dentofacial Orthopaedics, KDC, for providing archived data and technical assistance during tracing and measurement.

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