Original Article

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Dentistry Section

Evaluation of Cervico-vertebral Dimensions and Cranio-cervical Angulations in Adults with Different Vertical Growth Patterns: A Cross-sectional Cephalometric Study

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ABSTRACT

Introduction: The measurement of cervical vertebrae is a valuable diagnostic aid since it provides data on skeletal maturity and potential for growth. Research suggests the existence of a relationship between dentofacial characteristics and cranio-cervical morphology and posture. This relationship can provide insights into the development and treatment of malocclusions, particularly malocclusions in the vertical dimension.

Aim: To compare cervico-vertebral dimensions, morphology, and cranio-cervical postures in subjects with different skeletal growth patterns such as average, horizontal and vertical.

Materials and Methods: The study was cross-sectional in design and was conducted for a period of two years between January 2014 and December 2016 at KLE Society's Institute of Dental Science and Research, Bengaluru, Karnataka, India. A total of 102 lateral cephalograms were taken for the study and classified into three groups according to Frankfurt Mandibular Plane Angle (FMA angle) and Jarabak ratio as Horizontal (HR), Vertical (VR), and Average (AV) groups. Each group comprised 34 subjects (17 males, 17 females). A total of 28 morphological parameters of C3, C4, and C5 in the lateral cephalogram were measured and analysed. Each lateral cephalogram was scanned with a Konica Minolta Bighub Laser printer, and the area measurement was made with IMAGE J software to measure the area of cervical vertebrae. One-way Analysis of Variance (ANOVA) was used to compare the various parameters between the three groups, and pair-wise comparisons were done using the Least Significant Difference (LSD) test. Student's t-test was done to assess the differences between males and females. A p-value less than 0.05 was considered statistically significant.

Results: The mean chronological age of subjects was 21.2±3.14 years for the HR group, 21.3±3.78 years for the VR group, and 21±3.76 years for the AV group. There was a statistically significant difference between the three groups in the measurements of the anterior body height of C3 (ABHC3) (p=0.023), posterior Body Height of C3 (PBHC3) (p=0.007), vertical measurements of C3 (H3) (p=0.010) and (W3) (p=0.013), anterior body height of C4 (ABHC4) (p=0.010), Posterior Body Height of C4 (PBHC4) (p=0.005); H4 (p=0.002); Ratio of H4 and W4 (H4/W4) (p=0.048); area of the third cervical vertebrae (C3) (p=0.039) and area C4 (p=0.024). For cranio-cervical angulation, there were statistically significant differences found for the angle between the Nasion Sella Line (NSL) and the tangent to the Odontoid Process (NSL/OPT) (p<0.001), where the VR group had significantly larger values than the HR and AV groups. There was no significant difference found in fusion anomalies of cervical vertebrae among all three (HR, VR, and AV) groups.

Conclusion: The study found that individuals with a horizontal growth pattern tend to have larger cervical vertebral dimensions compared to average and vertical growers. Individuals with a vertical growth pattern exhibited a large cranio-cervical angulation. Overall, males had larger cervical vertebral dimensions compared to females. The studied population did not exhibit any fusion anomalies.

Keywords: Cervical vertebrae, Malocclusion, Orthodontics, Posture, Vertical dimension

INTRODUCTION

Lateral cephalograms are crucial for diagnosis and treatment planning in orthodontics [1]. The lateral cephalogram also provides information about the cervical vertebrae. It is routinely used in orthodontics for the assessment of skeletal maturation [2]. The seven cervical vertebrae make up the cervical vertebral column, which supports the head. The superior segment, which connects the spine to the occiput, is made up of the first vertebra (C1), also known as the atlas, and the second vertebra (C2), also known as the axis. Head posture is controlled by the suboccipital muscles linked to this area, which also govern delicate and complex actions for compound flexion and extension and lateral flexion with rotation of the neck [3]. There are proven relationships between upper cervical spine shape and craniofacial characteristics [4]. Evaluation of the relationship between cervical vertebral dimensions, morphologies, and posture to various malocclusions is of diagnostic importance to orthodontists. Various studies have investigated the association between sagittal malocclusions and cervical vertebral dimensions and anomalies [3,5].

