Spatial changes in upper airway induced by change in head postures in horizontal, average and vertical growth pattern: A comparative lateral cephalometric study

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Abstract

Introduction: The aim of the present study was to evaluate and compare the upper airway area on lateral cephalogram between vertical growth pattern and horizontal and average patterns. The airway was measured in three different head positions; the Natural Head Position (NHP), 20 degrees of extension and 20 degrees of flexion.

Materials and Methods: 60 subjects were divided into two groups Group A which consisted of horizontally and average growing patients and Group B consisting of vertically growth pattern patients. Using a derived trapezoid the area of the nasopharyngeal airway covered by the trapezoid was calculated in lateral cephalogram. The trapezoid represented the upper airway.

Results: At 20 degrees of extension the airway significantly increased more in Group A as compared to Group B. The difference between the two groups however was not statistically significant.

Conclusion: In the present study we found that the airway in both groups was affected by 20 degrees flexion and 20 degrees extension of the neck. Hence, improving airway patency by changing head postures is beneficial to all types of craniofacial growth patterns. The results can as well be functional in improving the patency of the airway in individuals with obstructive breathing problems. Airway patency has its application in emergency management, E.N.T., surgery, anesthesia and many more branches other than Orthodontics and Dentofacial Orthopaedics.

Keywords: Lateral cephalogram, Growth pattern, Airway, Natural head position.

Introduction

India has the highest rate of road traffic accidents (RTA) in the world. Even worldwide, the untreated OSA subjects are more vulnerable to RTA than their healthy counterparts.[1,2] Any repeated interference with the breathing can cause sleep disorders and events, ranging from throat infection to cardiovascular disorder. There is a significant relation between RTA and untreated cases of Obstructive Sleep Apnoea (OSA). Increase in craniocervial angle and forward inclination of the cervical column may be correlated with increase in the airway in OSA subjects.[3] This intriguing adaptation necessitates studying the effects of change in head postures on the airway. Monitoring the head position can be important in diagnosis and treatment planning of individuals with OSA.

The use of cephalometrics in investigating sleep related disorders is well recognized.[4] As orthodontists lateral cephalogram is most widely available tool and happens to be one of the primary diagnostic records. The gold standard in evaluating and measuring upper airway is Cone Beam Computed Tomography (CBCT). But CBCT still remains expensive and less available than the other. Hence, we chose lateral cephalography to study the airway.

Ucar and Uysal studied the airway in class I malocclusions in different growth patterns. They found the pharyngeal airway space smaller in high angle subjects than in low angle subjects.[5] But not many studies have been carried out comparing the nasopharyngeal airway between high angle subjects and low angle subjects with different head postures, hence encouraging us to conduct our study.

Preston states that, the largest increment of craniofacial development occurs within the first four years of life and 90% of craniofacial development is completed by the age of 12 years.[6] Therefore addressing and correcting these features early may significantly reduce medical problems that many children have as a result of untreated respiratory problems.

The NHP is the most reproducible and physiologic head position while standing. In the present study we evaluated the upper airway dimension at three different head positions in different patients and to find an association between them. The change in the airway during head extension and flexion was compared to that in the Natural Head Position (NHP).

The aim of the study was

1. To determine the airway dimension at normal head position, 20 degrees upward extension and 20 degrees downward flexion in patients with horizontal and normal growth patterns.
2. To determine the airway dimension at normal head position, 20 degrees upward extension and 20 degrees downward flexion in patients with vertical growth patterns.
3. To find an association between the values obtained between the two groups

Material and Methods

The materials that were used for the study were as follows:

1. Cephalostat machine
2. Acetate Tracing paper having a thickness of 0.003 mm
3. Tracing view box
4. A Camlin scale
5. A Camlin eraser
6. A Camlin micro tip pencil with 0.50 mm lead
7. A radio opaque solution of barium sulphate
8. A cotton thread
9. Measuring jig

Subjects, aged between18-25 were selected who reported to our department for orthodontic treatment and agreed to participate in the study and were randomly selected. Those with a history of any surgery, orthodontic treatment or pathology in head and neck region were excluded. Based on their lateral cephalograms, the sample was divided into two groups,

1. Group A – Consisting of average and horizontally growing patients (Steiner's mandibular plane angle equal and less than 32 degrees)
2. Group B - consisting of 30 vertically growing patients (Steiner's mandibular plane angle greater than 32 degrees). Since Steiner's mandibular plane angle of 31 degrees is considered to be dolichofacial and representative of more downward and backward growth.

