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Comparison of Pharyngeal Widths in Different Skeletal Malocclusions and Growth Patterns in a Sample of Nepali Population

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ABSTRACT

Introduction: Conflicting results have been reported relative to the correlation of pharyngeal dimensions with different sagittal skeletal malocclusions and growth patterns.

Objective: To compare the pharyngeal widths in different sagittal malocclusions and growth patterns in Nepali population.

Materials and Method: This was an analytical cross-sectional study conducted among patients visiting Department of Orthodontics, B.P. Koirala Institute of Health Sciences after institutional ethical approval. Lateral cephalometric radiographs of 135 patients were collected using convenience sampling technique for a period of one year. Medians and Interquartile Ranges of pharyngeal widths according to McNamara airway analysis and Arnett-Gunson face-airway-bite (FAB) analysis adapted by Santiago et al. in different skeletal malocclusions and growth patterns were compared.

Result: No statistically significant difference was found in upper pharyngeal width, lower pharyngeal width, nasopharyngeal width, oropharyngeal width, hypopharyngeal width, and deep pharyngeal width in different skeletal malocclusions. Statistically significant difference was found in nasopharyngeal width ($P = 0.010$), hypopharyngeal width ($P = 0.027$), and deep pharyngeal width ($P < 0.001$) in different growth patterns that is hypodivergent versus normodivergent, and in hypodivergent versus hyperdivergent; not in normodivergent versus hyperdivergent group of patients.

Conclusion: The pharyngeal widths of patients did not show a statistically significant difference in different skeletal malocclusions. Nasopharyngeal width, hypopharyngeal width, and deep pharyngeal width showed a statistically significant difference between hypodivergent versus normodivergent; and hypodivergent versus hyperdivergent growth patterns.

Keywords: Arnett-Gunson face-airway-bite analysis; lateral cephalogram; McNamara airway analysis; pharyngeal width.

INTRODUCTION

The pharyngeal airway obstruction results in significant changes in the pattern of facial growth.[1] Correlation between upper airway dimensions and sagittal skeletal patterns are conflicting. While some studies have shown that sagittal skeletal

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malocclusion affects the upper airway size,[2-6] others have failed to demonstrate such association.[7-9] The vertical growth pattern leads to the narrowing of the pharyngeal airway.[10,11]

The rationale behind this study was the lack of studies for the comparison of pharyngeal airway widths in different skeletal malocclusions and growth patterns in Nepali population.

The primary objective of this study was to compare the pharyngeal widths in different skeletal malocclusions (class I, class II, and class III) and growth patterns (hypodivergent, normodivergent, and hyperdivergent) of Nepali population. The secondary objective was to compare the pharyngeal widths in males and females. The null hypothesis formulated was "there are no differences in pharyngeal widths between different skeletal malocclusions and growth patterns."

MATERIALS AND METHOD

This was an analytical cross-sectional study conducted in a sample of Nepali population. The inclusion criteria were patients of age group above 16 years, lateral cephalograms with clearly visible landmarks, full complement of permanent teeth up to second molar, no history of previous orthodontic treatment, and only healthy individuals with no history of previous pharyngeal pathologies. The exclusion criteria were temporomandibular abnormalities, any craniofacial surgery, and history of craniofacial trauma. The patients were recruited at the Department of Orthodontics, B.P. Koirala Institute of Health Sciences using non-probability, convenience sampling for one year. The study was conducted after getting ethical approval from Institutional Review Committee (Ref. IRC/1704/019 – ACD/393/077/078). Informed consent was taken before initiating the study from all participants.

The definition of parameters/variables to be measured were defined as given below (Figure 1):

Upper airway width (mm) = Measured from point on posterior outline of soft palate to closest point on posterior pharyngeal wall, taken on anterior half of soft palate outline.

