Research Article

Correlation of Oropharyngeal Airway Volume and Transverse Dental Arch Form: A Cone Beam Computed Tomography (CBCT) Study

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Abstract: Background: Variations in transverse dental arch form can significantly impact airway and breathing. With the advent of cone beam computed tomography, accurate evaluation of airway can be performed, overcoming two-dimensional limitations of lateral Cephalogram.

Objective: The aim of the study is to compare oropharyngeal airway volume and index of inter-canine width relative to the intermolar width (ICW/IMW), and internal angles; interincisor, canine, and molar angle of the maxillary and mandibular arches using CBCT. The study also aims to compare gender and oropharyngeal airway volume and all transverse dental arch form variables.

Materials and Methods: This cross-sectional study was conducted in the duration of January 2024 to June 2024 at Margalla Institute of Health Sciences, Rawalpindi. The Ethics Review Committee of Margalla Institute of Health Sciences Rawalpindi, granted approval, (Ethical Approval Number: DM/199/23). The SPSS software version 23 was employed for data analysis. Independent T test was applied for gender comparison of OPV and all transverse dental arch form variables while correlation between OPV and transverse dental arch form variables was determined using Pearson's coefficient (r).

Result: A positive significant correlation was found between OPV and maxillary inter-incisor angle(r=0.363), maxillary canine angle (r=0.393) and mandibular inter-incisor angle. (r=0.476). Significant negative correlation was observed between OPV and maxillary molar angle (r=-0.348), mandibular canine angle (r=-0.559), ICW/IMW ratio of mandible (r=-0.224). There was insignificant negative correlation of OPV with maxillary ICW/IMW ratio (r=-0.151) and mandibular molar angle (r=-0.004).

Conclusion: Oropharyngeal volume was significantly positively correlated with transverse dental arch morphology. These results indicate a complex interdependence between transverse dental arch form and airway volume and call for airway assessment in conjunction with the dental arch form.

Keywords: Arch form, Cone beam computed tomography, Inter- canine width, Inter-molar width, Oropharyngeal airway volume, Transverse dental arch morphology.

INTRODUCTION

Respiratory tract is classified into the upper airway region (UA) and the lower airway region (LA). In orthodontics, upper airway is relevant which includes the nasal cavity, pharynx, and hypopharynx. The pharyngeal airway consists of three region: nasopharynx, oropharynx, and hypopharynx. Oropharynx is a part of airway extending from the soft palate to the upper border of the epiglottis, surrounded anteriorly by maxillomandibular complex, and confined by spinal column posteriorly [1, 2].

Transverse discrepancies of the dental arches can involve variations in the facial skeleton, and soft-tissue profile either individually or collectively. The morphology of the dental arch plays an essential role in the orthodontic management of various malocclusions. Assessment of dental arch dimensions require calculating arch width, which includes inter-canine and intermolar widths [3-5].

Airway obstruction effects respiration and contribute to craniofacial malformations. Conversely, abnormal craniofacial development can result in airway constriction, leading to impaired breathing, persistent oral respiration and sleep related disorders. Different treatment options in Orthodontics such as, orthodontic camouflage, growth modification, orthognathic surgeries of maxilla and mandible, and maxillary expansion effect airway dimensions in multiple ways. Rapid maxillary expansion, which enlarges upper arch width, results in the widening of the nasal cavity and an increase in nasopharynx volume. But, recent studies did not display any notable alterations in oropharyngeal airway volume, with the change in intermolar width and shift of mandibular position [6-8].

According to Ciavarella *et al.* significant inverse correlation between morphology of maxillary and mandibular dental arches with obstructive sleep apnea was found. Bokhari *et al.* studied pharyngeal airway volume in class I and class II malocclusion on CBCT and observed no significant difference between them [9, 10].

