Original Article

The association between soft palate shape and Need's ratio in various sagittal skeletal malocclusions: A digital lateral cephalometric study

ABSTRACT

Aim: The present study was aimed to investigate the variation of soft palate morphology and Need's ratio in various sagittal skeletal malocclusions.

Materials and Methods: The study was conducted on 300 individuals (aged 15–25 years) who presented to the department of orthodontics for orthodontic treatment. The participants were divided into skeletal Class I, II, and III based on ANB angle on the lateral cephalogram. The soft palate morphology was examined and individuals were grouped into six types. The Need's ratio was calculated for all the participants by division of pharyngeal depth by soft palate length. The results were then subjected to statistical analysis to find the association between morphological variants of soft palate and skeletal malocclusions.

Results: The most common type of soft palate was leaf shaped and the least common was S shaped. Leaf-shaped soft palate was the most common in males and rat tail-shaped soft palate was common in females. Individuals with skeletal Class I malocclusion were most frequently found to have leaf-shaped soft palate, skeletal Class II malocclusion had rat tail type, and skeletal Class III had leaf shape and crooked shape in equal proportions. Need's ratio was maximum in skeletal Class III and minimum in Class II malocclusions.

Conclusions: There was a significant correlation between the variants of soft palate and the types of skeletal malocclusion in North Indian individuals. The knowledge of morphological variants of soft palate helps the clinician in etiological study of obstructive sleep apnea syndrome, snoring, and other conditions.

Keywords: Malocclusion, morphology, radiography, soft palate

INTRODUCTION

The soft palate is the fibromuscular part of the palate that is attached to the posterior edge of the hard palate, sloping down and back between the oral and nasal parts of the pharynx. It is a thick fold of mucosa enclosing an aponeurosis, muscular tissue, vessels, nerves, lymphoid tissue, and mucus glands.[1] It participates in most of the oral functions, especially velopharyngeal closure which is related to the normal functions of sucking, swallowing, blowing, and pronunciation.[2] Soft palate anomalies are frequently seen in patients with cleft lip and palate, enlarged adenoids, obstructive sleep apnea syndrome (OSAS), snoring, poorly retained maxillary denture, and skeletal craniofacial malocclusion.[2,3] Hence, the normal anatomy and any other anomaly of soft palate can help in the diagnosis and successful treatment of some intricate cases.

Eenal Bhambri, Varun Ahuja, Sachin Ahuja, Gautam Bhambri[1], Amit Choudhary[2], Suruchi Sukhija[3]

Departments of Orthodontics, [1]Oral Pathology and [3]Pedodontics, Surendera Dental College and Research Institute, Sri Ganganagar, Rajasthan, [2]Department of Orthodontics, Institute of Dental Sciences, Sehora, Jammu and Kashmir, India

Address for correspondence: Dr. Eenal Bhambri, Department of Orthodontics, Surendera Dental College and Research Institute, H. H. Gardens, Powerhouse Road, Sri Ganganagar - 335 001, Rajasthan, India.
E-mail: dreenal700@gmail.com

Access this article online	
Website: www.orthodrehab.org	Quick Response Code
DOI: 10.4103/ijor.ijor_41_17	

How to cite this article: Bhambri E, Ahuja V, Ahuja S, Bhambri G, Choudhary A, Sukhija S. The association between soft palate shape and Need's ratio in various sagittal skeletal malocclusions: A digital lateral cephalometric study. Int J Orthod Rehabil 2018;9:8-13.

Numerous studies have been done in the past toward the dimensional analysis of soft palate and its surrounding structures, but little attention has been paid toward the morphological variants of soft palate and its configuration. By observing the image of soft palate on lateral cephalograms, You *et al*.[3] classified the soft palate into six morphological types (Type 1: leaf shaped/lanceolate shaped in which the middle portion of the soft palate was elevated to both the naso and oro sides; Type 2: rat tail shaped in which the soft palate showed inflated anterior portion and free margin with an obvious coarctation; Type 3: butt-like shaped which showed a shorter and fatter velum appearance with no distinct difference of width of the anterior portion to the free margin; Type 4: straight line shaped; Type 5: S-shaped/distorted soft palate; and Type 6: crook shaped) [Figure 1]. Pépin *et al*.[4] observed that the "hooked or S-shaped" appearance of the soft palate in awake patients indicated a high risk of OSAS.