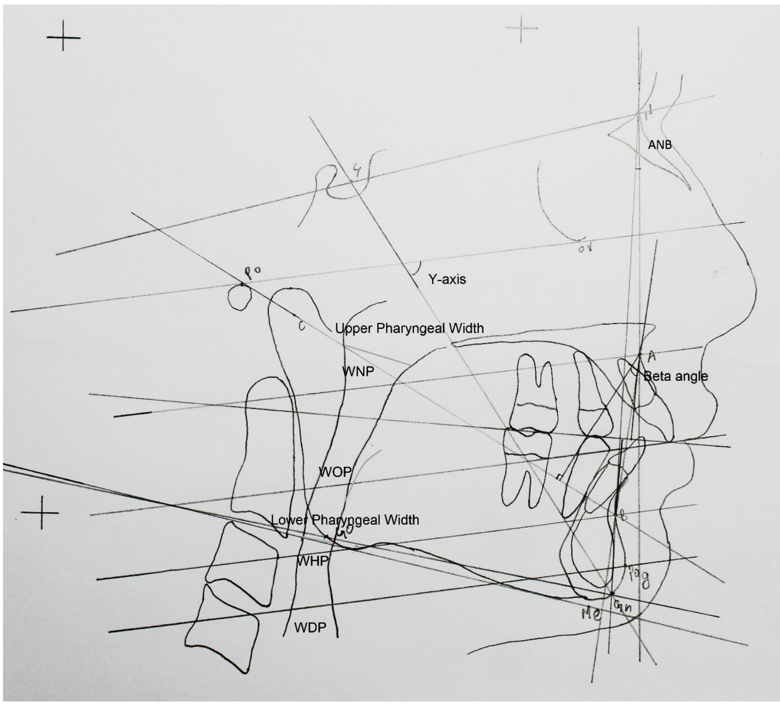

Figure 1: Anatomical landmarks and parameters to be measured.

Lower airway width (mm) = Measured from intersection of posterior border of tongue and inferior border of mandible to closest point on posterior pharyngeal wall.

Nasopharyngeal (WNP) width (mm) = Measured by drawing a line parallel to Frankfort Horizontal Plane (FHP) that passed through point A crossing the points of anterior and posterior walls of the pharyngeal airway.

Oropharyngeal (WOP) width (mm) = Measured by drawing a line parallel to FHP that passed through upper central incisor edge crossing the points of anterior and posterior walls of the pharyngeal airway.

Hypopharyngeal (WHP) width (mm) = Measured by drawing a line parallel to FHP that passed through point B crossing the points of anterior and posterior walls of the pharyngeal airway.

Deep pharyngeal (WDP) width (mm) = Measured by drawing a line parallel to FHP that passed through point Pog crossing the points of anterior and posterior walls of the pharyngeal airway.

Lateral cephalometric radiographs were taken in centric occlusion with patients' Frankfort horizontal plane parallel to the floor. After 21 radiographic tracings, that were 15% of the sample size, they were retraced after two weeks to determine the errors associated with radiographic measurements. After normality test, Dahlberg's formula ($Se^2=\Sigma d^2/2n$) was used to calculate the casual error and a dependent t-test at $P < 0.05$ was used for measurement of systematic error in locating cephalometric landmarks and variables measured.

The outcome measures were Upper pharyngeal width and Lower pharyngeal width (McNamara);[12] and Nasopharyngeal width (WNP), Oropharyngeal Width (WOP), Hypopharyngeal width (WHP), and Deep pharyngeal Width (WDP), the Arnett-Gunson face-airway-bite (FAB) adapted by Santiago et al. who used Dolphin Imaging Software for the measurement of pharyngeal widths, however, in this study, the hand-tracing method was used.[13,14]

The primary outcome measure used to calculate the sample size was pharyngeal widths in different growth patterns in a skeletal malocclusion. In a similar study,[7] mean widths of upper pharyngeal airway in normal and vertical growth pattern in skeletal class I malocclusion obtained was 12.58±2.04 mm and 9.33±3.9 mm respectively. With probability of significance of 95% and power of 80%, the estimated samples using two mean formula was 13.2 (≈15) in each growth pattern (hypodivergent, normodivergent, and hyperdivergent) in a skeletal malocclusion that were 45 in each skeletal malocclusion (class I, II, and III); thus making a total sample size of 135.

