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RESEARCH ARTICLE

EVALUATION OF SOFT PALATE MORPHOLOGY AND NEED'S RATIO IN PATIENTS WITH SKELETAL CLASS I AND CLASS II WITH DIFFERENT GROWTH PATTERNS

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ABSTRACT

Aim and objective: The study was aimed to evaluate the soft palate morphology and need's ratio in skeletal class I and class II subjects with various growth patterns. **Materials and methods:** The study was conducted on 240 subjects (aged 15-25 years) who presented to the department of orthodontics for orthodontic treatment. The subjects were divided into skeletal class I and class II which were further subdivided into hypodivergent, norm divergent and hyperdivergent growers. The soft palate morphology was examined and subjects were divided into 6 types. Need's ratio was calculated by division of pharyngeal depth by soft palate length. The results were then subjected to statistical analysis to evaluate the variation in need's ratio in patients with skeletal class I and class II with various growth patterns. **Results**: The most common type of soft palate was leaf shaped. Patients with skeletal class I were most frequently found to have leaf shaped and skeletal class II subjects had rat tail shape soft palate as the most common, irrespective of growth pattern. Need's ratios were the lowest in hyperdivergent growth pattern in both skeletal class I and class II subjects. There were significant differences in need's ratio of hypodivergent and hyperdivergent growers of both sagittal malocclusions. **Conclusion:** The need's ratio showed a statistically significant difference among hyperdivergent and hypodivergent growth patterns of class I and class II subjects. The knowledge of morphological variants of soft palate help the clinician in etiological study of OSAS, snoring and other conditions.

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INTRODUCTION

Soft palate morphology, dimensions and its dynamic relations with the pharyngeal airway space have an important role in swallowing, respiration, and phonation, which in turn are highly relevant to orthodontic diagnosis and treatment planning (Akcam *et al.,* 2002). The velopharyngeal closure mechanism functions to control nasal airflow, and disorders in this mechanism may cause phonation problems which can manifest as resonance or hypernasality in speech. Soft palate dysfunctions are frequently seen in cleft lip and palate patients, enlarged adenoids, obstructive sleep apnea syndrome (OSAS), snoring, poorly retained maxillary denture and skeletal craniofacial malocclusion (Moore *et al.,* 2008; Lindman *et al.,* 2001) and these dysfunctions can be classified as morphologically incompetent (absolute) where the soft palate length (SPL) is not adequate for velopharyngeal closure and functional incompetence (relative) where the soft palate dimensions are normal but dysfunction occurs as a result of insufficient muscular activity, particularly of the levator veli palatine (Lindman *et al.,* 2001). Because of speech problems as well as the increasing number of orthognathic procedures performed for orthodontic patients, an evaluation of soft palate growth and functions is important. Numerous studies have been done in the past towards the dimensional analysis of soft palate, but little attention has been paid to the varied soft palate morphology and configuration. By observing the image of soft palate on lateral cephalograms, You *et al.* (2008) 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: Crooked shaped) (Fig. 1). Pepin *et al.* (1999) observed that the "hooked or S-shaped" appearance of the soft palate in awake

