The Online
ANGLE ORTHODONTIST
An International Journal of Orthodontics and Dentofacial Orthopedics
78th Anniversary 1930–2008

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The Angle Orthodontist: **Vol. 72, No. 6, pp. 521–526.**

Longitudinal Investigation of Soft Palate and Nasopharyngeal Airway Relations in Different Rotation Types

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ABSTRACT

The relationship between the soft palate and the nasopharyngeal airway in different mandibular growth rotation models was investigated. A total of 72 lateral cephalograms were obtained three years longitudinally from 24 individuals. The subjects had a mean age of 10.7 ± 1.2 years and showed a normal (n = 8), posterior (n = 8), and anterior (n = 8) mandibular rotation pattern. Linear and angular measurements of the soft palate and nasopharyngeal airway were recorded by using PORDIOS computer program and were examined by means of descriptive statistics and paired *t*-tests. A linear increase in the soft palate length (SPL) was observed in all groups, with the posterior mandibular rotation group showing the largest increase within the observation period (28.56 ± 4.83 to 34.98 ± 2.87; $P < .01$). According to the paired *t*-test, palatal plane (ANS–PNS)/soft palate tip (SPT) angle showed a statistically significant decrease in the posterior rotation group ($P < .01$). The ratio between SPL and superior nasopharyngeal space (SPS) did not show a statistically significant difference among the groups. Although various amounts of soft palate and nasopharyngeal airway growth occurred in the different mandibular rotation types, the ratio between SPL and SPS (SPL/SPS), which plays an indispensable role in velopharyngeal functions, did not show a statistically significant difference in the groups. This assured velopharyngeal closure throughout the active growth period.

KEY WORDS: Soft palate, Pharyngeal airway, Mandibular rotation.

Accepted: April 2002. Submitted: February 2002

INTRODUCTION Return to TOC

Soft palate dimensions and their dynamic relations with the pharyngeal airway space have an important role in swallowing, respiration, and phonation. The velopharyngeal closure mechanism functions to control nasal airflow, and disorders in this mechanism may cause phonation problems.[1–3]

Soft palate dysfunctions are frequently seen in cleft lip and palate patients. They may also be observed in some syndromic patients or even in normal individuals and occasionally may contribute to hypernasal speech and misarticulation.[2] Soft palate dysfunctions can be classified as morphologically incompetent (absolute) where the soft palate length (SPL) is not adequate for velopharyngeal closure and functional incompetence (relative), and where the soft palate dimensions are normal but dysfunction occurs as a result of insufficient muscular activity, particularly of the levator veli palatini.[4–6] As a consequence of this muscle action, the soft palate plays a considerable role in regulating the size of the orifice of the velopharynx.[3,7]

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. Many articles have been published concerning craniofacial growth, but longitudinal studies involving the soft palate and its relations with the pharyngeal space are somewhat limited in the orthodontic literature,[6,8–10] and most of them are related to obstructive sleep apnea.[11–13]

The objective of this study was to investigate the soft palate dimensions and their relation to nasopharyngeal airway space in different human mandibular growth rotation models in a longitudinal sample. We evaluated the soft palate dimensions and their relation to the nasopharyngeal airway during growth among individuals having different craniofacial growth patterns determined by variations in the mandibular rotational growth pattern.

MATERIALS AND METHODS Return to TOC

This study was carried out using longitudinal lateral cephalograms obtained over three years from 24 individuals (nine girls, 15 boys) with a mean age of 10.7 ± 1.2 years (Table 1). The patients were grouped according to their mandibular plane angle (Go–Me/S–N) and the angle between the palatal and mandibular planes (ANS–PNS/Go–Me). Subjects were classified as group I with a normal vector of growth, group II with a posterior rotation of the mandible during growth, and group III with an anterior rotation of the mandible during growth. These angles remained relatively stable in the normal group, increased in the posterior rotation group, and decreased in the anterior rotation group over the observation period (Table 2). Cephalometric landmarks and measurements are shown in Figures 1–3.

Cephalometric points were transferred to the computer system by an optical digitizer (Genius New Sketch Digitizer) and analyzed with PORDIOS (Purpose on Request Digitizer Input Output System, Copenhagen, Denmark).