Dental radiography was reformed in the late 1990's when cone beam computed tomography became readily available. With the

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help of CBCT, it is possible to obtain a three-dimensional picture of all the components within the facial skeleton. It facilitates the evaluation of the airway in the frontal, transverse and anterior-posterior planes. It calculates the total airway volume and recognizes the areas with the greatest sagittal and latero-lateral constriction of the airways. Furthermore, on CBCT, images are not magnified and are recorded on a 1:1 scale, which gives accurate dimensional measurements. This enables it to address the limitations of two-dimensional radiographs, like lateral cephalograms. Additionally, this 3D imaging has much more advantageous risk- to-benefit ratio. When compared to multi-slice computed tomography, CBCT has a lower radiation dosage, a broader field of view (FOV), improved image quality, and faster scanning times, making it more efficient compared to CT [11-18].

In the recent study, the lateral cephalogram was used for measuring airway dimensions, while study casts were employed for assessment of transverse dental arch form [19]. With the help of CBCT, these measurements can be performed with higher accuracy and precision. Furthermore, there is scarce data about correlation of airway morphology with transverse dental arch form.

In light of this, knowledge of oropharyngeal airway of patients with wide or narrow arch form is essential. The aim of the study is to compare oropharyngeal airway volume and index of inter-canine width relative to the intermolar width (ICW/IMW), and internal angles; interincisor, canine, and molar angle of the maxillary and mandibular arches using CBCT. The study also aims to compare gender and oropharyngeal airway volume and all transverse dental arch form variables.

MATERIALS AND METHODS

This cross-sectional study was conducted at Margalla Institute of Health Sciences in Rawalpindi, Pakistan, from January 2024 to June 2024.The Ethics Review Committee of Margalla Institute of Health Sciences Rawalpindi, granted approval, (Ethical Approval Number: DM/199/23). The Patients included in the study were: patients of both genders, patients who had CBCT with full imaging of the airway, maxilla, mandible, incisors, canines, and molars and age> 12 years. The exclusion criteria for the study was: CBCT's having movement artifacts and swallowing during scan acquisition. Data of CBCT images was collected from Margalla Dental Hospital, Rawalpindi using non-probability consecutive sampling technique. Sample size was calculated as 149 utilizing WHO calculator using following parameters: Level of significance was 5, Power of test was 80%, population mean test value of Angle 2 (canine) of upper arch form was taken: 137.8 ±8.3 [17], anticipated population mean was 140.5, Population standard deviation was 8.3. Informed consent was taken for the use of CBCT images and identification of the patient was kept anonymous. All CBCT images were taken using a standardized procedure with a cone beam machine. The parameters used were: 96 kV, 5 mA, a field of view of 13.0 cm x 9.0 cm, a size of 651 x 651 x 451 voxels, voxel size of 0.200 mm, and a scan duration of 12.092 seconds. The CBCT data were saved in Digital Imaging and Communications in Medicine (DICOM) format. All the radiographs were evaluated by a single clinician using Planmeca Romexis software (version 6.2.1: Planmeca).

CBCT SCAN MEASUREMENTS

Oropharyngeal Airway Volume (OPV)

The oropharyngeal airway volume was assessed using "region growing tool" in Romexis. It was delineated on sagittal view as an area, having upper boundary at level of PNS and lower boundary established as crossing the front and lowest section of the second cervical vertebrae, parallel to palatal plane. A cube was outlined in the region of the airway in a sagittal grayscale view from PNS till the second cervical vertebrae [20, 21]. The PNS point, identified in the sagittal slice, was confirmed using axial and coronal slices. In three-dimensional region growing option, the 'air cavity' parameter was utilized. For the threshold, a standardized adjustment value of 795 was used for all patients to ensure consistent results [17]. Then within the airway, a seed point was selected to choose the type of density to be measured. The software then showed the airway volume (Fig. **1**).