Orientation of the head and fabrication of the measuring Jig.

To standardize the subject's head at the three positions, an 'ala- tragus line' was drawn on the left side of the face, by forming an impression using a thread dipped in radio opaque barium sulphate paste. To measure the orientation of the patient's head, a measuring jig was fabricated by joining two protractors, to obtain three hundred and sixty degrees orientation. A hole measuring 1.5 centimeters was drilled with an acrylic bur, so that the conical ear rods of the cephalostat could pass through the protractor.

Three 0.016x 0.022 inches stainless steel straight length wires were glued on the surface of the protractor such that they were at an angle of twenty degrees to each other to create radio opaque lines on the radiograph (Fig. 1). The upper first wire represented the head extension, the central line depicted the NHP and the last wire represented the head flexion. The jig was positioned onto the left conical ear rod such that the central wire of the jig was along the ala tragus line.

The subjects were positioned in NHP by using the mirror method. Three separate radiographs for (Fig. 2-4) NHP, 20 degrees flexion and 20 degrees extension were obtained by positioning the ala tragus line along the central, first and the last wire on the measuring jig in that order. All radiographs were traced and measured by deriving a trapezoid in the bony nasopharynx which was traced on the lateral cephalogram, similar to a method used by some authors.[6,7]

The trapezoid (Fig. 5, 6) was demarcated by the four lines.

1. A line drawn through Anterior arch of the atlas (AA), parallel to the pterygoid vertical extending to intersect the Ba-N line or the posterior pharyngeal wall (a)
2. The pterygoid vertical or the anterior pharyngeal wall (b)
3. The section of the Ba-N line between the pterygoid vertical and the vertical erected through point AA and The base of the trapezium formed by a line joining the posterior nasal spine (PNS) to AA(l).

Area of the Airway Space (trapezoid) = l x <u>(a+b)</u>

Where, 'l' = Length of perpendicular from 'a' to 'b'

(a+b) = Sum of parallel sides

A single clinician carried out tracing, measurements of the nasopharyngeal area for all the radiographs. For statistical analysis, quantitative analysis of the area between horizontal and vertical growers was carried out by unpaired t – test and within the same group ANOVA and Tukey's multiple comparison test was also calculated.

Results

Statistical analysis: All the values collected for variables 'a', 'b', 'l' and 'area' were subjected to statistical analysis. ANOVA (Table 1). In statistically significant results, Tukey's multiple comparison tests were used to evaluate the significance of difference between their mean.

Group A (Horizontal and average growth pattern): With a change in posture from NHP to 20 degrees extension there was gradual increase in the airway area. This was due to the changes in the variable 'l', variables a and b (Table 2-4). At 20 degrees flexion the variable 'l' increased but variables 'a' and 'b' decreased, however at 20 degrees of extension all the variables increased (Table 5, 6. There was a statistically significant change in the dimension of the airway space from NHP to 20 degrees of extension and also between 20 degrees of extension and 20 degrees of flexion. (Table 7, 8)

Group B (Vertical growth pattern): In Group B, with change in the posture the airway showed an increase from NHP to 20 degrees flexion and highest mean was at 20 degrees extension. At 20 degrees flexion, the increase in the airway was due to increase in the value of variable 'l' and 'b', only the variable 'a' decreased. Whereas, at 20 degrees of extension when compared to the other two postures, all the variables increased. Only for the variable 'a' (posterior pharyngeal wall) the difference was statistically significant between NHP and 20 degrees of extension, also between 20 degrees flexion and extension. (Table 9-11).

Nevertheless, the change in the airway space was statistically insignificant between NHP and 20 degrees

degrees of flexion. There was a statistically significant change in the dimension of the airway space between the NHP and 20 degrees extension and also between 20 degrees of flexion and 20 degrees of extension. (Table 12, 13)

Comparison of Group A and Group B: When the increase in the airway space was compared between the Groups A and B, it was found that the airway space increased more in Group A as compared to Group B at NHP and at 20 degrees of flexion but the increase was the greatest when at 20 degrees of extension. The difference between the two groups however was not statistically significant (Table 14-16).