After birth, during growth and development, the cervical spine and craniofacial system continue to interact. The sagittal relationship between the jaws is affected by the vertical facial growth pattern. Previous research has supported the influence of the craniofacial system's vertical [6,7] and sagittal [8-10] factors on cervical vertebral morphology and posture [11]. Extensive research exists regarding the impact of neck posture and size on sagittal malocclusions [8-10]. A recent study conducted a comparison of cervical posture both before and after the correction of sagittal malocclusion using twin block. The researchers discovered that the usage of twin block appliances results in a more upright cranio-cervical posture. Additionally, those with decreased vertical dimensions exhibit a more pronounced alteration in cervical posture [12]. The research on the correlation between cervico-vertebral dimensions and cranial angulation with vertical malocclusion is minimal. A recent study evaluated the morphological parameters of the cervical vertebrae in patients with different vertical facial patterns and found a positive correlation between the C1 vertebral dimensions and vertical growth [13]. The altered vertical growth of jaw bases may occur indirectly as a result of the altered muscle function and direction caused by the head posture [13]. Also, ethnic variations in previous studies [4,6] necessitate research in the local population. Hence, the present study aimed to assess and compare cervico-vertebral morphology, dimension, and cranio-cervical postural angulations in patients with different vertical facial growth patterns in a South Indian sample population. The primary objective of the study was to compare cervico-vertebral dimensions in subjects with different skeletal growth patterns such as average, horizontal, and vertical. The secondary objectives of the study were to compare the dimensions of cervical vertebrae in both sex groups and also to compare cranio-cervical postural angulations in subjects with different skeletal growth patterns and to study the distribution of fusion of C3 and C4 (FUSN C3-C4) among the three groups in both genders. The null hypothesis states that there is no relationship between the vertical growth of jaw bases and the cervical vertebral dimensions and cranio-cervical angulations in a South Indian population.

MATERIALS AND METHODS

The study was cross-sectional in design and the routine lateral cephalometric radiographs were collected from patients who reported for comprehensive orthodontic treatment from January 2014 to December 2016 at KLE Society's Institute of Dental Science and Research, Bengaluru, Karnataka, India Informed consent was obtained from all patients for the use of the records in the study. The institutional review board and the Ethical Committee approval were obtained before the commencement of the study (KIDS/IEC/11-2013/25). Pretreatment lateral cephalograms of patients were used for analysis of the cervical vertebral morphology and cranio-cervical postures in the study. All the lateral cephalograms were taken in Natural Head Posture (NHP) for standardisation [14]. All lateral cephalograms were taken digitally by the same operator using a Planmeca Promax machine (Planmeca, USA) which is set to program with image field sizes up to 30×27 cm and images will be obtained through Dimaxis imaging software 3.20.R (Planmeca, USA). Exposure was done at 70 kVps and 10 mAmp for 0.8 seconds for all the samples.

Inclusion criteria: Patients aged between 17-35 years; Lateral cephalograms used were taken before orthodontic treatment with the second, third, fourth, and fifth (C2, C3, C4, and C5) cervical vertebrae visible; Patients with a full complement of teeth.

Exclusion criteria: Patients suffering from craniofacial anomalies, systematic disorders, impacted, and missing teeth as they can act as confounding factors. Poor quality images where the second, third, fourth, and fifth cervical vertebrae (C2, C3, C4, and C5) were not visible, and patients with a previous history of orthodontic treatment or orthognathic surgery were also excluded.

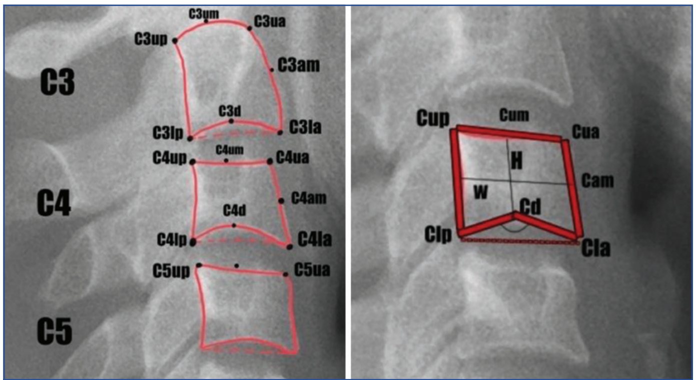
Sample size calculation: Based on the inclusion and exclusion criteria, the samples were selected and divided into three groups based on cephalometric parameters describing the vertical growth pattern of the patients. The Tweed's FMA and Jarabak ratio were used to classify the samples into three groups as follows [15]:

- Group HR: Horizontal growth pattern (FMA <21 degrees, Jarabak ratio >63%)
- Group VR: Vertical growth pattern (FMA >29 degrees, Jarabak ratio <59%)
- Group AV: Average growth pattern (FMA 25±4 degrees, Jarabak ratio 59-63%)

Study Procedure

A total of 102 pretreatment cephalograms (51 males and 51 females) were included in the study. The study was time-bound, and the data was collected starting from January 2014 for a period of two years until December 2016. The present study included 34 subjects per group with 17 males and 17 females in each group.