The soft palate plays a major role in velopharyngeal closure, which refers to the normal apposition of soft palate with posterior and lateral pharyngeal walls. Previous reports have shown that the velopharyngeal function can be assessed by the relationship between velar length (VL) and pharyngeal depth (PD) and this ratio of PD/VL is termed as Need's ratio. Subtelny[5] first reported that the Need's ratio ranged from 0.6 to 0.7 in normal individuals, and if it was more than 0.7, the condition demonstrated a risk of Velopharyngeal insufficiency (VPI). Studies reported that this ratio was of prime importance in speech resonance and there was a significant correlation between craniofacial growth changes and changes in resonance during puberty that might be influenced by both dentofacial orthopedics and maxillary surgery.[6,7] Haapanen *et al*.[8] reported that 27% of cleft lip and palate patients who underwent maxillary advancement surgery showed a reduced velopharyngeal function; they explained this situation by the advancement of the posterior border of the hard palate as a result of maxillary advancement.

Malocclusion can present itself in numerous ways and is frequently seen in patients with cleft lip and palate, enlarged adenoids, OSAS, and snoring. In sagittal plane, it is classified as skeletal Class I, Class II, and Class III depending on the relative positioning of jaw bases.

Correlation of shapes of soft palate in different Angle's malocclusions was studied by Samdani[9] which showed that Angle's Class I malocclusion was most frequently found to have rat tail-type soft palate (58.3%), Angle's

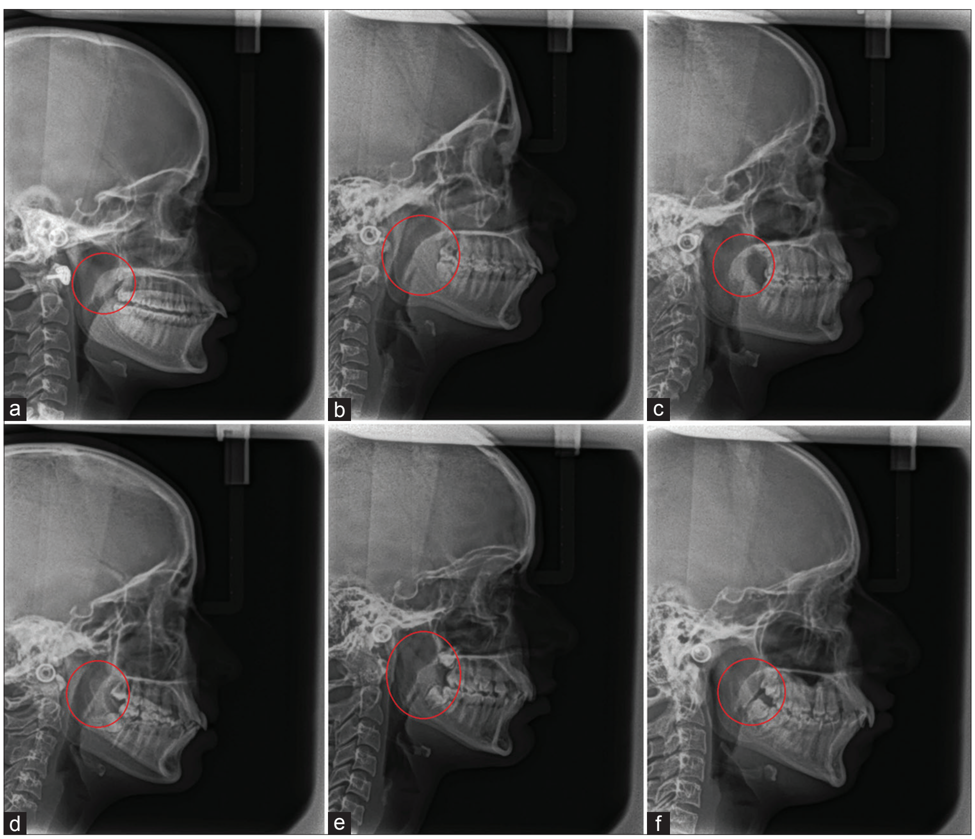

Figure 1: Various morphological types of soft palate seen on lateral cephalograms. (a) Type 1, i.e. leaf-shaped soft palate, (b) Type 2, i.e. rat tail-type soft palate, (c) Type 3, i.e. butt-like soft palate, (d) Type 4, i.e. straight line-type soft palate, (e) Type 5, i.e. S-shaped soft palate, (f) Type 6, i.e. crook-shaped soft palate

