VALÉRIO LANDIM DE ALMEIDA

"CORRELAÇÃO ENTRE PADRÃO ESQUELÉTICO, ESPAÇO AÉREO FARÍNGEO, ALTURA DO PALATO E ÁREAS DOS SEIOS MAXILAR E FRONTAL DE CRIANÇAS E ADOLESCENTES"

PIRACICABA

2013

UNIVERSIDADE ESTADUAL DE CAMPINAS

FACULDADE DE ODONTOLOGIA DE PIRACICABA

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Orientador: Prof. Dr. Paulo Henrique Ferreira Caria

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Este exemplar corresponde à versão final da dissertação defendida pelo aluno Valério Landim de Almeida e orientada pelo Prof. Dr. Paulo Henrique Ferreira Cária.

Assinatura do Orientador

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RESUMO

A morfologia de tecidos moles pode interferir no crescimento e no desenvolvimento das estruturas craniofaciais causando maloclusões. As avaliações dessas alterações durante o crescimento são importantes para a restauração do padrão do crescimento. O objetivo deste estudo foi correlacionar o padrão esquelético com o espaço aéreo faríngeo, a altura do palato e as áreas dos seios maxilar e frontal de crianças e adolescentes. Para isso, foram selecionadas 116 telerradiografias laterais, 55 do gênero feminino, com idade média de 12,04 (DP ±3,04) anos e 61 do gênero masculino com média de idade de 11,91 (DP ±2,92) anos. As telerradiografias foram digitalizadas e as aferições realizadas por um mesmo pesquisador com o software Image J. Para avaliação do padrão esquelético utilizou-se a análise de Wits. Em seguida, a altura do palato, o espaço aéreo faríngeo, as áreas do seio maxilar esquerdo e do seio frontal foram aferidas. Os grupos se distribuíram conforme o gênero e as classes esqueléticas I, II ou III. O coeficiente de correlação intraclasse para todas as medidas foi > 0,99. Adotaram-se modelos de análise de variância apropriados para cada uma das variáveis e houve comparação das médias pelo teste de Tukey a 5% de probabilidade. O espaço aéreo faríngeo foi significativamente maior para o grupo masculino III quando comparado com o feminino de mesma classe. O gênero masculino classe III apresentou maior altura do palato, havendo diferença significativa entre masculino III e masculino I. Não houve diferença entre as médias do seio maxilar. Para o seio frontal houve diferença estatística para as classes II e III e entre os gêneros, exceto para classe I. A análise de correlação de Pearson não comprovou associação entre o padrão esquelético e as demais variáveis, entretanto, sugeriu associação positiva entre seio frontal e seio maxilar ($p<0{,}0001$); seio frontal e espaço aéreo faríngeo ($p=0{,}025$); seio frontal e altura do palato ($p<0{,}0001$); seio maxilar e altura do palato ($p<0{,}0001$). Os resultados indicam que o crescimento da face sofre influência da tensão mastigatória e que o padrão esquelético não é o principal determinante das dimensões das variáveis estudadas nesse estágio de crescimento. As correlações positivas encontradas entre as outras variáveis indicam uma relação de dependência e sugere interação biomecânica entre essas estruturas.

Palavras-chave: Maloclusão; Faringe; Biomecânica; Seio Maxilar; Seio Frontal.