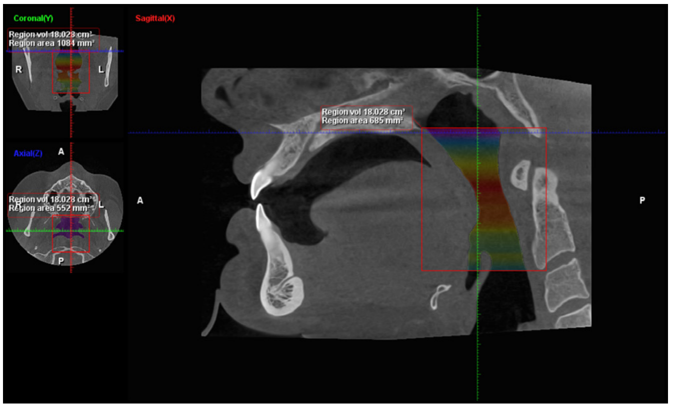

Fig. (1). Oropharyngeal Airway Volume Outlined within a Cube on Sagittal, Axial and Coronal Slices of Cone Beam Computed Tomography.

Arch From Evaluation

Internal Angles [19]

The three internal angles in both arches were measured on the axial view of CBCT by delineating a five- sided polygon. The vertices were positioned between the central incisors, at the cusp tips of the right and left canines, and at the central fossa on the occlusal surface of the molars on both sides of the upper and lower arches.

Inter-Incisor Angle (Angle 1)

It was measured on the axial view as the angle formed by the midpoint between both central incisors, connected with two vertices at the cusp tips of the right and left canines (Fig. **2a**). Axial slice was aligned with the central fossa of the molars on the right and left sides as a reference point on the coronal slice (Fig. **2b**).

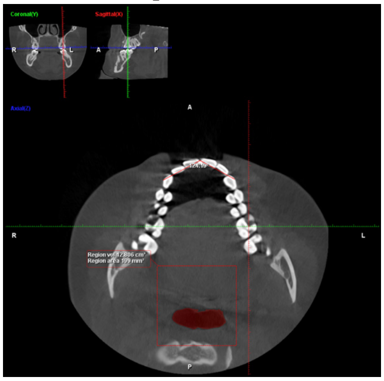

Fig. (2a). Red Line Showing Inter-Incisor Angle Measured on Axial View of Cone Beam Computed Tomography.

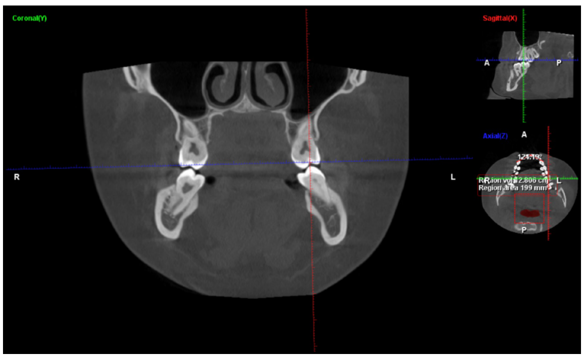

Fig. (2b). Showing Central Fossa of the Molars on Both Sides on the Coronal Slice used as Reference for Measurement of Internal Angles.

Canine Angle (Angle 2)

It was marked as the angle from the cusp tip of the canine connected to the midpoint between the two central incisors and to the central fossa of the occlusal surface of the molar (Fig. **3**). The transverse slice was oriented by using the central fossa of the molars on both sides as a reference on the coronal slice (Fig. **2b**).

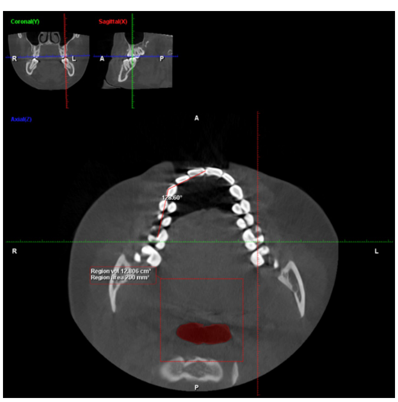

Fig. (3). Red Line Showing Canine Angle Measured on Axial View of Cone Beam Computed Tomography.