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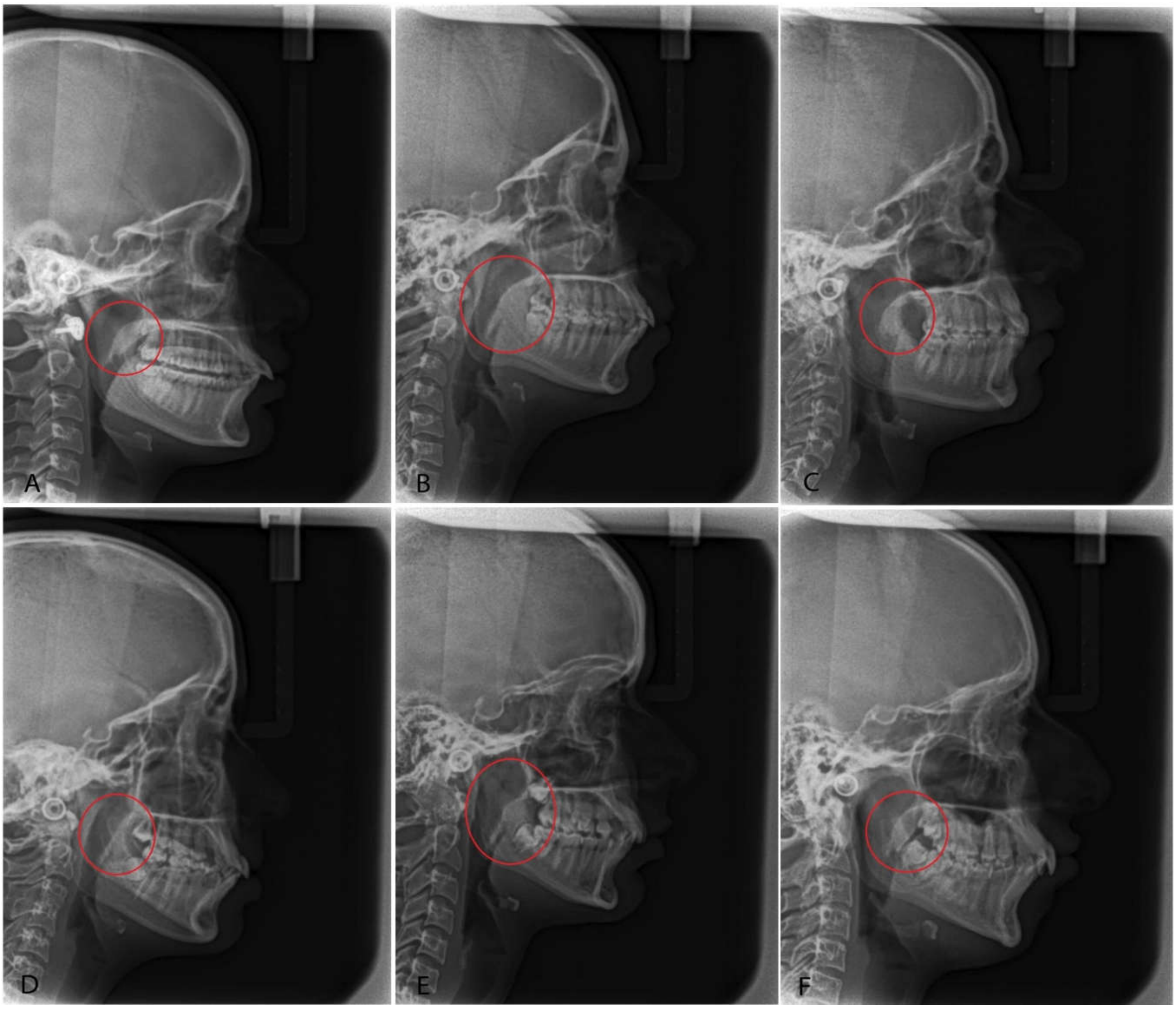

Fig. 1. Various morphological types of soft palate on lateral cephalograms.(A)Leaf shaped soft palate (B) Rat tail shaped soft palate (C)Butt like soft palate (D) Straight line type soft palate (E) S-shaped soft palate (F) Crook shaped soft palate