ABSTRACT

Morphology of the soft tissues interferes with growth and development of craniofacial structures causing malocclusions. Evaluation and diagnostic of musculoskeletal discrepancies in growing patients are especially important for the re-establishment of craniofacial growth pattern. The aim of this study was to correlate the skeletal patterns with the pharyngeal airway space, height of the palate, and areas of the maxillary and frontal sinuses of children and teenagers. Sample included 116 lateral cephalometric radiographs of 55 females with a mean age of 12.04 (SD ±3.04) and 61 males with a mean age of 11.91 (SD ±2.92). Cephalometric radiographs were digitized and all measurements performed by the same examiner using the software Image J. In each radiograph were measured the height of palate, pharyngeal airway space, area of the left maxillary sinus and area of the frontal sinus. Sample was divided in groups (I, II and III) according to gender and skeletal patterns defined by Wits appraisal. Intra-examiner reliability test showed ICC>0.99. Variables were summarized using basic statistics and subsequently by appropriated models of analysis of variance (ANOVA) for each variable. The means were compared by Tukey test at 5%. Pharyngeal airway space revealed a significant difference between the genders for class III group ($p<0.001$). The height of the palate showed a significant difference between the genders for classes I and III ($p<0.001$). To maxillary sinus there was no significant difference between the groups. The area of the frontal sinus showed a significant difference between genders for classes II and III ($p<0.001$). Data indicates that skeletal patterns was not related to the other variables, however a positive correlation was found between the area of the frontal sinus and the area of the maxillary sinus ($p<0.0001$); area of the frontal sinus and pharyngeal airway space ($p=0.025$); area of the frontal sinus and the height of the palate ($p<0.0001$); area of the maxillary sinus and the height of the palate ($p<0.0001$). The skeletal pattern is not the main factor to determine the pharyngeal airway space size, height of the palate and area of the maxillary and frontal sinuses in those stages of growth. However, the positive interactions found among other variables indicate a correlation of dependence and suggests biomechanical interaction between these structures.

Keywords: Malocclusion; Pharynx; Biomechanics; Maxillary sinus; Frontal sinus.

SUMÁRIO

INTRODUÇÃO

Forças mecânicas controlam os processos biológicos e suas alterações por meio de interações entre as células e o ambiente (Discher *et al*. 2005). Essas interações ocorrem sob condições dinâmicas, como o espaço aéreo faríngeo e as estruturas dentofaciais e podem levar a deformidades, como maloclusões (Ceylan &.Oktay, 1995). Pesquisas atribuem a maloclusão esquelética como etiologia ou como resultado de mudanças morfológicas das vias aéreas (Alves *et al*, 2008; Kim *et al*, 2010). As maloclusões podem afetar a morfologia de tecidos moles, principalmente da faringe, uma vez que seu diâmetro anteroposterior é influenciado pelo posicionamento de estruturas ósseas (Mergen & Jacobs, 1970; Solow, Siersbaek-Nielsen, Greve, 1984; Battagel *et al*, 1999; Archilleos, Krogstad, Lyberg, 2000).

Em telerradiografias laterais da cabeça, frequentemente observa-se um espaço entre a superfície da língua e o palato duro, sendo este último considerado um dos limites ósseos das vias aéreas superiores (Bourdiol *et al*, 2010). A morfologia do palato duro influencia o posicionamento da língua que pode exercer pressão sobre a parede posterior da faringe causando redução do espaço aéreo (Fairburn *et al*, 2007, Abramson *et al*, 2010, Bourdiol *et al*, 2010).

Conhecer o desenvolvimento e o tamanho do seio maxilar contribui para diagnosticar e tratar casos de maloclusões. Estudos baseados em tomografia computadorizada e em telerradiografia lateral mostram que medições morfológicas dentofaciais se correlacionam positivamente com as medidas do seio maxilar, sugerindo que, quando o seio maxilar é maior, maior é a morfologia dentofacial (Endo *et al*, 2010). De modo semelhante, trabalhos realizados com análises de imagens radiográficas ou de tomografia computadorizada relatam variações morfológicas do seio frontal, relacionando-as com dimensões cranianas (Ruiz & Wafae, 2004; Sahlstrand-Johnson *et al*, 2011).

O uso de radiografias é justificável uma vez que a telerradiografia lateral é validada como uma ferramenta útil para descrever o espaço aéreo nasofaríngeo ou retropalatal quando comparada a outros métodos de imagem tridimensionais como a ressonância magnética e a tomografia computadorizada (Van Vlijmen *et al*, 2010; Pirilä-

Parkkinen *et al*, 2011; Wang *et al*, 2012). Além desses aspectos, a telerradiografia oferece vantagens consideráveis sobre outras técnicas, incluindo o baixo custo, a menor exposição à radiação e a possibilidade de se analisar simultaneamente a posição da cabeça, do osso hioide e a morfologia craniofacial (Muto *et al*, 2006).