Molar Angle (Angle 3)

It was measured as an angle drawn from the central fossa on the occlusal surface of the molar, connected with the cusp tip of the canine and the central fossa of the molar on the other side (Fig. **4**). The axial slice was oriented by using the central fossa of the molars on both sides as a reference on the coronal slice (Fig. **2b**).

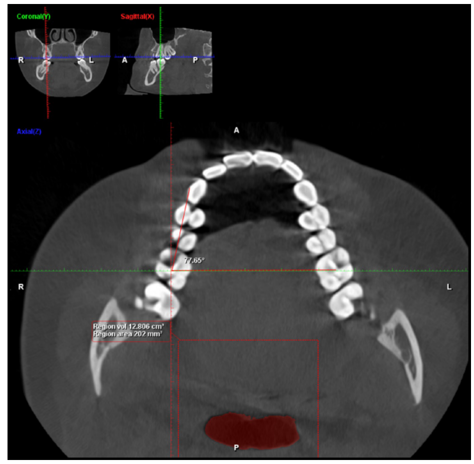

Fig. (4). Red Line Showing Molar Angle Measured On Axial View of Cone Beam Computed Tomography.

Arch Width Measurements [22]

Intermolar Width (IMW)

This measurement was taken on the axial slice of CBCT between the mesio-buccal cusp tips of molars from the right to the left side of the same arch for both jaws (Fig. **5a**), with verification of the cusp tips on the coronal slice (Fig. **5b**).

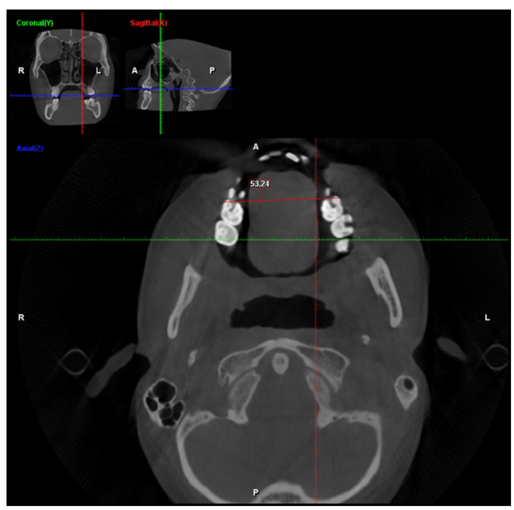

Fig. (5a). Red Line Showing Intermolar Width Measured on Axial View of Cone Beam Computed Tomography.

Intercanine Width (ICW)

This width was measured on the axial slice of CBCT between the cusp tips of the canines from the right to the left side of the same arch for both jaws (Fig. **6a**), with the cusp tips verified on the coronal slice (Fig. **6b**). Then, calculation for the ratio of inter-canine to intermolar width ratio for upper and lower arches was done.

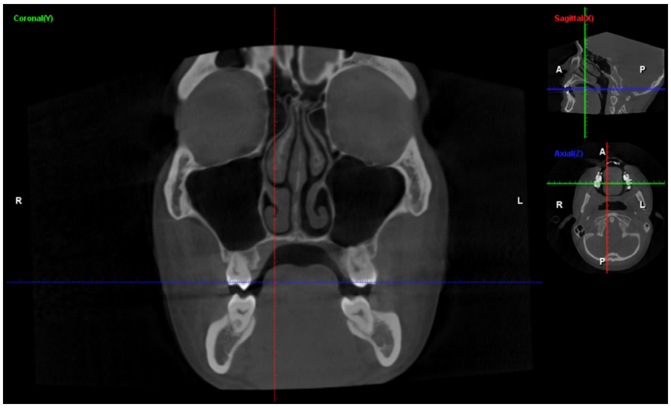

Fig. (5b). Blue Line Verifying Mesio-Buccal Cusp of Both Sides of Molars for Intermolar Width Measurement on Coronal Slice of Cone Beam Computed Tomography.