Statistical Methods

The tracing and digitizing processes of the cephalograms were repeated for 30 randomly selected cephalograms by the same examiner. The time span between these recordings was at least four weeks. Repeatability coefficients were calculated to determine any intraexaminer differences. Intraexaminer differences were evaluated and the repeatability coefficients were above 0.90 for all variables, thus confirming the reliability of the measurements.

Means and standard deviations were calculated for linear and angular measurements in the groups (Table 3). The differences of the measurements between the initial and final records were assessed using paired *t*-test in each group (Table 4).

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A linear increase was observed in the SPL (PNS–soft palate tip [SPT]) in all groups (Table 3). The posterior rotation group II showed the largest increase and, with the anterior rotation group III, was significant at the at $P < .01$ level. The normal rotation group I was significantly larger at the $P < .05$ level (Table 4).

The soft palate thickness (soft palate center–soft palate dorsum [SPC–SPD]) measurement showed a significant increase only in anterior rotation group III ($P < .05$; Table 4).

The SPT–SP_{PP} and SPT–posterior pharyngeal wall 1 (PPW1) dimensions, representing the vertical height of the soft palate, showed a linear increase in all groups (Table 3). The vertical height increase was statistically significantly larger in the posterior rotation group II at the $P < .01$, whereas the increase in groups I and III was significant at the $P < .05$ level (Table 4).

The superior nasopharyngeal airway space (PNS–PPW1) showed a linear increase in all groups (Table 3) at a significance level of $P < .01$ (Table 4), demonstrating an increase in the nasopharyngeal airway dimensions with growth.

The inferior airway space (SPT–posterior pharyngeal wall 2 [PPW2]) decreased in the posterior rotation group II with only slight increases in groups I and III. None of these changes were statistically significant (Tables 3 and 4).

The ANS–PNS/SPT angle decreased in all groups, but was only significant at the $P < .01$ level in the posterior rotation group II (Tables 3 and 4).

The ratio between soft palate and superior pharyngeal space (SPL/SPS) did not show a statistically significant change in any group (Tables 3 and 4). The SPL/IPS (inferior pharyngeal space) ratio demonstrated a significant increase only in group II ($P < .05$).

Statistically significant differences were most robust in the posterior rotation group II (Table 4).

DISCUSSION Return to TOC

This study consisted of the evaluation of lateral cephalograms obtained longitudinally over three years from a group of patients with a mean age of 10.7 ± 1.2. The reason for selecting the patients in this growth period was to evaluate the rapid changes that occur in the soft palate and neighboring soft tissues during a dynamic growth stage. Taylor et al[8] reported that growth changes in this region were accelerated in the ages between six and nine years and 12 and 15 years in their longitudinal study that involved the soft tissue measurements of the posterior pharyngeal wall. The study sample was followed for three years longitudinally.

Soft palate function and development can be monitored and recorded using a nasopharyngeal fiberscope[5,14] and magnetic resonance imaging (MRI)[7,15] methods. On the other hand, cephalometry is easy to use, economical, and can provide definite and quantitative information about the soft palate and nasopharynx.[16,17] Because of the ethical considerations of collecting cephalometric radiographs from growing children only for research purposes, the material for the current study was selected from the orthodontic department archives. Certainly longer-term follow-up of the patients would be more beneficial.

Mandibular rotation types were determined according to the changes in the Go–Me/S–N and ANS–PNS/Go–Me angles during the three-year observation period. The normal group did not exhibit a significant difference in both angles, whereas they increased in the posterior rotation group and decreased in the anterior rotation group (Table 2). This method of grouping, however, does not exclude the possibilities of using other parameters. Discrimination regarding gender was not considered because of the low number of subjects.