Muitas análises cefalométricas empregam medidas que não são adequadas para a avaliação da desarmonia maxilo-mandibular. Algumas relacionam mandíbula e maxila a referências cranianas que podem causar inconsistências devido às variações esqueléticas craniofaciais. No entanto, a análise de Wits determina a relação anteroposterior entre maxila e mandíbula e permite diagnosticar a severidade ou grau de desarmonia mandibular cefalometricamente (Jacobson, 1975, 2003). A influência dos tecidos moles no crescimento craniofacial é relevante para o diagnóstico ortodôntico e plano de tratamento. (Martin, Muelas, Vinas, 2006). Por essa razão, a avaliação bem como o diagnóstico precoce das discrepâncias musculoesqueléticas em pacientes ainda em crescimento são de grande importância para a restauração do padrão do crescimento craniofacial (Kim *et al*, 2010).

Baseado nos diferentes resultados entre a análise do espaço aéreo faríngeo e as estruturas esqueléticas, esta pesquisa avaliou a correlação entre mandíbula e maxila, medida pela avaliação Wits, espaço aéreo faríngeo, altura do palato e áreas dos seios maxilar e frontal de crianças e adolescentes.

CAPÍTULO 1

Esta dissertação está baseada na Resolução CCPG UNICAMP/002/06 que regulamenta o formato alternativo para teses e dissertações apresentadas aos cursos de Pós-Graduação da Universidade Estadual de Campinas e permite a inserção de artigo científico de autoria ou coautoria do candidato. Por se tratar de pesquisa envolvendo seres humanos, o projeto de pesquisa foi submetido à apreciação do Comitê de Ética em Pesquisa da Faculdade de Odontologia de Piracicaba, e obteve aprovação com o número de protocolo 005/2012 (Anexo 2). Assim sendo, esta dissertação é composta de um artigo, conforme descrito a seguir:

CORRELATION BETWEEN SKELETAL PATTERN, PHARYNGEAL AIRWAY SPACE, HEIGHT OF THE PALATE AND AREAS OF THE MAXILLARY AND FRONTAL SINUSES OF CHILDREN AND TEENAGERS.*

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*** Submitted to Dentomaxillofacial Radiology (Anexo 1)**

Abstract

Objectives: To correlate the skeletal pattern with the pharyngeal airway space, height of the palate, and areas of the maxillary and frontal sinuses of children and teenagers.

Methods: The skeletal malocclusion was determined by the Wits appraisal in 116 lateral cephalometric radiographs (55 females and 61 males). These radiographs were digitized and all measurements were performed by the same examiner.

Results: The intra-examiner reliability test showed a high value - ICC>0.99 (for a minimum period of 30 days, 20% of the sample were randomly selected and measured again). The pharyngeal airway space revealed a significant difference between the genders for the class III group ($p<0.001$). The height of the palate showed a significant difference between the genders for skeletal classes I and III ($p<0.001$). Regarding maxillary sinus there was no significant difference between the groups. The area of the frontal sinus showed a significant difference between genders for skeletal classes II and III ($p<0.001$). There was a moderate positive interaction between the frontal sinus with the maxillary sinus ($r=0.636$) and with the height of the palate ($r=0.404$). Still considering the frontal sinus, there was a weak positive correlation with the pharyngeal airway space ($r=0,209$). The maxillary sinus showed a moderate positive interaction with the height of the palate ($r=0.439$).

Conclusions: The skeletal pattern is not the main determinant of the size of the pharyngeal airway space, the height of the palate and the area of the maxillary and frontal sinuses in this stage of growth. However, the positive correlations found among other variables indicate a relationship of dependence and suggests biomechanical interaction between these structures.

Keywords: Malocclusion; Pharynx; Maxillary sinus; Frontal sinus.