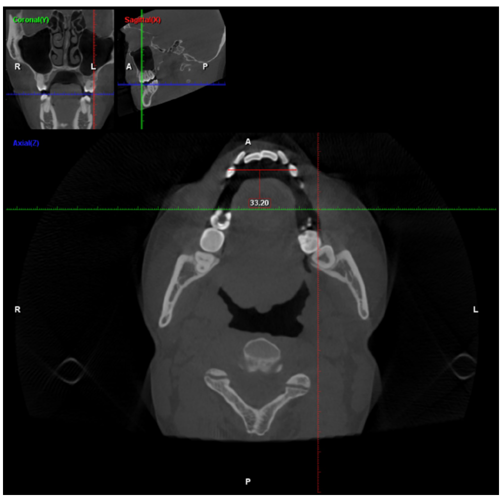

Fig. (6a). Red Line Showing Intercanine Width Measured on Axial View of Cone Beam Computed Tomography.

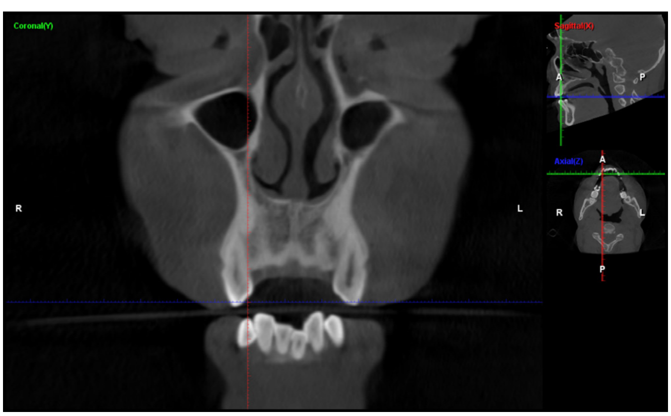

Fig. (6b). Blue Line Verifying Canine Cusp Tips of Both Sides for Intercanine Width Measurement on Coronal Slice of Cone Beam Computed Tomography.

STATISTICAL EVALUATION

The data were processed using SPSS software version: 23. Qualitative variables like gender was calculated as frequency and percentage, while quantitative variables were measured in terms of mean and standard deviation. Independent T test was applied for gender comparison of OPV and ratio of inter-canine width to intermolar width (ICW/IMW), and inter-incisor angle, canine angle, and molar angle of both the maxillary and mandibular arches. Pearson's coefficient (r) was employed to evaluate the extent of correlation between oropharyngeal volume and various variables related to transverse dental arch form. The null hypothesis states that there is no correlation between oropharyngeal airway volume and transverse dental arch form.

RESULT

This study found correlation of oropharyngeal airway volume and transverse dental arch form variables using 149 CBCT images of patients with age >12 years. The results showed 54.4% were females and males were 45.6%. Mean values of OPV and inter-incisor angle, canine angle, molar angle, ICW/IMW ratio of both maxilla and mandible are given in Table **1**. Males had statistically significant larger OPV, maxillary molar angle and mandibular inter-incisor angle values compared to females. In females, mandibular molar angle was significantly larger than males. Table **2** shows gender comparison of OPV and all transverse dental arch form variables.

Table 1. Mean± Standard Deviation of OPV and other Transverse Dental Arch Form Variables.