patients indicated a high risk of OSAS. Velopharyngeal function can be assessed by perceptual and instrumental methods which require a speech therapist and extensive equipment (Ma *et al.,* 2013). Previous reports have shown that the velopharyngeal function can also 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 (1957) first reported that the Need's ratio ranged from 0.6 to 0.7 in normal subjects, and if it was more than 0.7, the condition demonstrated a risk of velopharyngeal incompetency (VPI). Numerous researchers reported the interaction between pharyngeal dimensions and various sagittal and vertical facial growth patterns at varying degrees (Kirjavainen and Kirjavainen, 2007; Kapoor *et al.,* 2014; Reddy *et al.,* 2011; Sprenger *et al.,* 2017; Akcam, 2017). Skeletal features such as retrusion of maxilla and mandible, vertical maxillary excess in hyper divergent patients may lead to narrower anteroposterior dimensions of the airway (Joseph *et al.,* 1998). Others reported association of vertical growth patterns with obstruction in pharyngeal airway concomitant with mouth breathing (Cuccia *et al.,* 2008). However, several authors found that there is natural predisposition of narrower airway passages (Linder-Aronson and Leighton, 1983; Ceylan and Oktay, 1995). Some authors have also reported association between vertical growth pattern and obstruction of the upper pharyngeal airway (Ucar and Uysal, 2011). Also upper pharyngeal space may be affected by conditions such as functional anterior shifting, head posture, sagittal skeletal relation and maxillary protraction. So, the need's ratio may be influenced by facial skeletal pattern in which the relationship between the position of the maxilla and mandible in the anteroposterior and vertical direction has great influence on upper airway dimensions. Correlation of shapes of soft palate in different Angle's malocclusion was studied by Deepak Samdani (2015), who showed that Angle's class I malocclusion was most frequently found to have rat tail type soft palate (58.3%), Angle's class II had leaf shaped soft palate (36.71%), and Angle's class III had crooked shaped soft palate (35.71%).However, the skeletal malocclusion was not considered despite that the shape of soft palate depends upon the jaw and posterior teeth positioning. In addition, need's ratio was also not studied though this ratio plays an important role in velopharyngeal closure. Bhambri *et al.* (2018) investigated the association of soft palate morphology and need's ratios in various sagittal skeletal malocclusions but the growth patterns were not addressed. So, the objective of this study was to evaluate the soft palate morphology and need's ratio in skeletal Class I and II subjects with different growth patterns.

MATERIALS AND METHODS

The sample size calculation was made considering the test power of 95% confidence coefficient. According to the formula for sample size and based on a previous study, 40 cephalograms in each group were sufficient for performing this study. The study was carried out on lateral cephalometric records from patients visiting the department of Orthodontics and Dentofacial Orthopaedics for orthodontic treatment. A total of 240 subjects in the age range of 15-25 years, requiring lateral cephalogram for orthodontic treatment were selected for the study. As per Department protocol, informed written consent was obtained from each subject and ethical clearance was obtained from the Hospital's Institutional Ethics Committee (SDCRI/IEC/2015/015 dated 04.12.15). All the subjects included had no history of prior orthodontic treatment, natural dentition and no craniofacial anomalies, syndromes, clefting or signs of dysfunction of the masticatory system. Standard lateral cephalometric radiographs with the teeth in habitual occlusion and with the head oriented horizontally with the FH plane were taken with the same digital radiographic machine (Kodak 8000C, Carestream Health Inc., Rochester, NY). The cephalometric tracings, landmark identifications and measurements were performed by a single, blinded, duly calibrated examiner and the subjects were divided into two groups on the basis of ANB angle and WITS appraisal-skeletal class I(N=120)and skeletal class II(N=120). The subjects were further subdivided according to vertical pattern into normodivergent (n=40), hyperdivergent (n=40) and hypodivergent(n=40) FMA and Y axis were used to divide the sample into various facial patterns. The FMA measurement corresponded to the angle between the mandibular plane (GoMe) and the Frankfort plane (PoOr), and its reference value was 25°. Values above 30° were considered a vertical growth trend (hyperdivergent); below 20°, a horizontal trend (hypodivergent), and the Y-axis, also called the angle of facial growth was formed by the sella-gnathion line and the Frankfort horizontal plane intersection. The mean value was 59°. An increase in this value indicated a vertical growth trend, and a reduction, a horizontal growth trend. Shape of the soft palate as given by You *et al.* (2008) was determined for each patient.

The velar length (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 Pharyngeal depth (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. Twenty lateral cephalograms, randomly selected were traced again after an interval of one month by the same examiner to assess the intra-examiner reliability. Differences between the means of the first and second tracings for each variables were tested by means of paired t-test to evaluate the error of the method and all were well within the acceptable range.