Introduction

Mechanical forces control normal biological process and their alterations through cell-environment interactions. [1] These interactions occur under dynamic conditions, as pharyngeal airway space and the dentofacial structures and they can lead to deformities such as malocclusions [2]. Researches attribute the skeletal malocclusion as etiology or as a result of the morphology changes of the airway [3] [4]. Malocclusions can affect soft tissue morphology, mainly the pharynx, once its anteroposterior diameter is influenced by the positioning of bony structures [5] [6] [7] [8]. Cephalometric radiographs allow observing the space between the surface of the tongue and the hard palate, considered a bony limit of the upper airway [9]. The morphology of the hard palate influences the positioning of the tongue that can put pressure on the posterior wall of the pharynx, consequently reducing the airspace. [9] [10] [11]

The knowledge of the size and development of the maxillary sinus can help to diagnose and treat cases of malocclusion. Computed tomography and lateral cephalometric radiograph-based on studies show that morphologic measurements are positively correlated with the measures of the maxillary sinus, suggesting that when the maxillary sinus is greater, greater is the dentofacial morphology. [12]

Likewise, radiograph or computed tomography image analysis report morphological variations of the frontal sinus, relating them with cranial dimensions [13] [14]. Lateral cephalometric radiograph is validated as a useful screening tool to evaluate the nasopharyngeal or retropalatal airway size compared with other three-dimensional methods such as magnetic resonance imaging [15] and computed tomography [16] [17]. In addition, it offers considerable advantages over other techniques, including low cost, less exposure to radiation and the possibility of simultaneously analyze head and hyoid position and craniofacial morphology [18].

Many cephalometric analyses employ measurements that are not adequate for appraisal of maxillomandibular disharmony. Some relate jaw to cranial references which may cause inconsistencies because of craniofacial skeletal variations. However, Wits appraisal of jaw disharmony is a measure of the extent to which the jaws are related to each other anteroposteriorly. Wits appraisal is not only an assessment, but also an aid in the diagnosis of the severity or degree of anteroposterior maxillomandibular disharmony measured on a lateral cephalometric radiograph [19] [20]. The influence of soft tissues in craniofacial growth is relevant for orthodontic diagnosis and treatment plan [21]. For this reason, the evaluation and the early diagnostic of musculoskeletal discrepancies in growing patients are especially important for the re-establishment of craniofacial growth pattern [4].

Based on the different results between the pharyngeal airway space analysis and the dentofacial structures, this research evaluated the correlation among maxillomandibular relationship, measured by Wits appraisal, with the pharyngeal airway space, height of the palate and areas of the maxillary and frontal sinuses of children and teenagers.

Materials and methods

Sample

A total of 116 lateral cephalometric radiographs from the files of the Anatomy Area of Piracicaba Dental School - State University of Campinas (FOP/Unicamp) were evaluated. This radiographs comprised 55 females with an average age of 12.04 (SD ± 3.04) years and 61 with an average age of 11.91 (SD ± 2.92).

The sample included patients between 7 and 18 years who had minimally the first permanent molars. Were excluded from the study all subjects undergone tonsillectomy, adenoidectomy, orthodontic treatment or whose records showed agenesis or extractions, presence of cysts, sinusitis, tumors or asymmetry. The study was approved by the local research ethics committee (protocol nº 05/2012).

Measurements

Lateral cephalometric radiographs were scanned (HP Scanjet G4050, Hewlett-Packard Company, Palo Alto, CA-USA) with a resolution of 300 dpi and 100% image size. Points, lines and measurements were performed by the same examiner using the software Image J, version 1.45 (National Institutes of Health, Bethesda, MD-USA).