Therefore from the present study, we conclude that the change in the airway from NHP to 20 degrees of flexion and extension was found in both the growth patterns. But this difference was greater in individual with horizontal growth than vertical growth. Despite a numerical dissimilarity between the two groups, the disparity between the groups was found to be statistically insignificant. Hence the breathing pattern may not always be predicted accurately by studying ones growth pattern.

Table 1: Values of various parameters from the Group A & Group B

		NHP		20 Degrees Flexion		20 Degrees Extension	
		Mean	Standard Deviation	Mean	S.D.	Mean	S.D.
Group A	l	18.43	2.92	19.03	2.72	19.38	2.64
	a	9.63	2.25	9.50	2.37	12.50	3.71
	b	17.88	1.78	17.57	1.38	18.73	1.53
	Area	254.58	47.09	257.63	49.42	305.80	66.03
Group B	l	18.05	1.85	18.10	1.84	19.00	1.99
	a	9.13	2.01	9.12	2.85	10.90	2.75
	b	17.83	2.04	18.10	2.41	18.50	2. 71
	Area	243.35	39.12	245.67	47.84	279.03	5 1.84

Table 2: Anova table for Group A (Parameter 'L')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.850	2	6.925	.906	.408
Within Groups	665.175	87	7.646		
Total	679.025	89			

$p > 0.05$

Table 3: Anova table for Group A (parameter 'a')

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	172.356	2	86.178	10.560	.000
Within Groups	709.967	87	8.161		
Total	882.322	89			

$p < 0.05$

Table 4: Tukey's multiple comparison test for Group A (parameter 'a')

Minor	Minor	Mean Difference	Std. Error	Sig.
NHP	Below 20	.13333	.73759	.982
	Above 20	-2.86667*	.73759	.001
Below 20	Above 20	-3.00000*	.73759	.000

Table 5: Anova table for Group A (parameter 'b')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21.839	2	10.919	4.417	.015
Within Groups	215.075	87	2.472		
Total	2 36.914	89			

$p < 0.05$

Table 6: Tukey's multiple comparison test for Group A (parameter 'b')

Minor	Minor	Mean Difference	Std. Error	Sig.
NHP	Below 20	.31667	.40597	.716
	Above 20	-.85000	.40597	.097
Below 20	Above 20	-1.16667*	.40597	.014

Table 7: Anova table for Group A (parameter 'area')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	49524.772	2	24762.386	8.235	.001
Within Groups	261596.308	87	3006.854		
Total	311121.081	89			

$p < 0.05$

Table 8: Tukey's multiple comparison test for Group A (parameter 'area')

Minor	Minor	Mean Difference	Std. Error	Sig.
NHP	Below 20	-3.05000	14.15828	.975
	Above 20	-51.21667*	14.15828	.001
Below 20	Above 20	-48.16667*	14.15828	.003

Table 9: Anova table for Group B (parameter 'l')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.150	2	8.575	2.388	.098
Within Groups	312.375	87	3.591		
Total	329.525	89			

$p > 0.05$

Table 10: Anova table for Group B (parameter 'a')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	63.017	2	31.508	4.801	.011
Within Groups	571.008	87	6.563		
Total	634.025	89			

$p < 0.05$

Table 11: Tukey's multiple comparison test for Group B (Parameter 'A')

Minor	Minor	Mean Difference	Std. Error	Sig.
NHP	Below 20	.01667	.66148	1.000
	Above 20	-1.76667*	.66148	.024
Below 20	Above 20	-1.78333*	.66148	.023

Table 12: Anova table for Group B (Parameter 'B')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.756	2	3.378	.585	.559
Within Groups	502.367	87	5.774		
Total	509.122	89			

$p > 0.05$'

Table 13a: Anova table for Group B (parameter 'area')

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	23919.785	2	11959.893	5.514	.006
Within Groups	188703.947	87	2169.011		
Total	212623.732	89			

$p < 0.05$

Table 13b: Tukey's multiple comparison test for Group B (parameter 'area')