According to descriptive statistics, SPL (PNS–SPT), thickness (SPC–SPD), and height ($SPT–SP_{PP}$) linearly increased during the observation period in all groups. This is an expected consequence of the growth process and is harmonious with the studies reported by Johnston and Richardson.[10]

The PNS–PPW1 that represent pharyngeal airway space and SPT–PPW1 parameters also linearly increased with growth, which coincides with the interpretations of Taylor et al.[8] Considering the paired *t*-test, the decrease in the ANS–PNS/SPT angle was significant only in the posterior rotation group ($P < .01$). Although statistically insignificant, the decrease in the inferior pharyngeal space (SPT–PPW2) in the posterior rotation group is parallel to the findings reported by Joseph et al[18] in which they determined the narrowing of the pharyngeal space at the level of the soft palate in hyperdivergent subjects. The larger SPL, height, superior nasopharyngeal space (SPS), and decrease in ANS–PNS/SPT angle in the posterior rotation group may attribute to distinct relations between soft palate and nasopharyngeal space in subjects having normal, posterior, and anterior mandibular rotation patterns, which should be considered.

The SPL/IPS ratio showed a significant increase only in the second group, which may be a result of the larger increase in the SPL in the posterior rotation group (Tables 3 and 4). SPL/SPS ratio, which plays an important role in velopharyngeal closure, did not show a significant difference between the groups (Tables 3 and 4). This situation indicates a certain ratio between SPL and superior pharyngeal space in individuals having a normal phonation. The velopharynx is completely closed when phonating most vowels and many consonants. An incomplete closing movement of the soft palate plays an important role in speech problems.[3] Subtelny et al[19] described the ratio between soft palate and pharyngeal space as the 'need ratio.' A decrease in this ratio coincides with velopharyngeal dysfunction and speech problems.[20] These interpretations are in harmony with the studies done by Satoh et al,[21] who pointed out the importance of the harmonious growth of the nasopharyngeal area for the continuity of velopharyngeal closure function. Stellzig-Eisenheuer[9] reported that the ratio between the soft palate and the sagittal depth of the nasopharyngeal airway was of prime importance in the resonance of speech. He found significant correlations between craniofacial growth changes and changes of resonance during puberty that might be influenced both by dentofacial orthopedics and maxillofacial surgery. Haapanen et al[22] reported that 27% of cleft lip and palate patients who received maxillary advancement surgery showed a reduced velopharyngeal function, and they explained this situation by the advancement of the posterior border of the hard palate as a result of the maxillary advancement. Lowe et al[23] studied obstructive sleep apnea patients and determined there was a decrease in the upper airway dimensions at the velopharyngeal level together with an increase in soft palate and tongue dimensions.

It should be noted that pharyngeal morphology is not immutably established during childhood and adolescence but changes throughout adult life.[10] The clinician could follow the stability of the ratio between the soft palate and pharynx to prevent speech disorders and/or obstructive sleep apnea in later life, thereby avoiding treatment planning that may disturb the balance between the soft palate and the pharyngeal space. For instance, SPL does not increase in the anterior rotation as much as in the posterior rotation group, and, therefore, treatment planning involving an increase in pharyngeal space should be considered. Clinicians should be vigilant when using orthopedic treatment methods that may involve maxillary advancement. This aspect should be evaluated with more intensive methods with longer follow-up periods.

The results of this study demonstrated different quantities and directions of soft palate and velopharyngeal growth in different mandibular rotation growth types. The posterior rotation group showed the greatest change, although the ratio between the soft palate and upper airway dimensions did not show a significant difference in the groups during the three-year observation period. As reported previously, articulatory speech disorders are frequently observed in severe skeletal class III patients.[24] Therefore, the soft palate dimensions and its functional relations with the surrounding structures should be examined in detail in the treatment planning of various skeletal problems in order to avoid post treatment speech problems, particularly for orthopedic treatment involving the maxilla.

CONCLUSIONS Return to TOC

The SPL and height showed the largest increase in the posterior rotation group II subjects, whereas a significant decrease in the ANS–PNS/SPT angle was observed in this group.

The SPL and SPS ratio (SPL/SPS) did not show a significant difference among the individuals having normal, posterior, and anterior rotation growth patterns, which indicates that this ratio is preserved during the active growth period.

It is suggested that clinicians should regard 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.

ACKNOWLEDGMENTS

We thank Associate Professor E. Başpınar (Ankara University, Department of Biostatistics and Genetics) who managed the statistical analysis of this study. This study was presented in the 77th European Orthodontic Society Congress in Gent, Belgium, June 19–23, 2001.