Class II had leaf-shaped soft palate (36.71%), and Angle's Class III had crook-shaped soft palate (35.71%). However, the skeletal malocclusion was not considered despite that the shape of soft palate depends on the jaw and posterior teeth positioning. Hence, the aim of the study was to find association between various morphological types of soft palate and sagittal skeletal malocclusions.

MATERIALS AND METHODS

The study was carried out on patients visiting the department of orthodontics and dentofacial orthopedics for orthodontic treatment. A total of 300 individuals in the age range of 15–25 years, requiring lateral cephalogram for orthodontic treatment, were selected for the study. Informed written consent was obtained from each individual and ethical clearance was obtained from the hospital's Institutional Ethics Committee (SDCRI/IEC/2015/015 dated 04.12.15). All the individuals met the following exclusion criteria following which 14 individuals were excluded from the sample.

- Individuals with cleft lip and palate
- A history of chronic mouth breathing or snoring
- A history of tonsillectomy or adenoidectomy.

Lateral cephalograms were exposed with the patients standing upright in a natural head position and were instructed to contact their molars and breathe through their nose using the same digital radiographic machine (Kodak 8000C, Carestream Health Inc., Rochester, NY, USA). A tube potential of 82 kV, a tube current of 10 mA, and an exposure time of 500 ms were used to optimize the contrast of the digital images.

On all the lateral cephalogram films, analyses were performed, and based on sagittal skeletal pattern, they were categorized into three groups: skeletal Class I (ANB 0°–4°), skeletal Class II (ANB >4°), and skeletal Class III (ANB <0°). Shape of the soft palate as given by You *et al*.[3] was determined for each patient. The VL was evaluated by measuring the linear distance from the posterior nasal spine to the tip of the uvula of the resting soft palate. The PD was noted as a linear distance from the posterior surface of the nasal spine marker to the posterior pharyngeal wall along the palatal plane. The measurements were carried out for each digital radiograph and the Need's ratio was calculated by the division of PD by VL. All the measurements were done twice by the same examiner and the obtained mean value was considered.

Statistical analysis

All the collected data were analyzed using the IBM SPSS Statistics 23.0 Data Editor software (Version 23.0, IBM Corp., Armonk, NY, USA). A cross-tab was composed by dividing the individuals based on (1) the type of skeletal malocclusion and (2) the shape of soft palate. Chi-square test and one-way ANOVA were used to evaluate the relationship among the variables in the cross-tabs.

RESULTS

The lateral cephalograms were divided into three categories: skeletal Class I malocclusion, Class II malocclusion, and Class III malocclusion. The malocclusions were insignificantly correlated ($P \geq 0.05$) among both the genders. Class II malocclusion was the most common (44.1%) among both genders, followed by Class I (39.9%) and Class III (16.1%) which was the least prominent type [Table 1].

By observing the shapes of soft palate on digital lateral cephalograms in our study, it was revealed that 46.2% of cases had Type I, i.e. leaf-shaped type of soft palate, 34.6% of cases had Type II, i.e. rat tail-shaped type of soft palate, 2.4% cases had Type III, i.e. butt type of soft palate, 8.7% cases had Type IV, i.e. straight line type of soft palate, 1.7% cases had Type V, i.e. distorted S-shaped type of soft palate, and 6.3% of the cases had Type VI, i.e. crooked type of the soft palate [Table 2]. The correlation between both the genders with the shapes of soft palate and types of malocclusion was done using *t*-test. The shapes of soft palate were significantly correlated ($P \leq 0.05$) among both the genders. The frequency of rat tail type of soft palate was seen in highest proportion (58.3%) in females and the leaf-shaped type of soft palate was seen in highest proportion (47.4%) in males, whereas the frequency of distorted S-shaped soft palate was the least in both males (1.4%) and females (2%) [Table 2].