Variables	Gender	Mean	Std. Deviation
OPV	Male	16.821	6.451
	Female	14.248	5.975
Maxillary inter-incisor angle	Male	131.517	7.940
	Female	131.277	10.688
Maxillary canine angle	Male	127.014	4.915
	Female	127.110	5.858
Maxillary molar angle	Male	76.656	7.329
	Female	73.573	6.674
Maxillary ICW/IMW ratio	Male	.656	.038
	Female	.662	.037
Mandibular inter-incisor angle	Male	146.977	11.288
	Female	139.392	13.828
Mandibular canine angle	Male	120.007	6.119
	Female	120.083	8.923
Mandibular molar angle	Male	73.378	4.160
	Female	76.866	5.252
Mandibular ICW/IMW ratio	Male	.590	.025
	Female	.623	.035

OPV= Oropharyngeal airway volume, ICW= Inter-canine width, IMW= Intermolar width.

Table 2. Gender Comparison of OPV and Transverse Dental Arch Form Variables using Independent Sample T- test.

Variable	Male Mean ± SD	Female Mean ± SD	t-value	P-value
OPV	16.821±6.45	14.248±5.97	2.524	0.013*
Maxillary inter-incisor angle	131.517±7.94	131.277±10.68	0.153	0.878
Maxillary canine angle	127.014±4.91	127.110±5.858	-0.107	.915
Maxillary molar angle	76.656±7.329	73.573±6.674	2.686	.008*
Maxillary ICW/IMW ratio	.656±.038	.662±.037	-0.981	.328
Mandibular inter-incisor angle	146.977±11.288	146.977±11.288	3.622	.000*
Mandibular canine angle	120.007±6.119	120.083±8.923	-0.060	.951
Mandibular molar angle	73.378±4.160	76.866±5.252	-4.431	.000*
Mandibular ICW/IMW ratio	.590±.025	.623±.035	-6.408	.000*

OPV= Oropharyngeal airway volume, ICW= Inter-canine width, IMW= Intermolar width, *p< 0.05= Statistically significant.

A positive significant correlation was found between OPV and maxillary inter-incisor angle(r=0.363), (p=0.00) and maxillary canine angle (r=0.393), (p=0.00). Significant negative correlation was observed between OPV and maxillary molar angle (r=-0.348), (p=0.00). Significant positive correlation of OPV was noted with mandibular inter-incisor angle. (r=0.476), (p=0.00). There was statistically significant negative correlation of OPV with mandibular canine angle. (r=-0.559), (p=0.00). ICW/IMW ratio of mandible was found to have statistically significant inverse correlation with OPV. (r=-0.224), (p=0.006). Table **3**, shows correlation of oropharyngeal airway volume with various transverse dental arch form variables.

Table 3. Correlation of OPV with Various Transverse Dental Arch Form Variables using Pearson's Coefficient.

Variables	Correlation (r)	Significance (p)
OPV and maxillary inter-incisor angle	0.363	0.00*
OPV and maxillary canine angle	0.393	0.00*
OPV and maxillary molar angle	-0.348	0.00*
OPV and maxillary ICW/IMW ratio	-0.151	0.06
OPV and mandibular inter-incisor angle	0.476	0.00*
OPV and mandibular canine angle	-0.559	0.00*
OPV and mandibular molar angle	-0.004	0.96
OPV and mandibular ICW/IMW ratio	-0.224	0.006*

OPV= Oropharyngeal airway volume, ICW= Inter-canine width, IMW= Intermolar width, r= Pearson's correlation coefficient, *p< 0.05=Statistically significant, Positive r= Direct relationship, Negative r= Inverse relationship.

DISCUSSION

The ICW/IMW ratio exhibited a weak negative correlation with OPV, hinting that higher OPV values may correspond with slightly narrower ratios. This shows that patients having constricted arch form can have airway volumes in normal ranges and arch form alone may not be a single predictor of airway patency. Miranda *et al.* found a direct correlation between OPV and arch width at the molar level, with lower OPV values being associated with a narrow arch form. This relationship was found because of the structural restriction placed by narrow arch width on adjacent structures, decreasing upper airway volume. According to Ciavarella *et al.* there was no difference in the upper arch width associated with lower airway volume among obstructive sleep apnea patients This can be explained by compensatory mechanisms that may occur in surrounding soft tissue structures irrespective of maxillary arch width. Irlandese *et al.* reported reduced mandibular inter-canine width and inter-molar width among OSA patients [23-25], which are contradictory to our findings. De Oliveira *et al.* found positive relationship between the lower oropharyngeal airway volume and the ratio of the intercanine to intermolar dental widths, suggesting that narrower upper arch configurations are linked with reduced volume of the lower oropharynx.