Statistics

All the collected data was analyzed using the IBM SPSS Statistics 23.0 Data Editor software (Version 23.0. Armonk, NY: IBM Corp.). A cross-tab was composed by dividing the subjects based on (1) the type of skeletal malocclusion (2) growth pattern and (3) 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. Post hoc test was used to find the inter group comparisons.

RESULTS

The sample comprised of 240 lateral cephalograms. They were divided into skeletal class I and skeletal class II which were further divided into three categories: normodivergent, hypodivergent and hyperdivergent. By observing the shapes of soft palate on digital lateral cephalograms in our study, it was revealed that overall leaf shape morphology was the most common(55.8%).32.9% subjects had type 2 soft palate, 0.8% had type 3 soft palate, 7.5% subjects had type 4, 1.3% had type 5 and 1.7 % subjects had type 6 soft palate. Types 3, 5 and 6 were not seen in skeletal class II subjects (Table 1). Comparison between the type of malocclusion and the frequency of shapes of soft palate revealed that leaf shape morphology(60%) was the most common in skeletal class I

Table 1. Types of soft palate in different skeletal malocclusions

Types of soft palate	Skeletal class I			Skeletal class II			Total	Frequency
	Hypo	Normo	Hyper	Hypo	Normo	Hyper		
Type 1	25	20	25	22	12	17	121	55.8%
Type 2	9	12	2	25	24	20	92	32.9%
Type 3	0	0	2	0	0	0	2	0.8%
Type 4	3	6	5	1	0	3	18	7.5%
Type 5	0	0	3	0	0	0	3	1.3%
Type 6	2	2	0	0	0	0	4	1.7%

Table 2. Variation in Need's ratio with different growth patterns

Type of growth	Skeletal class I	Skeletal class II	p-value
Hypodivergent	0.76	0.72	0.001*
Normodivergent	0.73	0.69	
Hyperdivergent	0.69	0.65	

Table 3. Variation in Need's ratio in skeletal class I with different growth patterns

Type of growth pattern	Mean Need's ratio	Standard deviation	p-value	Intergroup comparison		
				Hypo-hyper	hypo-normo	normo- hyper
Hypodivergent	0.76	0.15				
Normodivergent	0.73	0.16	0.03*	0.001*	0.27	0.33
Hyperdivergent	0.69	0.10				

Table 4. Variation in Need's ratio in skeletal class II with different growth patterns

Type of growth pattern	Mean Need's ratio	Standard deviation	p-value	Intergroup comparison		
				Hypo-hyper	hypo-normo	normo- hyper
Hypodivergent	0.72	0.14				
Normodivergent	0.69	0.15	0.018*	0.005*	0.27	0.09
Hyperdivergent	0.65	0.11				

Table 5. Variation in Need's ratio in sample with Hypodivergent growth pattern with different skeletal malocclusion

Type of malocclusion	Mean Needs ratio	Standard deviation	p-value
Skeletal class I	0.76	0.15	0.10
Skeletal class II	0.72	0.14	

Table 6. Variation in Need's ratio in sample with Normodivergent growth pattern with different skeletal malocclusion

Type of malocclusion	Mean Need's ratio	Standard deviation	p-value
Skeletal class I	0.73	0.16	0.15
Skeletal class II	0.69	0.15	

Table 7. Variation in Need's ratio in sample with Hyperdivergent growth pattern with different skeletal malocclusion

Type of malocclusion	Mean Need's ratio	Standard deviation	p-value
Skeletal class I	0.69	0.10	0.14
Skeletal class II	0.65	0.11	

and rat tail(55.8%) was the most frequent in skeletal class II malocclusion, irrespective of growth pattern (Table 1). Mean need's ratios were significantly correlated among various sagittal and vertical malocclusions($p \leq 0.05$). (Table 2)They were the lowest in hyperdivergent growth pattern in both skeletal class I and class II subjects (Table 3, 4). For normodivergent, hypodivergent and hyperdivergent growth patterns, there were non significant differences in skeletal class I and class II subjects.(Table 5, 6, 7).