Table 1: Gender distribution among skeletal malocclusion types

Type of skeletal malocclusion	Gender distribution			Frequency (%)	χ^2	*P*
	Male	Female	Total			
Skeletal Class I	55	59	114	39.9	0.452	0.798
Skeletal Class II	62	64	126	44.1		
Skeletal Class III	20	26	46	16.1		
Total	137	149	286			

$P > 0.05$ – nonsignificant

Table 2: Gender distribution among various soft palate types

Soft palate shapes	Gender distribution			Frequency (%)	χ^2	*P*
	Male	Female	Total			
Leaf shaped	45	87	132	34.6	32.506	<0.01*
Rat tail shaped	65	34	99	46.2		
Butt like	2	5	7	2.4		
Straight line	18	7	25	8.7		
Distorted S shaped	2	3	5	1.7		
Crooked	5	13	18	6.3		
Total	137	149	286	100		

*$P < 0.05$ – significant

Comparison between the type of malocclusion and the frequency of shapes of soft palate revealed that Type I, i.e. leaf-shaped soft palate (57.8%), was the most frequent in skeletal Class I malocclusion, Type II, i.e. rat tail type of soft palate (55.5%), was most frequently found in skeletal Class II malocclusion, and in skeletal Class III malocclusions, Type 1, i.e. leaf shaped, and Type 6, i.e. crooked type of soft palate, were found in equal proportions (26.1%) [Table 3].

A significant association between morphological types of the soft palate and Need's ratio was observed, with the Need's ratio being the lowest in Type 2 and the highest in Type 5 velar morphology [Table 4]. Mean Need's ratios were significantly correlated among various sagittal skeletal malocclusions. Need's ratio was maximum in skeletal Class III (0.75) and minimum in skeletal Class II (0.67) malocclusions [Table 5].

DISCUSSION

Normal respiration is dependent on sufficient anatomic dimensions of the airway. In the recent years, studies have been done concluding that variations in skeletal pattern could predispose to upper airway obstruction.[10] The dimensional analysis of the soft palate and its surrounding structures, especially the VL and width, has also been studied; nevertheless, the variety of velar morphology which is the most logical cause of different dimensions on the soft palate has been frequently overlooked. Even after closure of the soft-tissue defect in cleft patients, normal function of the soft palate is frequently not achieved and velopharyngeal insufficiency (VPI) with hypernasal speech ensues in 30% or more of patients.[5,7] Cohen *et al*.[11] suggested that one of the several explanations for this surgically successful yet functionally compromised repair may be the difference in morphology of the soft palate and other associated structures in these patients from that of normal individuals. Hence, presurgical evaluation of soft palate morphology will aid in the success of surgery.

Table 3: Soft palate type distribution among skeletal malocclusion types

Type of soft palate	Skeletal malocclusion			*P*
	Skeletal Class I	Skeletal Class II	Skeletal Class III	
Leaf like	66	51	12	0.004*
Rat tail	22	70	10	
Butt like	2	3	2	
Straight	18	0	7	
Distorted S	2	0	3	
Crooked	4	2	12	
Total	114	126	46	

*$P \leq 0.05$ – significant

The lateral cephalogram is the most common diagnostic radiograph used in clinical orthodontics, and cephalometric analysis is a commonly accepted technique for evaluation of soft palate in both normal individuals and in those with cleft palate and OSAS because of its easy availability, cost-effectiveness, and relatively good assessment of soft tissue and its surrounding structures with reduced radiation exposure.[12] A digital radiographic technique is used in the study as it enables the technician to take the image from the posterior to the anterior portion in the sagittal plane. Further, professional software is used to enhance and elicit the velar morphology by adjusting the contrast.[13] The age range of the individuals chosen for the study was 15–25 years to ensure that the pharyngeal structures had reached adult size.[14]

In addition, head posture has been suggested to influence the dimensions of the pharyngeal airway passage.[15] Thus, in order to eliminate those effects, patients were kept in standing position with the head erect and with the Frankfort horizontal plane parallel to the floor during cephalogram exposure.