Lateral cephalogram done by the patients for orthodontic treatment were collected for cephalometric analysis. Total samples were divided into three groups, class I, class II, and class III depending upon Steiner's ANB angle, Wits appraisal AO-BO, and Beta angle (Table 1). Also total samples were divided into hypodivergent, normodivergent, and hyperdivergent groups based on Frankfort mandibular plane angle (FMA), SN-GoGn, and Y-axis angle (Table 1). Data collected were entered into Microsoft Excel 2013 and transferred into SPSS Statistics for Windows, version 11.5 (SPSS Inc., Chicago, Ill., USA) for statistical analysis. For intraobserver reliability, 21 samples were traced first and retraced in two weeks. The test for the normality of distribution of variables was done by Shapiro-Wilk test. In each group, Medians and Interquartile Ranges (IQRs) of age and upper and lower pharyngeal widths, WNP, WOP, WHP, and

WDP were determined. The comparison of upper and lower pharyngeal widths, WNP, WOP, WHP, and WDP in different skeletal malocclusions (Table 2) and growth patterns (Table 3) were done by Kruskal-Wallis test, followed by Mann-Whitney U (z-test) test for intergroup comparisons at P <0.05 (Table 4). The intergroup comparisons of upper and lower pharyngeal widths, WNP, WOP, WHP, and WDP between males and females were done by Mann-Whitney U test (Table 5).

RESULT

Number of patients in skeletal Class I, Class II, and Class III groups were 48, 45, and 42 respectively; in hypodivergent, normodivergent, and hyperdivergent groups were 33, 72, and 30 respectively. Shapiro-Wilk test for 21 samples showed normal distribution of variables. Dalberg's error of first 21 radiographic tracings for linear measurement ranged from 0.27 mm to 0.46 mm whereas angular measurement ranged from 0.31° to 0.62°. A dependent t-test showed no statistically significant difference between the first and second measurements at P <0.05.

After radiographic tracing of 135 samples, Shapiro-Wilk test showed non-normal distribution of variables except Beta angle, FMA, and Y-axis. Medians and IQRs of upper pharyngeal width, lower pharyngeal width, nasopharyngeal width, oropharyngeal width, hypopharyngeal width, and deep pharyngeal width in different skeletal malocclusions (Table 2). Medians and IQRs of upper pharyngeal width, lower pharyngeal width, nasopharyngeal width, oropharyngeal width, hypopharyngeal width, and deep pharyngeal width in hypodivergent, normodivergent, and hyperdivergent growth pattern were measured (Table 3). Mann-Whitney U test (z-test) showed statistically significant difference in nasopharyngeal width, hypopharyngeal width, and deep pharyngeal width in hypodivergent versus normodivergent groups of patients and hypodivergent versus hyperdivergent groups of patients but not in normodivergent versus hyperdivergent groups of patients (Table 4). Kruskal-Wallis test did not show a statistically significant difference in age (P = 0.197) in males and females. Also, Mann-Whitney U test showed no statistically significant difference in pharyngeal airway widths in males and females (Table 5).

Table 1: Division of samples into Class I, Class II, and Class III based on Steiner's (ANB) angle, Wits appraisal (AO-BO), and ß angle and division of samples into Hypodivergent, Normodivergent, and Hyperdivergent based on FMA, SN-GoGn and Y-axis.

	Steiner's ANB in degree (°)	Wits appraisal in mm (AO-BO)	ß angle in °
Class I	2°±2°	-1 for male 0 for female	27°-35°
Class II	>4°	>-1 for male >0 for female	<27°
Class III	<0°	<-1 for male <0 for female	>35°
	FMA (°)	**SN-GoGn (°)**	**Y-axis (°)**
Hyperdivergent	>28°	>36°	>66°
Normodivergent	22°-28°	28°-36°	53°-66°
Hypodivergent	<22°	<28°	<53°

Table 2: Medians and Inter Quartile Ranges (IQRs) of age, pharyngeal widths, and results of Kruskal-Wallis test in different skeletal malocclusions.

	Class I	Class II	Class III	P
	Median (IQR)	Median (IQR)	Median (IQR)	
Age (years)	22.00 (19 to 25)	21.00 (17 to 25)	22 (18 to 24)	0.430
Upper pharyngeal width (mm)	17.00 (14 to 19)	16.00 (14 to 19.5)	18.00 (16 to 19)	0.610
Lower pharyngeal width (mm)	9.00 (8 to 11)	9.00 (8 to 11)	9.00 (8 to 10.25)	0.983
Nasopharyngeal width (mm)	15.00 (13 to 17)	15.00 (12 to 18.5)	14.00 (12 to 18.25)	0.934
Oropharyngeal width (mm)	9.00 (8 to 11)	10.00 (8 to 12)	10.00 (8 to 11)	0.753
Hypopharyngeal width (mm)	9.00 (8 to 11)	10.00 (8.5 to 11)	9.00 (8 to 11)	0.402
Deep pharyngeal width (mm)	11.00 (9.25 to 13)	12.00 (9 to 14.5)	11.00 (9.75 to 13)	0.837

Statistically significant at P <0.05

Table 3: Medians and IQRs of age, pharyngeal widths, and results of Kruskal-Wallis test in different growth patterns.