DISCUSSION

Normal respiration is dependent upon sufficient anatomic dimensions of the airway (Ceylan and Oktay, 1995). Numerous studies have been done which correlate upper airway space with different growth patterns, however, the variety of velar morphology which is the most logical cause of different dimensions on the soft palate and upper pharyngeal space has been frequently overlooked. Soft palate function and development can be monitored and recorded using a nasopharyngeal fiberoscope and magnetic resonance imaging methods (Ma *et al.,* 2013). However, cephalometric analysis is also 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. Malkoc *et al.* (2005) concluded that cephalometric films are significantly reliable and reproducible in determining airway dimensions. When CT and cephalometric films were compared in subjects with skeletal malocclusion, Aboudara *et al.* (2009) found a significant positive relationship between nasopharyngeal airway size on cephalogram and its true volumetric size as determined from CBCT.A recent longitudinal study also used lateral cephalograms for associating changes in the morphology of the nasopharyngeal space in different facial patterns, which made this method of evaluation reliable. A digital radiographic technique was used in the study as it enables the technician to take the image from the posterior to the anterior in the sagittal plane. Further, professional software was used to enhance and elicit the velar morphology by adjusting the contrast. The age range of the subjects chosen for the study was 15-25 years to ensure that the pharyngeal structures had reached adult size (Jena *et al.,* 2010). In addition, head posture has been suggested to influence the dimensions of the pharyngeal airway passage (Allhaija and Al-khateeb, 2005). Thus in order to eliminate those effects, patients were kept in standing position with the head erect and with the FH plane parallel to the floor during cephalogram exposure. Samples were classified as skeletal class I and skeletal class II according to ANB angle and WITS analysis. Qamaruddin *et al.* (2018) reported that ANB and WITS are reliable for determining the anteroposterior relationship of the jaws. The results of the current study demonstrated that overall Type 1 soft palate morphology was the most common which is in accordance with You et al(2008), Kumar and Gopal (2011), Deepa *et al.* (2013) and Verma *et al.* (2014) and Bhambri *et al.* (2018). Skeletal class I subjects had type 1 soft palate as the most common whereas type 2 morphology was more prevalent in skeletal class II subjects in various growth patterns. Type 3, 5 and 6 was not observed in skeletal class II subjects. This is in accordance with Subramaniam (2015) who also found leaf shape to be the most frequent in Class I and rat tail type in class II. In the present study, there was no significant difference in the need's ratio in patients with class I and class II. Ackam (2017) also found non significant difference in SPL/NAS ratio among class I and Class II subjects. Also, though the dimensions of the nasopharynx were slightly larger among class I subjects than class II, the depth of the pharyngeal airway was not significantly different in patients with class I and II and increase in the ANB did not affect the characteristics of upper airway (Ackam, 2017). This could be the case because the dimensions of the bony nasopharynx are a relatively independent variable in relation to other dimensions of the facial complex (Jena *et al.,* 2010). This was in agreement with Abu Alhaija *et al.* (2005), Zhong *et al.* (2010), Jena *et al.* (2010), Reddy *et al.* (2011), Nanda *et al.* (2012), Soheilifar *et al.* (2014), Kapoor *et al.* (2014) and Chaturvedi *et al.* (2014). Ceylan and Oktay (1995) reported that a number of postural changes might occur in the structures of head and neck in response to the changes in sagittal jaw relationships that result in constant depth of upper airway In contrast, Kirjavainen *et al.* (2007) showed that class II was related to a narrower oral space than class I and this could be probably due to difference in case selection. They classified according to dental malocclusion. EI hakan *et al.* (2011) found significantly smaller nasopharyngeal volume in class II than class I, however, linear measurements were not considered in the study. Kim *et al.* (2010) reported that the mean total airway volume in patients with retrognathia was significantly smaller than in patients with normal anteroposterior skeletal relationship, with no difference in the volume of subregions. Akcam (2017) found significant differences in nasopharyngeal passage in skeletal class II than class I. However, class II malocclusion due to true mandibular retrognathism were selected.