The reference points on the cervical vertebrae listed in [Table/Fig-1,2] were marked on acetate paper using a soft (0.3 mm) lead pencil and measured with a micrometer caliper. The 28 morphologic characteristic parameters of C3, C4, and C5 in the lateral cephalogram were measured and analysed [Table/Fig-2]. Each lateral cephalogram was scanned (300×300 dpi resolution) with a Laser printer (Konica Minolta Bighub), and the area measurements were made with Image J software (LOCI, University of Wisconsin) to measure the area of cervical vertebrae (C3 and C4). Computer-based image enhancement was carried out to improve the visibility of fine bony details and skeletal contour. Each area was measured on three successive occasions, and the mean value of the three measurements was computed.



[Table/Fig-1]: Landmarks used in the study.
C3: Third cervical vertebra; C4: Fourth cervical vertebra; C5: Fifth cervical vertebra; C3up, C4up, C5up: The most superior points of the posterior border of the body of C3, C4 and C5, respectively; C3ua, C4ua, C5ua: The most superior points of the anterior border of the body of C3, C4 and C5 respectively; C3am, C4am: The middle of the anterior border of the bodies of C3 and C4 respectively; C3d, C4d: The most superior point of the lower border of the bodies of C3 and C4 respectively; C3lp, C4lp: The most posterior points on the lower border of the bodies of C3 and C4 respectively; C3la, C4la: The most anterior points on the lower border of the bodies of C3 and C4 respectively; C3um, C4um: The middle of the upper border of the bodies of C3 and C4; H: Vertical distance from Cum to the connection of Clp and Cla; W: Vertical distance from Cam to the connection of Cup and Clp

Landmarks	Descriptions
C3d, and C4d	The most superior point of the lower border of the bodies of C3 and C4, respectively
C3la, C3lp, C4la,C4lp	The most anterior and most posterior points on the lower border of the bodies of C3 and C4, respectively
C3ua, C3up, C4ua, C4up, C5ua C5up	The most superior points of the anterior and posterior borders of the bodies of C3, C4 and C5, respectively
C3um,C4um	The middle of the upper border of the bodies of C3 and C4
C3am and C4am	The middle of the anterior border of the bodies of C3, and C4
ABHC3	Anterior body height of C3-Vertical distance of C3ua to C3la
PBHC3	Posterior Body Height of C3-Vertical distance of C3up to C3lp
IDC3	Inferior depth of C3-Vertical distance of C3d to the connection of C3lp and C3la
H3	Vertical distance from C3um to the connection of C3lp and C3la
W3	Vertical distance from C3am to the connection of C3up and C3lp
AISC3	Anterior inter vertebral space of C3-Anterior vertical distance between C3la and C4ua
PISC3	Posterior intervertebral space of C3-Posterior vertical distance between C3lp and C4up
C3 angle	Angle between line connecting C3d-C3lp and C3d -C3la

H3/W3	Ratio of H3 to W3
ABHC3/PBHC3	Ratio of ABHC3 to PBHC3
ABHC4	Anterior body height of C4-Vertical distance of C4ua to C4la
PBHC4	Posterior Body Height of C4 (PBHC) -Vertical distance of C4up to C4lp
IDC4	Inferior depth of C4-Vertical distance of C4d to the connection of C4lp and C4la
H4	Vertical distance of C4um to the connection of C4lp and C4la
W4	Vertical distance of C4am to the connection of C4up and C4lp
AISC3	Anterior intervertebral space of C4-Anterior vertical distance between C4la and C5ua
PISC4	Posterior intervertebral space of C4-Posterior vertical distance between C4lp and C5up
C4 angle	Angle between line connecting C4d-C4lp and C4d -C4la
H4/W4	Ratio of H4 to W4
ABHC4/PBHC4	Ratio of ABHC4 to PBHC4
Different angulations used in the study	
Cranio-cervical angles	Angle between NSL and OPT line
	Angle between NSL and CVT line
Cranio-vertical angles	Angle between NSL and VER line
	Angle between NL and VER line
Cervico-horizontal angles	Angle between OPT line and HOR line
	Angle between CVT line and HOR line
FUSN C3-C4	Fusion of C3-C4
B FUSN	Block fusion