	Hypodivergent	Normodivergent	Hyperdivergent	P
	Median (IQR)	Median (IQR)	Median (IQR)	
Age (years)	23.00 (20 to 25)	22.00 (18 to 25)	20.00 (16 to 23.25)	0.142
Upper pharyngeal width (mm)	18.00 (15 to 19.5)	17.00 (14 to 19)	16.50 (13.75 to 18)	0.493
Lower pharyngeal width (mm)	9.00 (8 to 9.5)	9.00 (8 to 11)	9.00 (7 to 11)	0.608
Nasopharyngeal width (mm)	17.00 (13 to 20.5)	15.00 (12 to 17)	13.50 (12 to 16)	0.010
Oropharyngeal width (mm)	9.00 (8 to 11.5)	10.00 (8 to 11)	10.00 (7.75 to 12)	0.894
Hypo pharyngeal width (mm)	9.00 (8 to 9.5)	10.00 (8.25 to 11.75)	10.00 (8 to 12.25)	0.027
Deep pharyngeal width (mm)	10.00 (8 to 11)	12.00 (10 to 14)	13.00 (10.75 to 15)	<0.001

Statistically significant at P <0.05

Table 4: Significance of pharyngeal airway widths between the groups of different growth patterns by Mann-Whitney U test.

Comparisons	Airway Width (mm)	z-test	P
Hypodivergent Versus Normodivergent	Upper pharyngeal width	-0.968	0.333
	Lower pharyngeal width	-0.961	0.336
	Nasopharyngeal width	-2.629	0.009
	Oropharyngeal width	-0.303	0.762
	Hypopharyngeal width	-2.348	0.019
	Deep pharyngeal width	-3.884	<0.001
Hypodivergent Versus Hyperdivergent	Upper pharyngeal width	-1.101	0.271
	Lower pharyngeal width	-0.690	0.490
	Nasopharyngeal width	-2.652	0.008
	Oropharyngeal width	-0.409	0.682
	Hypopharyngeal width	-2.440	0.015
	Deep pharyngeal width	-3.546	<0.001
Normodivergent Versus Hyperdivergent	Upper pharyngeal width	-0.388	0.698
	Lower pharyngeal width	-0.293	0.770
	Nasopharyngeal width	-0.779	0.436
	Oropharyngeal width	-0.318	0.750
	Hypopharyngeal width	-0.456	0.649
	Deep pharyngeal width	-1.017	0.309

Statistically significant at P <0.05

Table 5: Medians and IQR of age, pharyngeal widths, and results of Mann-Whitney U test in males and females.

	Male	Female	Total	P
	Median (IQR)	Median (IQR)	Median (IQR)	
Age (years)	21.00 (17 to 25)	23.00 (19 to 25)	22.00 (18 to 25)	0.197
Upper pharyngeal width (mm)	16.50 (14 to 19)	18.00 (15 to 19)	17.00 (14 to 19)	0.238
Lower pharyngeal width (mm)	9.00 (8 to 11)	9.00 (8 to 11)	9.00 (8 to 11)	0.904
Nasopharyngeal width (mm)	14.00 (12 to 18)	15.00 (13 to 17.5)	15.00 (12 to 18)	0.231
Oropharyngeal width (mm)	10.00 (8 to 11.25)	10.00 (8 to 11)	10.00 (8 to 11)	0.759
Hypopharyngeal width (mm)	10.00 (8 to 11.25)	9.00 (8 to 11)	9.00 (8 to 11)	0.385
Deep pharyngeal width (mm)	11.50 (9 to 14)	11.00 (9 to 13)	11.00 (9 to 13)	0.546

Statistically significant at P <0.05

DISCUSSION

Current study included 135 patients meeting the inclusion criteria. Lateral cephalogram is the frequently prescribed radiograph before the commencement of orthodontic treatment.[15,16] So this radiograph was used in current study for the outcome assessment. Although the lateral cephalogram provides a two-dimensional image of the pharyngeal airway, the study by Vizzotto et al.,[16] and Major et al.,[15] showed good correlation for airway measurements between lateral cephalograms and cone beam computed tomography (CBCT) records. Thus lateral cephalograms are considered excellent screening tools to determine the need for more rigorous ear-nose-throat (ENT) follow-up.