Wits appraisal of jaw disharmony was used to evaluate skeletal patterns by drawing a perpendicular line from point A (the deepest concavity of anterior nasal spine) to the occlusal plane (the region of maximum intercuspation, considering molars and premolars). Another perpendicular line was drawn from the point B (the deepest concavity of anterior mandibular symphysis) to the occlusal plane. These contact points on the occlusal plane are named AO and BO, respectively (Figure 1) [19] [20]. Skeletal patterns are defined according to linear measurement between AO and BO:

Class I: AO-BO between -3.07 e 0.73 (men); AO-BO between -1.87 e 1.67 (women).

Class II: AO-BO greater than 0.73 (men); AO-BO greater than 1.67 (women).

Class III: AO-BO less than -3.07 (men); AO-BO less than -1.87 (women).

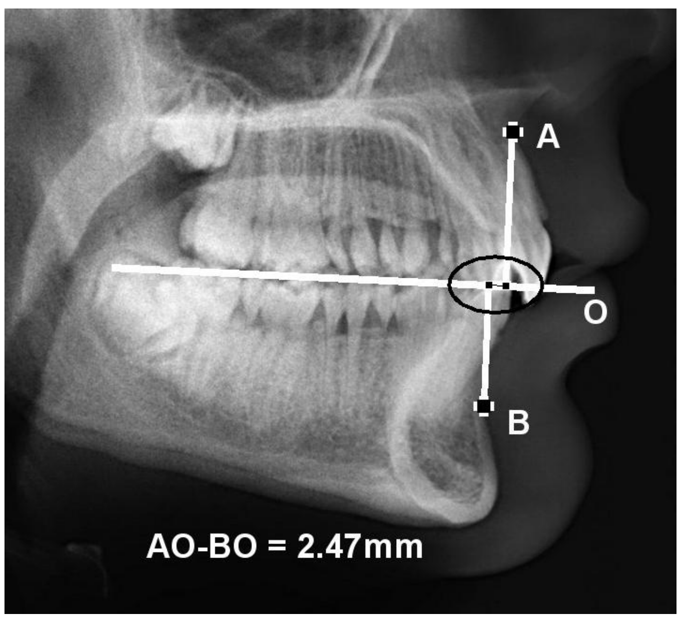

Figure 1 - Lateral cephalometric radiograph with tracings according Wits appraisal [19] [20]. The length of line AO-BO defines the skeletal patterns. The radiograph in this example shows a female who has a class II malocclusion.

The anteroposterior diameter of the pharyngeal airway space was measured perpendicularly to the direction of the airway at 6 levels. For each subject 11 anatomic landmarks (Table 1) and 6 linear measurements were defined: mp-ad1, mp -ad2, tu-ad3, ve-pve, uv-puv e rl-prl.

The mean value (in millimeters) of 6 linear measurements was used to represent the pharyngeal airway space (Figure 2). These criteria were adapted from Solow [(22)] who evaluated the pharyngeal airway space ranging from the maxillary tuberosity to the vallecula of the epiglottis. That region was not measured in this study because it is has no clear outline.

Height of the palate was obtained from the length (mm) of a perpendicular line drawn from the occlusal plane, used at Wits appraisal, to the point of highest elevation of the hard palate on its underside (Figure 3).

Table 1 – Definition of landmarks (adapted from Solow) [20] on the lateral cephalometric radiographs.

Landmarks	Definition
Anterior Landmarks	
tu	Tuber maxillae, the most dorsal point of the maxillary tuberosity.
pm	Pterygomaxillary, the intersection between the nasal floor and the dorsal contour of the maxilla.
ve	Velum palate, the point on the soft palate closest to the dorsal pharyngeal wall.
uv	Uvula, the tip of the uvula of the soft palate.
rl	Radix linguae, the point on the root of the tongue closest to the dorsal pharyngeal wall.
Posterior Landmarks	
ad1	The intersection of a line from pm to the Basion (Ba) with the adenoid tissue/dorsal pharyngeal wall closest to pm.
ad2	The point on the adenoid tissue/dorsal pharyngeal wall closest to pm.
ad3	The point on the adenoid tissue/dorsal pharyngeal wall closest to tu.
pve	The point on the dorsal pharyngeal wall closest to ve.
puv	The point on the dorsal pharyngeal wall closest to uv.
Prl	The point on the dorsal pharyngeal wall closest to rl.