[Table/Fig-2]: Points, reference lines, and the measurement parameters used in the study.
C3: Third cervical vertebra; C4: Fourth cervical vertebra; Sella (S): The geometric center of the contour of the Sella turcica; Nasion (N): The most anterior point on the fronto-nasal suture in the mid-sagittal plane; cv4ip: The most posterior and inferior point of the body of the fourth cervical vertebra; cv2ip: The most infero-posterior point of 2nd vertebra; cv2sp: The most posterior and superior point of the body of the second cervical vertebra; OPT: Odontoid process tangent through cv2ip and cv2sp; CVT: Cervical vertebra tangent through cv4ip and cv2sp; VER: True vertical; HOR: True horizontal; NSL: Nasion-sella line; NL: Nasal line

The morphological anomalies of cervical vertebrae were classified based on previous studies [3,16,17]. They were divided into two categories as 'posterior arch deficiency' and 'fusion anomalies'. Posterior arch deficiency consisted of partial cleft and dehiscence, and fusion anomalies of fusion block fusion, and occipitalisation. In the present study, fusion anomalies of C3 and C4, i.e., fusion of C3 and C4 (FUSN C3-C4) and Block Fusion (B FUSN), were assessed to determine cervical vertebrae morphology in different growth patterns because of poor localisation of the entire cervical column in the lateral cephalogram.

STATISTICAL ANALYSIS

The data collected were entered into Microsoft Excel, and statistical analyses were performed using the Statistical Package for Social Science (SPSS version 10.5) software. One-way ANOVA were used to test the differences between the three groups (HR, VR, and AV). Pair-wise comparisons were done using the Least Significant Difference (LSD) test. The unpaired t-test was used to determine whether there was a statistical difference between male and female subjects in the parameters measured for each of the groups. The proportion of fusion anomalies between males and females in the three groups was assessed using the Chi-square test. The reliability of the visual assessment of the morphologic characteristics of the cervical vertebral units was determined by intraobserver examination and assessed by the Kappa coefficient. Pearson's correlation coefficient was evaluated to assess the correlation between cervico-vertebral dimensions and cranio-cervical angulations. The p-value was set at p<0.05.

RESULTS

The mean chronological age of subjects was 21.2±3.14 years for the HR group, 21.3±3.78 years for the VR group, and 21±3.76 years for the AV group. Both males and females were equally distributed in all three groups.

Cervical vertebrae dimensions: The study showed that cervico-vertebral dimension parameters ABHC3 (p=0.002), PBHC3 (p=0.015), H3 (p<0.001), W3 (p=0.004), ABHC4 (p<0.001), PBHC4 (p=0.002), H4 (p<0.001), W4 (p<0.001), area C3 (p<0.001), and area C4 (p<0.001) were significantly larger in males compared to females in the HR group. In the VR group, PBHC3 (p=0.009), H3 (p=0.016), H4 (p<0.001), area C3 (p=0.006), and area C4 (p=0.001) were significantly larger in males than females, and only ABHC3/PBHC3 (p=0.006) was significantly larger in females compared to males (p<0.05). All other cervical vertebrae dimensions were not statistically significant between males and females (p>0.05) [Table/Fig-3]. In the AV group, ABHC3 (p<0.001), H3 (p=0.002), W3 (p=0.006), ABHC3/PBHC3 (p=0.033), ABHC4 (p=0.005), PBHC4 (p=0.038), H4 (p=0.005), W4 (p=0.001), area C3 (p=0.018), and area C4 (p=0.003) were significantly larger in males than females. All other cervical vertebrae dimensions were not statistically significant between males and females [Table/Fig-3].