The adenoids which are found in pharynx,[17] attain their maximum bulk between the ages of nine years and 15 years and thereafter show subsequent atrophy.[18] Thus to eliminate the influences of growth and ageing, this study included subjects above 16 years. McNamara's airway analysis,[12] was used in present study because it was relatively easy and simple method. Arnett-Gunson,[14] initially was designed for FAB treatment planning for the simultaneous correction of facial, airway, and bite abnormalities in orthognathic surgery. This analysis helps to compare the pharyngeal airway widths before and after orthognathic surgery. It was used in this study because it is based on the hard tissue landmarks which are relatively easy to identify than soft tissue landmarks in lateral cephalogram.

Pharyngeal widths comparison in different skeletal malocclusions: In this study, no significant difference was found in pharyngeal widths among the three different skeletal malocclusion groups. Oh et al.,[19] de Freitas et al.,[7] Memon et al.,[8] Kapoor et al.,[9] reported similar findings to present study. However, present study was in contradiction to findings of Martin et al.,[3] Alves et al.,[4] Eslamian et al.,[5] and Iqbal et al.,[6] and Yousif.[20] Alves et al.,[4] reported that the dimensions of pharyngeal airway space were statistically larger in group I ($2^{\circ} \leq$ ANB $\leq 5^{\circ}$) than in group II (ANB $>5^{\circ}$). This disagreement could be because their study sample included children of the mean age of 9.16±0.64 years and CBCT scans were used to compare the pharyngeal airway space amongst different skeletal patterns. Kirjavainen and Kirjavainen,[21] reported a narrower upper airway structure in Class II malocclusion, and their cervical headgear treatment resulted in an increase in the retropalatal space with the conversion into Class I. This contrasting result with current study could be because they randomly selected subjects without concern about adenoids and tonsils. Grauer et al.,[22] reported partial agreement with present study as they showed statistically significant difference in the volume of inferior component of the airway for the Class II subjects from Class I and Class III but there was no difference between Class I and Class III in CBCT records and no significant difference in the volume of the superior component of the airway.

Ize-Iyamu,[2] was in agreement with this study regarding upper airway width but was in disagreement regarding lower airway width who reported skeletal Class II with the narrowest upper airway width, and skeletal Class III with the narrowest lower airway width but present study showed largest upper pharyngeal width in skeletal Class III, followed by Class I and Class II, and lower pharyngeal width was equal in skeletal Class I, Class II, and Class III. Yousif reported a highly significant difference in upper and lower pharyngeal widths between Class II division 1 mandibular deficiency and maxillary prognathism.[20] A significant difference was found in lower pharyngeal width between

Class II division 1 maxillary prognathism and Class III. This disagreement could be because maxillary prognathism, mandibular deficiency, maxillary deficiency, and mandibular prognathism was not considered in current study during the division of groups.

Few studies measured the pharyngeal airway widths at different point levels using Arnett-Gunson FAB analysis. In this study, no statistically significant difference was found in nasopharyngeal width, oropharyngeal width, hypopharyngeal width, and deep pharyngeal width in different skeletal malocclusions which is in accordance with findings by Lopatiene et al.[23]

Pharyngeal widths comparison in different growth patterns: The median (IQR) nasopharyngeal width was smallest for hyperdivergent that is 13.5 (12 to 16) mm. The lowest median (IQR) nasopharyngeal width in hyperdivergent group may be because of downward and backward positioning of mandible which could lead to posteriorly postured tongue, maxillary deficiency, mandibular deficiency, or vertical maxillary excess or could also be a compensatory mechanism. Thus reduction of pharyngeal airway in hyperdivergent patients cannot be attributed only due to large adenoids and only the speculations for the cause of such association could be made.[11] For the definitive diagnosis of the cause, a more detailed clinical ENT examination as well as other diagnostic procedures need to be carried out to reach out for conclusion. Current study showed narrower nasopharyngeal width in hyperdivergent group than hypodivergent and normodivergent groups which is similar to Eslamian et al.,[5] who reported that size of nasopharynx (PNS-UPW), oropharynx (U-MPW), and hypopharynx (V-LPW) significantly smaller in subjects with hyperdivergent facial patterns compared to hypodivergents.