Minor	Minor	Mean difference	Std. Error	Sig.
NHP	Below 20	-2.31333	12.02500	.980
	Above 20	-35.68167*	12.02500	.011
Below 20	Above 20	-33.36833*	12.02500	.018

Intergroup comparison between Group A and Group B at NHP, 20 degrees flexion and 20 degrees extension

Table 14: At the NHP

		N	Mean	Std. Deviation	Std. Error Mean	t-test value	d.f.	p-value
l	Group A	30	18.4333	2.92060	.53323	0.607	58	0.546
	Group B	30	18.0500	1.84928	.33763			
a	Group A	30	9.6333	2.25118	.41101	0.907	58	0.368
	Group B	30	9.1333	2.01260	.36745			
b	Group A	30	17.8833	1.77959	.32491	0.101	58	0.920
	Group B	30	17.8333	2.03560	.37165			
Area	Group A	30	254.5833	47.09182	8.59775	1.005	58	0.319
	Group B	30	243.3533	39.12461	7.14314			

Table 15: At flexion

		N	Mean	Std. Deviation	Std. Error Mean	t-test value	d.f.	p-value
l	Group A	30	19.0333	2.72262	.49708	1.554	58	.126
	Group B	30	18.1000	1.84484	.33682			
a	Group A	30	9.5000	2.37443	.43351	.567	58	.573
	Group B	30	9.1167	2.84570	.51955			
b	Group A	30	17.5667	1.38174	.25227	1.051	58	.298
	Group B	30	18.1000	2.41190	.44035			
Area	Group A	30	257.6333	49.42304	9.02337	.953	58	.345
	Group B	30	245.6667	47.83869	8.73411			

Table 16: At extension

		N	Mean	Std Deviation	Std. Error Mean	t-test value	d.f.	p-value
l	Group A	30	19.3833	2.64472	.48286	.635	58	.528
	Group B	30	19.0000	1.98703	.36278			
a	Group A	30	12.5000	3.71158	.67764	1.898	58	.063
	Group B	30	10.9000	2.74616	.50138			
b	Group A	30	18.7333	1.52978	.27930	.410	58	.683
	Group B	30	18.5000	2.71331	.49538			
Area	Group A	30	305.8000	66.03246	12.05582	1.746	58	.086
	Group B	30	279.0350	51.84359	9.46530			

Discussion

Natural head posture (NHP) is the upright position of the head of a standing or sitting subject, while it is balanced by the post-cervical and masticatory-suprahyoid-infrahyoid muscle groups, with the eyes directed forward so that the visual axis is parallel to the floor. It is primarily controlled by the need to maintain a patent pharyngeal airway, and other guiding mechanisms such as sight, hearing and vestibular orientation, and mass and contour of the head.

The physiologic position of the head in standing (NHP) has been used in earlier airway studies too. Obstructed airways can cause adaptation in anatomic structures. Solow B, Siersbaek-Nielsen S, Greve E.[8] (1984), Solow. B (1993)[9] Özbek.M.10 (1998) large craniocervical angle in OSA patients is a physiological adaptation aiming to maintain airway adequacies while the head and the visual axis, is kept in its natural relationship to the true vertical. The average craniocervical angle was found to be extremely large exceeding the average values in the control samples. The large craniocervical angle in OSA patients is a physiological adaptation aiming to maintain the airway adequacies while the head, and the visual axis is kept in its natural relationship to the true vertical. The average craniocervial angle in the obstructive sleep apnoea sample was found to be 12 degrees larger than that observed in control. Monitoring of head posture is important in diagnosis and evaluation of treatment results. Tangugsom. V, Lyberg. T[4] (1995), Cuccia. M.A et al[11] (2008) concluded that oral breathers showed greater extension of the head related to the cervical spine, more skeletal divergence, compared with physiologic breathing subjects. They found that oral breathing causes an increase in head elevation and a greater extension of the head related to the cervical spine and influences hyoid bone position and inter maxillary divergence. Changing the mode of breathing from oral to nasal early in adolescence may promote a tendency towards normalization of the craniofacial dimensions with growth.