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TABLES Return to TOC

TABLE 1. Distribution of the Subjects

	Group I (Normal)	Group II (Posterior Rotation)	Group III (Anterior Rotation)
Chronological age (y)	10.1 ± 1.1	10.4 ± 0.7	11.5 ± 1.7
Number of subjects	8	8	8
Follow-up (y)	3	3	3

TABLE 2. The Mean Variations in the Go-Me/S-N and ANS-PNS/Go-Me Angles During the Observation Period

	Group I (*n* = 8) (Normal) Mean ± SD	Group II (n = 8) (Posterior Rotation) Mean ± SD	Group III (n = 8) (Anterior Rotation) Mean ± SD
Go-Me/S-N			
First year	37.6° ± 4.9	35.0° ± 3.7	34.7° ± 4.4
Second year	37.4° ± 4.8	36.4° ± 3.8	33.2° ± 4.2
Third year	37.5° ± 5.0	36.9° ± 4.0	32.8° ± 4.7
ANS-PNS/Go-Me			
First year	22.8° ± 4.1	24.4° ± 3.7	27.2° ± 5.7
Second year	22.6° ± 3.8	25.2° ± 3.2	26.2° ± 5.0
Third year	22.7° ± 3.0	25.9° ± 2.5	25.7° ± 4.1

TABLE 3. Measurements in Each Group

	Group I (n = 8) (Normal) Mean ± SD	Group II (n = 8) (Posterior Rotation) Mean ± SD	Group III (n = 8) (Anterior Rotation) Mean ± SD
PNS-SPT (mm)			
First year	29.17 ± 4.15	28.56 ± 4.83	29.24 ± 1.92
Second year	30.23 ± 3.78	32.50 ± 4.35	31.02 ± 2.68
Third year	31.86 ± 5.27	34.98 ± 2.87	33.47 ± 2.59
SPC-SPD (mm)			
First year	4.71 ± 1.19	6.11 ± 0.84	4.91 ± 1.84
Second year	6.32 ± 2.25	6.59 ± 2.14	6.08 ± 1.73
Third year	5.05 ± 1.33	6.82 ± 1.54	6.31 ± 1.59
$SPT-SP_{PP}$ (mm)			
First year	22.33 ± 4.30	20.47 ± 4.68	21.60 ± 2.99
Second year	23.14 ± 3.71	24.88 ± 5.54	23.98 ± 1.66
Third year	24.80 ± 5.40	26.87 ± 3.89	25.64 ± 2.04
SPT-PPW1 (mm)			
First year	22.74 ± 3.96	20.73 ± 4.43	21.92 ± 3.36
Second year	23.66 ± 3.38	25.28 ± 5.44	24.58 ± 2.22
Third year	25.43 ± 4.78	27.20 ± 3.66	26.15 ± 1.83
PNS-PPW1 (mm)			
First year	20.92 ± 2.31	23.08 ± 3.48	22.79 ± 2.68
Second year	21.63 ± 3.55	23.33 ± 4.31	22.76 ± 5.18
Third year	23.85 ± 2.94	25.53 ± 3.51	24.60 ± 3.87
SPT-PPW2 (mm)			
First year	9.14 ± 1.22	10.68 ± 3.18	9.46 ± 1.25
Second year	8.78 ± 2.01	8.48 ± 2.85	9.38 ± 1.91
Third year	9.65 ± 3.0	8.96 ± 3.36	10.14 ± 2.85
ANS-PNS/SPT (°)			
First year	130.54 ± 5.19	134.82 ± 5.85	131.89 ± 8.53
Second year	129.68 ± 6.61	131.0 ± 7.41	128.56 ± 8.63
Third year	129.28 ± 5.65	130.19 ± 5.31	129.34 ± 4.61
SPL/SPS (ratio)			
First year	1.42 ± 0.31	1.25 ± 0.19	1.29 ± 0.12
Second year	1.44 ± 0.36	1.43 ± 0.27	1.42 ± 0.33
Third year	1.35 ± 0.30	1.40 ± 0.25	1.39 ± 0.24
SPL/IPS (ratio)			
First year	3.28 ± 0.81	2.94 ± 1.17	3.15 ± 0.51
Second year	3.70 ± 1.39	4.21 ± 1.51	3.42 ± 0.72
Third year	3.86 ± 2.26	4.37 ± 1.59	3.58 ± 1.21