Present study was not in agreement with Freitas et al.,[7] Ansar et al.,[24] Ucar et al.,[11] regarding upper pharyngeal width; Batool et al.,[25] who reported subjects with Class II malocclusions and vertical growth patterns have significantly narrower upper and lower pharyngeal airways than those with Class II malocclusions and horizontal growth patterns. Memon et al.,[8] reported a statistically significant narrow upper pharyngeal airway width in hyperdivergent facial patterns as compared to normodivergent and hypodivergent facial patterns. Also, they reported no statistically significant difference in lower pharyngeal airway widths in various vertical facial patterns. Kapoor et al.,[9] reported patients with Class I and Class II malocclusions and vertical growth patterns had significantly narrower upper pharyngeal airway than those with normal or horizontal growth patterns. Iqbal et al.,[6] reported a significant correlation between upper and lower pharyngeal widths and facial skeletal patterns that is horizontal and vertical growth patterns. The difference of upper pharyngeal airway width was narrower in long faces in comparison to short faces. These findings contradicted current study which could be because of racial, and ethnic differences in Asians, Europeans, Americans, and Africans.[26] Joseph et al.,[10] reported hyperdivergent group had a narrower anteroposterior pharyngeal dimension than the normodivergent control group in the nasopharynx at the level of the hard palate and in the oropharynx at the level of the tip of the soft palate and the mandible. The findings of current study were not in agreement with this study as current study showed no statistically significant difference in pharyngeal widths in normodivergent versus hyperdivergent groups of patients which could be because of differences in methods of measurements. Yousif,[20] reported the hyperdivergent growth patterns with the statistically narrower pharyngeal airway width than normal and hypodivergent growth pattern in class II division 1 group. This study contradicts this finding which could be because maxillary prognathism, mandibular deficiency, maxillary deficiency, and mandibular prognathism were not considered during division of groups in present study.

The findings of this study were in partial agreement with Lopatiene et al.,[23] who reported no statistically significant difference in nasopharyngeal, oropharyngeal, hypopharyngeal, and deep pharyngeal widths in different growth patterns whereas we found a statistically significant difference in nasopharyngeal, hypopharyngeal, and deep pharyngeal widths in different growth patterns

Pharyngeal widths comparison in males and females: The pharyngeal widths showed no statistically significant difference between males and females which was not in agreement with Grauer et al.,[22] Ize-Iyamu,[2] and Yousif.[20] Brooks and Strohl,[26] found larger pharynx in males than in females. This may be because they measured the pharyngeal cross-sectional area during the quiet breathing using the acoustic pulse technique.

Peltomaki,[27] has stated that the normal pharyngeal airway is important to promote normal facial development. Thus the decreased pharyngeal airway in patients observed cephalometrically could serve as a "red flag" and if indicated the patient should be examined medically to determine if true airway impairment is present.

The pharyngeal width varies among various races.[26] In this study, the racial difference among the samples were not considered. Present study included a two-dimensional cephalometric radiograph which may not represent the accurate pharyngeal airway width.[16] Hence to reduce the error, three-dimensional CBCT, magnetic resonance (MRI) or other more accurate measures like fluoroscope may be used in further studies.

CONCLUSION

Thus the null hypothesis was not completely rejected. The conclusions of the study were that the pharyngeal widths did not show a statistically significant difference in different skeletal malocclusions; nasopharyngeal width, hypopharyngeal width, and deep pharyngeal width showed a statistically significant difference between hypodivergent versus normodivergent and hypodivergent versus hyperdivergent growth patterns; nasopharyngeal width, hypopharyngeal width, and deep pharyngeal width did not show a statistically significant difference between normodivergent versus hyperdivergent growth pattern; upper pharyngeal width, lower pharyngeal width, oropharyngeal width did not show a statistically significant difference in different growth patterns; and the pharyngeal widths did not show a statistically significant difference in males and females.

The recommendation of this study would be to compare the pharyngeal widths in a particular race of Nepal. For the generalisation of results, multicentre study can be carried out in the future.

Conflict of interest: None.

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