Soft palate length was also not significantly different between class I and class II in the present study. This is in accordance with the results by Ceylan and Oktay (1995), Alhaija *et al.* (2005), Kim (2010), Nanda *et al.* (2012), Soheilifar *et al.* (2014). Muto *et al.* (2008) and Jena *et al.* (2010) found significant differences in soft palate length in patients with mandibular retrognathism and prognathism when compared to normal mandible. This could be due to the difference in criterion for segregation of subjects. They used SNB angle for subject selection and ANB angle was used for subject segregation in this study. Associations of class II malocclusions and vertical growth pattern with obstruction of the upper and lower pharyngeal airways and mouth breathing on the basis of predisposing anatomical factor have been suggested. Raffat and Hamid (2009) concluded that subjects with upper airway obstruction displayed excessive vertical Dentofacial development, leading to a long face appearance. Kapoor *et al.* (2014) compared upper and lower pharyngeal airways in skeletal class I and II malocclusions with different growth patterns and inferred that patients with class I and Class II and vertical growth patterns have significantly narrower upper pharyngeal airways than those with class I and class II and normal or hypodivergent growth patterns. Freitas *et al.* (2006) also concluded that upper pharyngeal width in subjects with class I and Class II and vertical growers were significantly narrower than in normal growth pattern groups. Celikoglu *et al.* (2014) concluded that when nasopharyngeal space is reduced, there is a tendency towards neuromuscular adaptation, leading to vertical growth of face that is associated with hyperdivergent growth pattern. In the present study, hyperdivergent facial pattern subjects belonging either to skeletal class I or class II showed a statistically significant difference in upper pharyngeal width as compared to normodivergent and hypodivergent growth patterns. This is in accordance with Akcam et al(2002), Ucar *et al.* (2011), Kapoor (2014), Idia Nibokun Ize-Iyamu (2016). Shastri *et al.* (2015) found decreased nasopharyngeal dimensions from normal to high angle patients. Zhong *et al.* (2010) concluded that vertical facial pattern was responsible for the deficiency in depth of the superior part of the upper airway because of the craniomaxillary complex. Sprenger *et al.* (2017) did not find a difference in superior pharyngeal space in various growth patterns. This could be attributed to different population and different norms for them. The need's ratio intergroup comparisons in various sagittal patterns showed no significant differences, revealing no association of need's ratio with type of malocclusion. This is in accordance with Ceylan *et al.* (1995), Kapoor *et al.* (2014). However, some studies have found relationships between upper airway and type of malocclusion, showing narrower nasopharynges in subjects with Class II malocclusion (Mergen and Jacobs, 1970; Paul and Nanda, 1973). Our findings regarding the relationship between need's ratio and anteroposterior skeletal pattern are inconsistent with those that reported a relationship between pharyngeal structures and ANB. However, the variables used to measure upper airway in the previous studies differed from those used in this study, which makes the comparison more difficult. The present study suggested that vertical growth pattern might predispose a person to upper airway narrowing, which in turn might predispose the person to obstruction in a population without permanent snoring. A longitudinal study of craniofacial morphology as a potential pathogenic factor is warranted in the future. The results of this study demonstrated different quantities and directions of soft palate and velopharyngeal growth in different skeletal types. The hyperdivergent growth pattern showed the greatest change, though the need's ratio did not show a significant difference in class I and Class II subjects. Therefore, the soft palate dimensions and its functional relations with the surrounding tissues should be examined in detail in the treatment planning of various skeletal problems in order to avoid post treatment speech problems, particularly for orthopaedic treatment involving the maxilla.

Conclusion

In conclusion, it can be said that a number of postural changes can occur and these can involve the structures of head and neck regions in response to the changes in sagittal jaw relationships. So, the need's ratio, which plays an indispensable role in velopharyngeal function, did not show a statistically significant difference among the sagittal malocclusion groups, though the need's ratio showed a statistically significant difference among hyperdivergent and hypodivergent growth patterns of class I and class II subjects. Considering nasopharyngeal airway dimensions, clinicians should follow the stability of the ratio between the soft palate and pharynx to prevent speech disorders and obstructive sleep apnea in later life, thereby avoiding treatment planning that may disturb the balance between the soft palate and pharyngeal space.

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