Head postures can affect the airway too. G. Liistro, D. Stanescu[12] (1988) measured healthy volunteers, resistance of the respiratory system and supra laryngeal resistance in the different head positions such as neutral, extended, and partially and fully flexed. Resistances decreased when the subject's heads were extended. Unlike our study, instead of a cephalogram, a Sagittal magnetic resonance images used to measure the changes. The results were similar to the present study. A decrease in both diameter and surface area of the hypo pharyngeal airways with total head flexion was accompanied by significant increases in all measured resistances. Changes in the caliber of hypo pharynx appear to be responsible for the increase in resistance during head flexion. Odeh.M[13] (1995) examined the effect of flexion and extension of the head on upper airway (UAW) patency in anesthetized dogs; they compared the dilatory and stabilizing effects of electrically stimulated UAW muscles at the different head positions. The genioglossus stimulation was most effective in reducing upper airway resistance. They concluded that, head position affects the mechanical properties of the UAW and the effects of UAW muscle contraction.

Applications of these findings is wider under general anesthesia Murali and James[14] (1996) Walsh.J[15] (2008) involving lateral cephalograms of supine patients, in head flexion and extension, during consciousness and after induction of general anaesthesia and muscle paralysis. General anaesthesia causes posterior displacement of upper airway structures that is associated with airway obstruction. Extension of the head, helps restore patency. With the head in flexion, anaesthesia and paralysis caused posterior displacement of the epiglottis and oropharyngeal narrowing. Neck flexion displaces the tongue backward, E.Verin, S. Series[16] (2002) thereby reducing the pharyngeal caliber and modifying the oropharyngeal shape.

Respiratory airway functions influences craniofacial morphology as well as cervical posture. Rickets suggested that head extension represented a functional response in mouth breathing patients to compensate for nasal obstructions. There exist an intrinsic relationship between craniofacial morphology and upper airway morphology; this can be applied in the diagnosis and treatment of patients with respiratory problems. Neck extension decreases closing pressures of the velopharynx and oropharynx and increases maximum oropharyngeal airway size, while neck flexion and bite opening increased closing pressures of the velopharynx and oropharynx and decreased maximum oropharyngeal airway size, Isono. S, et al[17] (2004). Isono conducted invitro study where, he used a collapsible tube surrounded by soft material within a rigid box as a two-dimensional mechanical model for the pharyngeal airway. This was the first study that purely evaluated regional structural changes of airway collapsibility by mechanical interventions under the elimination of neural mechanisms. While we used 20 degrees of extension and flexion, E. Anegawa, H. Tsuyama[18] (2008) studied the posterior airway space by using Five different head postures at +/-5mm, +/-10mm, +/-15mm and +/-20 mm from position 0, to evaluate the PAS. Additional radiographs were taken after extending the cervical spine forwards from the natural head position up to 20mm. At natural head position the mean angle between the cranio- cervical angulations and the sella nasion line was 100.9 degrees for males and 103.5 degrees for females. In the forward neck extension all the cranio cervical inclination, the PAS increased significantly. The study revealed a strong co relation between cranio cervical inclination and the PAS at every pharyngeal level.

The malocclusion cannot influence the upper pharyngeal airway width and neither the malocclusion type nor the growth pattern influences lower pharyngeal airway width. Lowe et al[19] (1986), Marcos Roberto de Freitas[20] (2006) compared upper and lower pharyngeal widths in patients with untreated Class I and Class II malocclusions and normal and vertical growth patterns. The results showed that the upper pharyngeal width in the subjects with Class I and Class II malocclusions and vertical growth patterns was statistically significantly narrower than in the normal growth-pattern groups. F. Ucar, T. Uysal[21] (2011) cephalometrically studied Class I malocclusion subjects for orofacial airway dimensions with different growth patterns and found that there is significant difference in airway dimension in normal, vertical and horizontal growth patterns. Similar to our study, they found no significant relation between a normal growing and a low angle growing subjects. They also found the nasopharyngeal space and PAS to be smaller in the high angle subjects than the low mandibular angle.