Parameters		n	Mean	SD	Min	Max	p-value
Horizontal group (HR)							
ABHC3	Male	17	14.44	1.356	12	16	**0.002**
	Female	17	12.85	1.344	11	15	
PBHC3	Male	17	14.97	1.615	13	18	**0.015**
	Female	17	13.62	1.453	12	18	
H3	Male	17	14.62	1.317	12	17	**<0.001**
	Female	17	12.76	1.427	11	16	
W3	Male	17	14.38	1.364	12	16	**0.004**
	Female	17	13.03	1.166	11.5	16.5	
ABHC4	Male	17	13.85	1.477	11	16	**<0.001**
	Female	17	12.21	0.902	11	14.5	
PBHC4	Male	17	14.56	1.029	13	16	**0.002**
	Female	17	13.38	0.993	12	15.5	
IDC4	Male	17	3.12	3.15	1	15	**0.138**
	Female	17	1.94	0.496	1	3	
H4	Male	17	14.35	1.332	12	17	**<0.001**
	Female	17	12.47	0.96	11	14.5	
W4	Male	17	14.42	1.393	12	16	**<0.001**
	Female	17	12.53	0.943	11.5	14.5	
Area C3	Male	17	181.38	24.083	147.22	226.48	**<0.001**
	Female	17	141.71	14.662	98.84	158.95	
Area C4	Male	17	173.84	27.609	131.84	229.32	**<0.001**
	Female	17	134.19	15.976	115.44	166.56	
Vertical group (VR)							
PBHC3	Male	17	13.71	1.076	12	15	**0.009**
	Female	17	12.71	1.032	11	15	
H3	Male	17	13.15	1.012	11.5	15	**0.016**
	Female	17	12.26	1.017	11	14	
ABHC3/ PBHC3	Male	17	0.92	0.084	0.78	1.11	**0.006**
	Female	17	1	0.074	0.88	1.15	
H4	Male	17	13.06	0.768	12	14.5	**<0.001**
	Female	17	11.97	0.856	10	13	
Area C3	Male	17	155.16	12.609	126.11	179.86	**0.006**
	Female	17	137.75	20.918	111.93	177.87	
Area C4	Male	17	148.61	14.085	126.83	176.93	**0.001**
	Female	17	129.28	17.503	103.14	165.68	

Average group (AV)							
ABHC3	Male	17	13.68	0.789	12	15	**<0.001**
	Female	17	12.12	1.364	10	15	
H3	Male	17	13.65	0.931	11.5	15	**0.002**
	Female	17	12.38	1.18	11	16	
W3	Male	17	13.59	1.406	11	17	0.006
	Female	17	12.47	0.649	11.5	13.5	
ABHC3/ PBHC3	Male	17	0.98	0.073	0.87	1.11	0.033
	Female	17	0.91	0.095	0.75	1.11	
ABHC4	Male	17	12.94	1.059	12	15	0.005
	Female	17	11.74	1.288	10	14	
PBHC4	Male	17	13.56	1.424	10	16	0.038
	Female	17	12.56	1.273	10	14.5	
H4	Male	17	12.94	1.029	11.5	15	0.005
	Female	17	11.94	0.899	10	13	
W4	Male	17	14	1.029	11.5	16	0.001
	Female	17	12.65	0.899	11.5	14	
Area C3	Male	17	160.27	32.336	98.47	224.13	0.018
	Female	17	136.71	21.978	99.62	174.22	
Area C4	Male	17	151.93	22.963	108.61	200.08	0.003
	Female	17	130.2	16.576	99.8	154.33	
Cranio-cervical angulations							
NL/VER	Male	17	86.71	4.135	80	95	0.039
	Female	17	90.00	4.770	79	98	

[Table/Fig-3]: Comparison between mean cervico-vertebral dimensions and cranio-cervical angulations between males and females in HR, VR and AV groups.
Test used: Unpaired t-test. A p-value less than 0.05 indicate statistical significance

One-way ANOVA was used to assess the differences in the cervico-vertebral dimensions between the HR, VR, and AV groups. The results showed that there were statistically significant differences between the three groups with respect to the following parameters: ABHC3 (p=0.023), PBHC3 (p=0.007), H3 (p=0.010), W3 (p=0.013), ABHC4 (p=0.010), PBHC4 (p=0.005), H4 (p=0.002), H4/W4 (p=0.048), area C3 (p=0.039), and area C4 (p=0.024) [Table/Fig-4].