The ANB angle, which is most commonly used in the determination of anteroposterior dentofacial discrepancy, was used to classify the individuals according to their skeletal configuration.[16] Ishikawa *et al*.[17] reported that it is reliable for determining the anteroposterior relationship of the jaws. This segregation of individuals was preferred as the shape of soft palate depends on the jaw positioning and posterior teeth positioning.

In the present study, Type 1, i.e. leaf-like type was the most frequent velar morphology, which was in accordance with You *et al*.,[3] Kumar and Gopal,[18] Deepa *et al*.,[19] Verma *et al*.,[13] and Santosh *et al*.[20] Samdani[9] and Agrawal *et al*.[21] found rat tail type to be the most frequent and the difference can be attributed to the different population groups. Patients with

Table 4: Correlation of mean Need's ratio with skeletal malocclusions

Type of skeletal malocclusion	Mean soft palate length	Mean pharyngeal depth	Mean Need's ratio	SD	*P*
Skeletal Class I	30.99	22.31	0.72	0.15	0.006*
Skeletal Class II	32.42	21.72	0.67	0.14	
Skeletal Class III	30.54	22.90	0.75	0.12	

*$P \leq 0.05$ – significant. SD: Standard deviation

Table 5: Correlation of mean Need's ratio with morphological types of soft palate

Variables	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	*P*
Soft palate length	30.66	32.74	30.21	30.54	30.91	30.58	<0.01*
Pharyngeal depth	22.07	21.60	22.05	21.38	23.49	22.62	<0.01*
Need's ratio	0.72	0.66	0.73	0.70	0.76	0.74	<0.01*

*$P \leq 0.05$ – significant

skeletal Class I malocclusion were most frequently found to be associated with leaf-like morphology of soft palate, Class II with rat tail-shaped soft palate, and Class III with leaf-shaped and crook-shaped soft palate. In a previous study conducted by Subramaniam[22] in dental malocclusions' sample, Leaf shape was found to be the most frequent to be the most frequent in Class I and rat tail type in Class II malocclusions.

Obstructive sleep apnea is characterized by the recurrent occlusion of the upper airways resulting due to the inspiratory collapse of pharyngeal walls during sleep.[23] Pepin *et al*.[4] found that a "hooked" morphology of the velum, which was described as "S shape" in our study, indicated a high risk for obstructive sleep apnea. The hooking of the soft palate was defined as an angulation of 30° between the distal part of the uvula and the longitudinal axis of the velum. They hypothesized that soft palate hooking results in a sudden and major reduction in oropharyngeal dimensions, thus increasing the upper airway resistance and the transpharyngeal pressure gradient resulting in a pharyngeal collapse. The Type 5 (S shaped) soft palate was seen in 1.7% of the cases in the present study. Guttal *et al*.[24] found it in 1.5% of cases, You *et al*.[3] observed in 3.5% of the cases, and Verma *et al*.[13] in 4.7% of the cases.

The velopharyngeal closure is obtained by a normal apposition of the soft palate with the posterior and lateral pharyngeal walls, thus separating the oral cavity from the nasal cavity during deglutition and speech. When the velum, lateral, and posterior pharyngeal walls fail to separate the two cavities, VPI occurs. Nakamura *et al*.[25] reported that patients with persistent VPI had a shorter VL and greater PD, resulting in a higher value of the Need's ratio (PD/VL).

The overall mean Need's ratio of 0.71 was reported in the present study, which was higher in females than in males. This was in accordance with the results of Verma *et al*.,[13] Guttal *et al*.,[24] and Agrawal *et al*.,[21] thus highlighting that females are more prone to VPI than males.

A highly significant correlation was found between the Need's ratio and six variants of soft palate, which was similar to the results of Wada *et al*.,[26] You *et al*.,[3] Praveen *et al*.,[27] and Verma *et al*.[13] Need's ratio was noted to be the lowest in Type 2 and the highest in Type 5 soft palate morphologies which was in accordance with the results of Verma *et al*.[13]

In our study, significantly larger VL was observed in skeletal Class II as compared to Class I and Class III malocclusions. The results are in concurrence with those of Muto *et al*.[28] and Jena *et al*.[14] who suggested that the backward position of tongue compressed the soft palate, resulting in decreased thickness and increased length of soft palate.