In our study, OPV shows direct correlations with the inter-incisor angle of both arches and canine angle of maxillary arch indicating that higher OPV values tend to correspond with larger angles in these areas. This shows that arch forms should be well aligned to achieve normal airway dimensions. These findings are consistent with a recent study, and concluded that larger oropharyngeal dimensions are associated with a larger canine angle at the vertex. However, the study also noted an inverse relationship of the inter-incisor angle with OPV. This indicates that retroclination of incisors restricts airway volume and shows influence of incisor inclination on oropharyngeal airway dimension. Contrary to the current results of our study, which showed a negative correlation of OPV with both upper and lower molar angles, a previous study revealed that a greater molar vertex angle was correlated with increased oropharyngeal volumes

[19]. These results explain that prognathic lower jaw is related to larger oropharyngeal airway. This association is dependent on the mandible and the tongue, being positioned more forward, which helps prevent constriction of the airway. Literature suggests that oropharyngeal volume is reduced in adolescents with a backward positioned mandible [26]. This indicates that early diagnosis of retrognathic mandible is crucial to maintain airway patency and reducing the risk of sleep related disorders. Females displayed lower mean values of OPV compared to males. These results are supported by a study conducted by Al-Bahrani *et al.* who found greater oropharyngeal volume in male subjects than in females [27].

Although cephalometric radiographs involve lower radiation exposure compared to CBCT, CBCT is preferred for its 3D imaging capacity. Nevertheless, CBCT should be employed strictly for diagnostic purposes and following the principle of minimizing radiation exposure as much as possible [28].

LIMITATION

The limitation of this study was the variability in age among different patients. Additionally, the correlation of airway volume with transverse dental arch morphology couldn't be studied across various malocclusions like Class I, II, and III, as these conditions can significantly alter oropharyngeal volumes. Since this study was cross-sectional, future research should aim to find longitudinal changes in airway volume and its correlation with transverse dental arch form.

CONCLUSION

Males exhibited greater OPV, maxillary molar angle and mandibular inter-incisor angle values, while mandibular inter-incisor angle values were larger in females. Oropharyngeal volume was significantly positively correlated with OPV and maxillary inter-incisor angle, maxillary canine angle and mandibular inter-incisor angle. Significant inverse correlation of OPV with maxillary molar angle, mandibular canine angle and mandibular ICW/IMW ratio was found. These results indicate a complex interdependence between transverse dental arch form and airway volume and call for airway assessment in conjunction with the dental arch form.

AUTHORS' CONTRIBUTION

Muteen Fatima: Conceptualization, Study design, Writing draft.

Kausar Ilyas: Critical review and revision the manuscript, Final approval, final proof to be published.

Yusra Shaukat: Methodology, Data analysis and interpretation.

Mehwish Shaheed and Amjad Mahmood: Critical review and revision the manuscript.

ACKNOWLEDGEMENTS

Declared none.

ETHICAL DECLARATIONS

Data Availability Statement

Data are available upon reasonable request. The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The Ethics Review Committee of Margalla Institute of Health Sciences Rawalpindi, granted approval, ethical approval number: DM/199/23.

Consent to Participate

Informed consented.

Consent for Publication

Consented.

Conflict of Interest

Declared none.

Competing Interest/Funding

The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not- for-profit sectors.

Use of AI-Assisted Technologies

The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were utilized in the writing of this manuscript, in the creation of images/graphics/tables/captions, or in any other aspect of its preparation.

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