Parameters	Group	Mean	SD	p-value
Cervico-vertebral dimensions				
ABHC3	HR	13.65	1.55	**0.023**
	VR	12.84	1.02	
	AV	12.90	1.35	
PBHC3	HR	14.29	1.66	**0.007**
	VR	13.21	1.15	
	AV	13.53	1.38	
H3	HR	13.69	1.64	**0.010**
	VR	12.71	1.09	
	AV	13.01	1.22	
W3	HR	13.71	1.42	**0.013**
	VR	12.84	1.06	
	AV	13.03	1.21	
ABHC4	HR	13.03	1.46	**0.010**
	VR	12.15	0.83	
	AV	12.34	1.31	
PBHC4	HR	13.97	1.61	**0.005**
	VR	13.13	1.17	
	AV	13.06	1.42	
H4	HR	13.41	1.49	**0.002**
	VR	12.51	0.973	
	AV	12.44	1.07	
H4/W4	HR	0.99	0.096	**0.048**
	VR	0.97	0.11	
	AV	0.93	0.09	
Area C3	HR	161.54	28.12	**0.039**
	VR	146.45	19.164	
	AV	148.49	29.73	
Area C4	HR	154.01	29.97	**0.024**
	VR	138.95	18.465	
	AV	141.06	22.59	
Cranio-cervical angulations				
NSL/OPT	HR	96.7	5.88	**<0.001**
	VR	104.1	7.8	
	AV	100.0	6.62	

[Table/Fig-4]: Comparing the mean cervico-vertebral dimensions and cranio-cervical angulations between HR, VR and AV groups.
Test used: One-way ANOVA. A p-value less than 0.05 indicate statistical significance

Pair-wise comparison using the LSD test found that the most significant differences were concentrated between the HR-VR and HR-AV groups. No significant difference was found between the VR-AV groups [Table/Fig-5].

Parameters	HR-VR		HR-AV		VR-AV	
Cervico-vertebral dimensions						
	Mean diff	p-value	Mean diff	p-value	Mean diff	p-value
ABHC3	0.809	**0.036**	0.750	0.056	-0.059	0.982
PBHC3	1.088	**0.006**	0.765	0.072	-0.324	0.615
H3	0.985	**0.009**	0.676	0.100	-0.309	0.612
W3	0.868	**0.014**	0.676	0.069	-0.191	0.802
ABHC4	0.882	**0.011**	0.691	0.059	-0.191	0.799
PBHC4	0.838	**0.019**	0.912	**0.010**	0.074	0.968
H4	0.897	**0.008**	0.971	**0.003**	0.074	0.966
H4/W4	0.026	0.553	0.061	**0.038**	0.036	0.321
Area C3	15.091	**0.049**	13.053	0.103	-2.038	0.944
Area C4	15.067	**0.031**	12.948	0.074	-2.120	0.930
Cranio-cervical angulations						
NSL/OPT	-7.34	**<0.001**	-3.265	0.052	4.059	**0.016**

[Table/Fig-5]: Pair-wise comparison of the cervico-vertebral dimensions and cranio-cervical angulations between the three groups using (HR, VR and AV).
Test used: LSD test. A p-value less than 0.05 indicate statistical significance

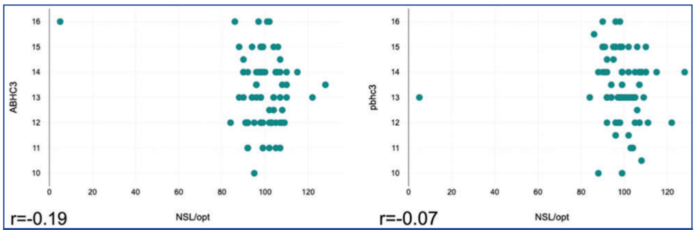
Cranio-cervical angulation: The Student's t-test did not find any statistically significant difference between males and females in HR as well as VR groups. In the AV group, the parameter NL/VER (p=0.039) was significantly higher in females than males. All other parameters did not show statistical significance [Table/Fig-3]. When comparing the cranio-cervical angulation parameters between the three groups, NSL/OPT (p<0.001) showed statistical significance [Table/Fig-4]. Pair-wise comparison using the LSD test found that the most significant differences were concentrated between the HR-VR and VR-AV groups. No significant difference was found between the HR-AV groups [Table/Fig-5].

Cervical vertebrae morphology (Fusion anomalies): There were no statistically significant differences between males and females with respect to the fusion anomalies of cervical vertebrae (FUSN C3-C4) in the HR and AV groups. However, females in the VR group (64.7%) showed higher fusion anomalies (FUSN of C3-C4) than males (17.6%), and the difference was statistically significant (p=0.005). When comparing the three groups, FUSN C3-C4 was more prevalent in the HR group (47.1%), followed by VR (41.2%), and the AV group (32.4%). However, the differences were not statistically significant. The study did not find Block Fusions (B FUSN) anomalies in any of the sample groups [Table/Fig-6].