Though the dimensions of the nasopharynx were slightly smaller among skeletal Class II patients, these dimensions were comparable among the three groups. Many previous studies[10,14] also reported no significant differences in the nasopharyngeal dimension among individuals with different morphologic configurations of the dentofacial structures and maxillomandibular relations. Ceylan and Oktay[29] observed that the nasopharyngeal area was not affected by the ANB angle. Similarly, Solow *et al*.[30] could find no relationship between the pharyngeal size and the measurements regarding anteroposterior jaw relationship. However, in contrast to our findings, Muto *et al*.[28] too observed significantly larger airway dimensions at the level of soft palate in Class III followed by Class I and Class II malocclusions. The reason for this difference could be due to the difference in the criterion for the selection of the individuals. In their study, SNA and SNB angles were considered for segregation of the individuals, whereas in our study, ANB angle was used for participant segregation.

The results of this study demonstrated variable radiographic appearances of the soft palate on lateral cephalogram in different skeletal malocclusions. The statistical findings of pharyngeal morphology in this study might help in a better understanding of velopharyngeal closure and etiology of OSAS. As reported, speech problems are common in skeletal Class III malocclusion patients. Therefore, the soft palate dimensions and their functional relationships with the surrounding structures should be examined in the diagnosis and treatment planning of various skeletal problems in order to avoid posttreatment speech problems. In addition, the clinician should regard the stability of the ratio between the soft palate and pharynx. For instance, soft palate length does not increase in the skeletal Class III malocclusion patients as much as in skeletal Class II and therefore, treatment planning involving an increase in pharyngeal space should be considered. Clinicians should be vigilant when using orthopedic or surgical methods that may involve maxillary advancement.

Furthermore, it is recommended that a similar study with a larger sample size with different sagittal and vertical growth patterns should be conducted.