Although long-faced subjects have a higher mean value of nasal resistance, the nasal obstruction cannot be diagnosed by assessing facial morphology. Respirometric techniques have been used for the relationship between facial morphology and nasal respiration. Vig P. S, Sarver D.M[22] (1981), studied three groups based on those having normal facial proportions with competent lips, normal facial proportions with incompetent lips and long vertical face height. They did not differ significantly in terms of nasal airflow. The normal and long-faced individuals significantly differ with respect to lower face form. Feilds H. and Warren.D.[23] (1991) demonstrated that airway impairment may be behavior based and not always airway dependent. Despite these findings, we can't ignore long face syndrome, as the switching range from nasal to nasal-oral breathing is very narrow. Warren D. confirmed the contention that in adults an airway <0.4 cm^2 can lead to mouth breathing.

Like the present study, a derived geometry on radiograph was used by Harvold E. P[24] (1954) they used The X – line. It was a horizontal line connecting the lateral part of the zygomatic co-frontal sutures bilaterally. Another vertical line was drawn perpendicular to that line from the root of crysta galli. The growth of the nasal septum and the premaxilla occur at an early age and can be modified at a later stage. Hence it should be the objective of an orthodontist to try and bring the growth to as normal as possible. In the present study we borrowed the trapezoid rule, introduced by Preston, Lapasso and Tobias[6] (2004). They demarcated the borders of the trapezoid by lines derived by joining various points on the cephalometric tracing. According to them this trapezoidal areas depicts the combination of adenoid tissue and the airway space. The flow of inspired air is subjected to the physical restraints of the fluid flow dynamics. Any constriction in the airway leads to resistance to the nasal air flow

Conclusion

In the present study we established that, the increase in the airway with extension was seen in horizontal, average and vertical growth pattern. Although this increase was greater in the horizontal and normal counterparts than the vertical, the difference was not statistically significant. Hence vertical growers can equally benefit from head extension in temporary increase in the airway. By increasing the patency of the airway, we can improve the overall quality of life of an individual.

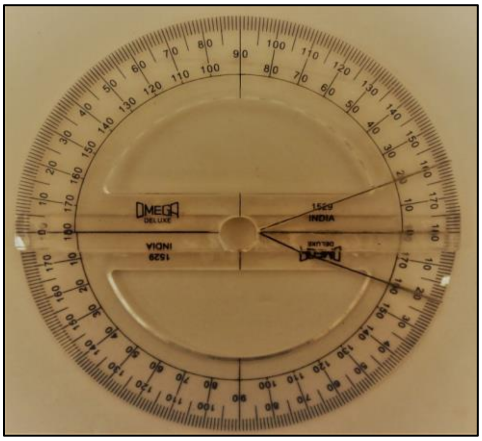

Fig. 1: Measuring Jig

Fig. 2: Patient positioned in the cephalostat at NHP

Fig. 3: Patient positioned in the cephalostat at flexion

Fig. 4: Patient positioned in the cephalostat at extension

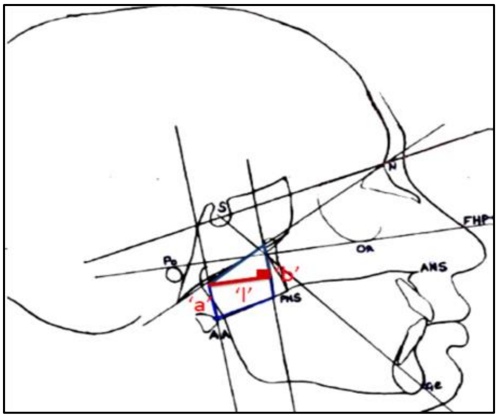

Fig. 5: Cephalometric tracing on radiograph

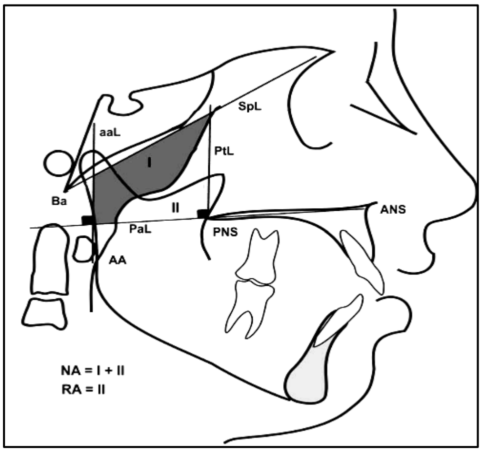

Fig. 6: Derived trapezoid

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