Groups		FUSN C3-C4		Total	χ^2	p-value
		Yes	No			
HR	Male	10	7	17	1.889	0.169
		58.8%	41.2%	100%		
	Female	6	11	17		
		35.3%	64.7%	100%		
	Total	16	18	34		
		47%	52.9%	100%		
VR	Male	3	14	17	7.771	**0.005**
		17.6%	82.4%	100%		
	Female	11	6	17		
		64.7%	35.3%	100%		
	Total	14	20	34		
		41.2%	58.8%	100%		
AV	Male	7	10	17	1.209	0.271
		41.2%	58.8%	100%		
	Female	4	13	17		
		23.5%	76.5%	100%		
	Total	11	23	34		
		32.4%	67.6%	100%		

[Table/Fig-6]: Distribution of fusion of C3 and C4 (FUSN C3-C4) among the three groups in both genders.
Test used: using Chi-square test. p-values less than 0.05 is considered statistically significant

In present study, no statistically significant correlation was found between cervical vertebrae dimensions and cranio-cervical angulations [Table/Fig-7]. The reliability of the visual assessment of the morphologic characteristics of the cervical vertebral units was determined by intraobserver examination, which showed very good agreement (1.00) as assessed by the kappa coefficient.



[Table/Fig-7]: Scatter Plots for Pearson's Correlation between the Cervico-vertebral dimensions (ABHC3 and PBHC3) and Cranio-cervical angulation (NSL/OPT). The test did not show any correlation between the cervico-vertebral dimensions and cranio-cervical angulations.

DISCUSSION

Lateral cephalometric radiographs play a beneficial role in evaluating the changes that occur during orthodontic treatment and in assessment of growth [18]. Various computer programs are available to digitally capture scanned lateral cephalometric radiographs and perform many orthodontic functions, including cephalometric landmark identification and analysis, superimposition of sequential radiographs, and printing hard copies of the cephalogram, tracing, or superimposition. Recommendations by Rogers MB and Held CL et al., indicate that 75 dpi is sufficient for scanning lateral cephalograms [19,20]. In the present study, 300 dpi was used for scanning the lateral cephalogram to measure the area of the 2nd and 3rd cervical vertebrae.

In the present study, the sample consisting of 102 subjects was divided according to Jarabak's ratio and FMA angle as used earlier by Zaher AR et al., [21]. The mandibular plane angle with the Frankfort plane (FMA) is an important criterion for the assessment of the vertical facial pattern. This angle is affected by the vertical development of the alveolar process, by the mandibular ramus growth, and gonial angle [22]. According to the study by Ahmed M et al., [22], FMA is considered to be the most reliable parameter in the assessment of vertical growth. The age range of 17-35 years was selected because most growth would have been completed by that age. Bishara SE and Jokobsen JR concluded in their longitudinal study that the differences among facial types are more pronounced in adulthood [23]. The study by Karlsen AT found an association between Gonion and the C2 vertebrae body, suggesting a mutual relationship between incremental growth of the upper cervical spine and the lower face. However, they did not find any association between the dimensions of cervical vertebrae and the vertical dimension of the face up to six years, and found a weak correlation at 6-12 years [6]. Hence, the present study was done on a group of young adults with an age range of 17-35 years in order to investigate any relationship between the vertical skeletal pattern of the jaws and cervicovertebral dimension. The variables characterising cranial and facial morphology were studied in NHP digital cephalograms.

The present study revealed an overall larger dimension of the cervical vertebrae in male patients than female patients in all three groups. These findings were similar to those done by Tulsi RS [24]. However, there was no statistically significant difference between males and females regarding the cranio-cervical, craniovertical, and cervico-horizontal angles. The study by Miller CA et al., found sexual dimorphism in relation to the size, form, and shape of cervical vertebral bodies [25]. They concluded that females have larger vertebrae up to age five, but by the end of puberty, males outgrow females and this trend continues for longer. This finding was consistent with the present study as male vertebral dimensions were larger overall compared to females. The findings of the present study were also similar to a study by Gupta DD et al., where they found that an increase in the vertical dimension of the axis or second cervical vertebrae is related to severe vertical skeletal malformations [13].