CONCLUSIONS

- There was a significant correlation between the variants of soft palate and the types of skeletal malocclusion in North Indian individuals
- The length of the soft palate was smaller among individuals with skeletal Class III malocclusion than individuals with skeletal Class I or II malocclusion
- The dimensions of the nasopharynx at the level of soft palate were independent of sagittal skeletal pattern
- Clinicians should maintain the stability of the ratio between the soft palate and pharyngeal space to prevent speech disorders, and treatment planning that may disturb the balance between soft palate and pharyngeal space should be avoided.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Shimokawa T, Yi S, Tanaka S. Nerve supply to the soft palate muscles with special reference to the distribution of the lesser palatine nerve. Cleft Palate Craniofac J 2005;42:495-500.
2. Moore KL, Agur AM. Essential Clinical Anatomy. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2002.
3. You M, Li X, Wang H, Zhang J, Wu H, Liu Y, *et al.* Morphological variety of the soft palate in normal individuals: A digital cephalometric study. Dentomaxillofac Radiol 2008;37:344-9.
4. Pépin JL, Veale D, Ferretti GR, Mayer P, Lévy PA. Obstructive sleep Apnea syndrome: Hooked appearance of the soft palate in awake patients – Cephalometric and CT findings. Radiology 1999;210:163-70.
5. Subtelny JD. A cephalometric study of the growth of the soft palate. Plast Reconstr Surg (1946) 1957;19:49-62.
6. Stellzig-Eisenhauer A. The influence of cephalometric parameters on resonance of speech in cleft lip and palate patients. An interdisciplinary study. J Orofac Orthop 2001;62:202-23.
7. Akcam MO, Toygar TU, Wada T. Longitudinal investigation of soft palate and nasopharyngeal airway relations in different rotation types. Angle Orthod 2002;72:521-6.
8. Haapanen ML, Kalland M,Heliovaara A, Hukki J, Ranta R.Velopharyngeal function in cleft patients undergoing maxillary advancement.Folia Phoniatr Logop 1997;49:42-7.
9. Samdani D, Saigal A, Garg E. Correlation of morphological variants of soft palate and types of malocclusion: A digital lateral cephalometric study. J Indian Acad Oral Med Radiol 2015;27:366-71.
10. Nanda M, Singla A, Negi A, Jaj HS, Mahajan V. The association between maxillomandibular sagittal relationship and pharyngeal airway passage dimensions. J Indian Orthod Soc 2012;46:48-52.
11. Cohen SR, Chen L, Trotman CA, Burdi AR. Soft-palate myogenesis: A developmental field paradigm. Cleft Palate Craniofac J 1993;30:441-6.
12. Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue growth of the oropharynx. Angle Orthod 1996;66:393-400.
13. Verma P, Verma KG, Kumaraswam KL, Basavaraju S, Sachdeva SK, Juneja S, *et al.* Correlation of morphological variants of the soft palate and need's ratio in normal individuals: A digital cephalometric study. Imaging Sci Dent 2014;44:193-8.
14. Jena AK, Singh SP, Utreja AK. Sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage. Angle Orthod 2010;80:1061-7.
15. Allhaija ES, Al-Khateeb SN. Uvuloglossopharyngeal dimensions in different anteroposterior skeletal patterns. Angle Orthod 2005;75:1012-8.
16. Chang HP. Assessment of anteroposterior jaw relationship. Am J Orthod Dentofacial Orthop 1987;92:117-22.
17. Ishikawa H, Nakamura S, Iwasaki H, Kitazawa S. Seven parameters describing anteroposterior jaw relationships: Postpubertal prediction accuracy and interchangeability. Am J Orthod Dentofacial Orthop 2000;117:714-20.
18. Kumar DK, Gopal KS. Morphological variants of soft palate in normal individuals: A digital lateral cephalometric study. J Clin Diagn Res 2011;5:1310-3.
19. Deepa V, David CM, Ramnarayan BK. Morphological varieties of soft palate in normal individuals, cleft palate patients and obstructive sleep apnea patients with reference to Indian population: A preliminary digital cephalometric study. World J Dent 2013;4:241-9.
20. Santosh VK, Singh P, Pagare SS. Normative soft palate dimensions and morphology in a subset of Indian population: A digital cephalometric study. Indian J Oral Health Res 2015;1:48-51.
21. Agrawal P, Gupta A, Phulambrikar T, Singh SK, Sharma BK, Rodricks D, *et al.* A focus on variation in morphology of soft palate using cone-beam computed tomography with assessment of need's ratio in central Madhya Pradesh population. J Clin Diagn Res 2016;10:ZC68-71.
22. Subramaniam N. Correlation of morphological variants of soft palate and types of occlusion in patients seeking orthodontic assessment. Int J Sci Res 2015;6:1923-6.
23. Maltais F, Carrier G, Cormier Y, Sériès F. Cephalometric measurements in snorers, non-snorers, and patients with sleep apnoea. Thorax 1991;46:419-23.
24. Guttal KS, Breh R, Bhat R, Burde KN, Naikmasur VG. Diverse morphologies of soft palate in normal individuals: A cephalometric perspective. J Indian Acad Oral Med Radiol 2012;24:15-9.
25. Nakamura N, Ogata Y, Kunimitsu K, Suzuki A, Sasaguri M, Ohishi M, *et al.* Velopharyngeal morphology of patients with persistent velopharyngeal incompetence following repushback surgery for cleft palate. Cleft Palate Craniofac J 2003;40:612-7.
26. Wada T, Satoh K, Tachimura T, Tatsuta U. Comparison of nasopharyngeal growth between patients with clefts and noncleft controls. Cleft Palate Craniofac J 1997;34:405-9.
27. Praveen BN, Amrutesh S, Pal S, Shubhasini AR, Vaseemuddin S. Various shapes of soft palate: A lateral cephalometric study. World J Dent 2011;2:207-10.
28. Muto T, Yamazaki A, Takeda S. A cephalometric evaluation of the pharyngeal airway space in patients with mandibular retrognathia and prognathia, and normal subjects. Int J Oral Maxillofac Surg 2008;37:228-31.
29. Ceylan I, Oktay H. A study on the pharyngeal size in different skeletal patterns. Am J Orthod Dentofacial Orthop 1995;108:69-75.
30. Solow B, Siersbaek-Nielsen S, Greve E. Airway adequacy, head posture, and craniofacial morphology. Am J Orthod 1984;86:214-23.