TABLE 4. Paired *t*-Test for the Difference Between Initial and Final Measurements (Third Year–First Year)

	Paired *t*-Test					
	Group I (Normal)		Group II (Posterior Rotation)		Group III (Anterior Rotation)	
Parameters	Difference[a] (Mean ± SD)	Significance	Difference[a] (Mean ± SD)	Significance	Difference[a] (Mean ± SD)	Significance
PNS-SPT	2.69 ± 3.23	*	6.42 ± 3.83	**	4.23 ± 2.73	**
SPC-SPD	0.34 ± 1.98	NS	0.71 ± 1.54	NS	1.40 ± 1.28	*
$SPT-SP_{PP}$	2.47 ± 2.91	*	6.40 ± 3.19	**	4.04 ± 3.73	*
SPT-PPW1	2.69 ± 2.65	*	6.47 ± 2.64	**	4.23 ± 3.82	*
PNS-PPW1	2.93 ± 3.15	*	2.45 ± 2.96	*	1.81 ± 2.03	*
SPT-PPW2	0.51 ± 2.97	NS	−1.72 ± 3.89	NS	0.68 ± 3.64	NS
ANS-PNS/SPT	−1.26 ± 5.37	NS	−4.63 ± 3.43	**	−2.55 ± 6.42	NS
SPL/SPS	−0.07 ± 0.29	NS	0.15 ± 0.22	NS	0.10 ± 0.22	NS
SPL/IPS	0.58 ± 1.87	NS	1.43 ± 1.53	*	0.43 ± 1.52	NS

[a] Third year to first year.
* $P < .05$.
** $P < .01$; NS indicates not significant.

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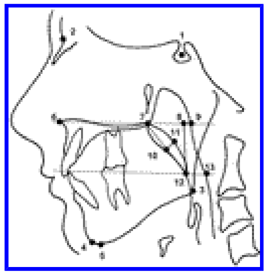

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FIGURE 1. Cephalometric landmarks: (1.) sella; (2) nasion; (3) gonion; (4) gnathion; (5) menton; (6) ANS; (7) PNS; (8) SP_{PP}—intersection point of the perpendicular line drawn from the soft palate tip (SPT) to the palatal plane (ANS–PNS); (9) posterior pharyngeal wall 1 (PPW1)—the intersection point of the palatal plane at the posterior pharyngeal wall); (10) soft palate center (SPC)—the midpoint of the PNS–SPT line; (11) soft palate dorsum (SPD)—intersection point of the perpendicular line drawn from the SPC to the SPD; (12) SPT; (13) posterior pharyngeal wall 2 (PPW2)—intersection point of the parallel plane to palatal plane drawn from the SPT point to the posterior pharyngeal wall

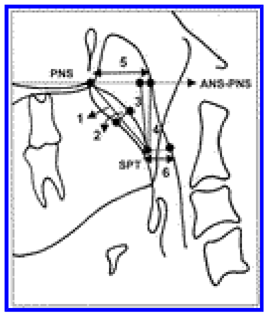

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FIGURE 2. Linear measurements: (1) PNS–SPT (SPL—soft palate length); (2) SPC–SPD (soft palate thickness); (3) SPT–SP_{PP} (soft palate height); (4) SPT–PPW1 (soft palate height); (5) PNS–PPW1 (SPS—superior pharyngeal space); (6) SPT–PPW2 (IPS—inferior pharyngeal space)

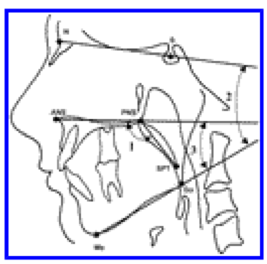

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FIGURE 3. Angular measurements: (1) ANS–PNS/SPT (the angle between palatal plane and soft palate); (2) Go–Me/S–N (mandibular plane angle); (3) ANS–PNS/Go–Me (the angle between palatal and mandibular planes)

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