The present study also found statistically significant differences in the measurements of ABHC3, PBHC3, H3, W3, ABHC4, PBHC4, H4/W4, area C3, and area C4 between the three groups, with the HR group having significantly larger values compared to the VR and AV groups. There was also a statistically significant larger cranio-cervical angle (NSL/OPT) in the VR group compared to the HR and AV groups. The findings were similar to the study by Solow B and Tallgren A [26]. They conducted a correlation study with 120 Danish male dental students aged 20-30 years and found that subjects with a large cranio-cervical angle had, on average, large anterior face heights, maxillary and mandibular retrognathism, and a large mandibular plane inclination. In a recent study by Alexa VT et al., cranio-cervical posture was assessed for various sagittal malocclusions and significant differences were found between Class II and Class III malocclusions, with patients with Class II malocclusion showing a more backward posture of the neck [11].

From the total sample, 47.1%, 41.2%, and 32.4% of the subjects had fusion of cervical vertebrae (FUSN C3-C4) in the HR, VR, and AV groups, respectively. A study by Anusuya V et al., analysed six types of cervical vertebral anomalies among patients with different sagittal and vertical growth patterns [3]. The study concluded that dehiscence, fusion anomalies, and partial cleft were the most frequently seen anomalies, while block fusion was the least common. The findings were similar to the present study, as fusion anomalies were common in the samples studied and block fusion was not observed in any patients.

Cranio-cervical posture (NSL/OPT) is related to craniofacial development. The cervico-horizontal angles {OPT/Horizontal (HOR), Craniovertebral angle (CVT)/HOR} are important in mediating large changes in the cranio-cervical relationship. Obstruction of the upper airway could lead to a postural change resulting in extension of the cranio-cervical angle through a neuro-muscular feedback mechanism. The relationship between cranio-cervical angle and malocclusion can be attributed to the soft tissue stretching mechanism [27], which describes the effect of extension of the cranio-cervical angle on the development of the face. Extension of the cranio-cervical posture leads to a passive stretching of the soft tissue layer comprising skin, muscles, and fascia that covers the head and neck. This convex soft tissue layer is stretched, producing a force that is dorsally directed, impeding the forward-directed portion of the normal growth of the face and rerouting it more caudally. It was found that extension of the head from the natural head position led to an increase in the force applied by the lips to the facial surfaces of the maxillary incisors [28]. A study by Sandoval C et al., investigated the relationship between cranio-cervical postures and sagittal malocclusions [29] and concluded that Class II malocclusions presented with a more extended head than Class III malocclusion. In a recent study by Anushka et al., various cranio-cervical angles were measured and their association with vertical growth patterns was examined [2]. They found a relationship between extended neck posture and vertical growth pattern. These findings were consistent with the results of the present study. An explanation for the connection between the fusion of the cervical column and craniofacial morphology lies in early embryogenesis. The link between the formation of the cervical vertebral column, cranial base, and craniofacial region during early embryogenesis may be explained by signaling between the notochord, para-axial mesoderm, neural tube, and neural crest [30]. Based-on the findings of the present study, the null hypothesis is rejected.

Limitation(s)

The sample size in the present study was relatively small to generalise it to a larger population. Identification of the landmarks on the 2D lateral cephalograms was hand-traced, and some errors can be expected. This can be reduced with the use of digital tracing. However, the results should be interpreted with caution due to the cross-sectional nature of the study, which does not permit inferences regarding cause and effect relationships. Further longitudinal studies are required to clarify the relationship between craniofacial development and functional aspects of head and cervical posture. Despite its limitations, the study evaluated both cervical dimensions, posture, and anomalies in vertical malocclusion in both genders. It is crucial to assess and comprehend the relationship between the cervical spine and malocclusion. This understanding is essential because during the treatment of malocclusions, modifying posture to prevent relapse and intercepting specific malocclusions can be achieved.

CONCLUSION(S)

The present study demonstrated that there were differences in cervico-vertebral morphology in subjects with different vertical skeletal patterns. Significant gender differences in cervico-vertebral dimensions were found, and males tend to exhibit larger vertebral dimensions than females. The cervical vertebral dimensions were significantly larger in individuals with a horizontal growth pattern compared to average and vertical growth patterns. The vertical growth pattern group had a larger cranio-cervical angle compared to the other groups. No differences were found between the groups in terms of cervical vertebral anomalies. These findings are considered important for the diagnosis and more accurate treatment of adults with different vertical growth patterns. It is suggested that this knowledge be incorporated into future diagnostic and orthodontic treatment planning.

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