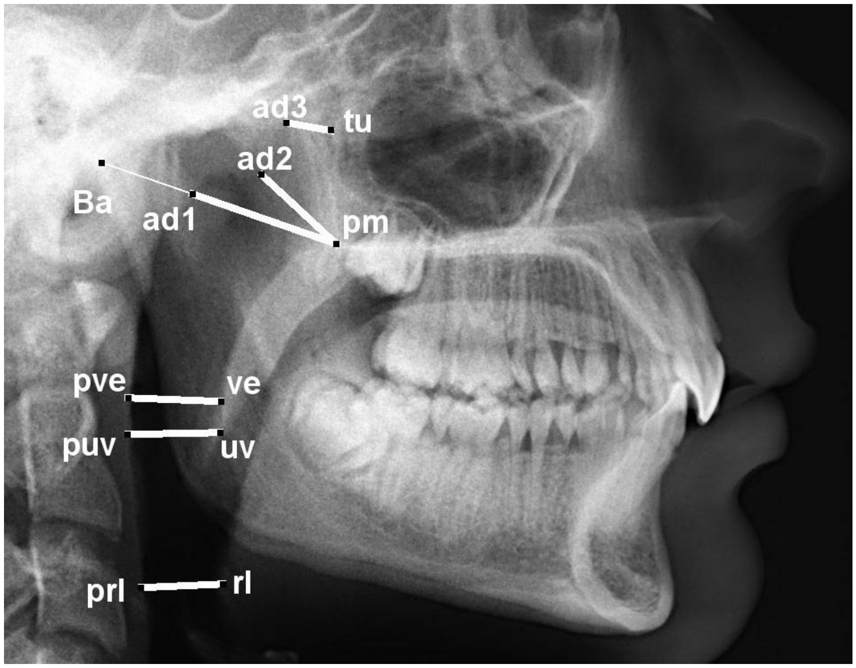

Figure 2 - Linear measurements of 6 regions of the pharyngeal airway space. [22]

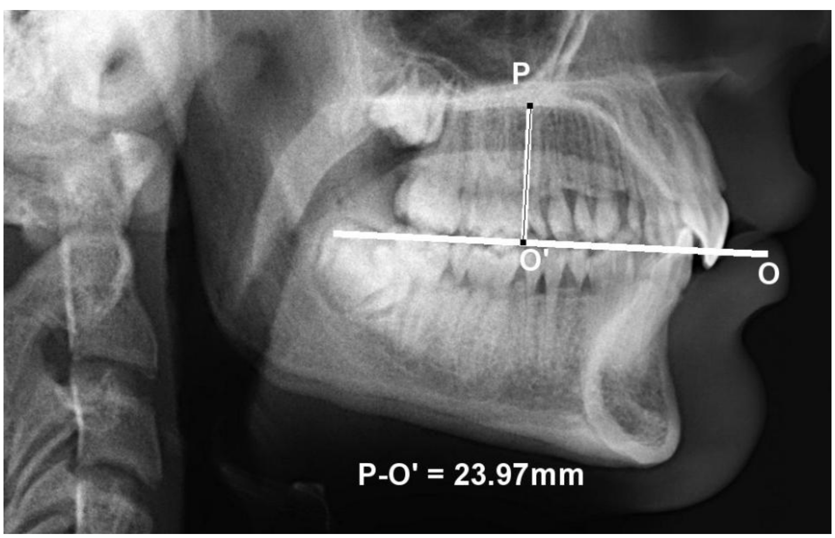

Figure 3 - Height of the palate measured from occlusal plane.

To measure the area of the maxillary sinus, the right and left sinuses were distinguished, so tracing was performed at the left maxillary sinus [12]. After outlining the limits, the area in mm^2 was calculated (Figure 4).

Frontal sinus was measured (mm^2) after outlining the limits [(23)], similarly to the maxillary sinus (Figure 4).

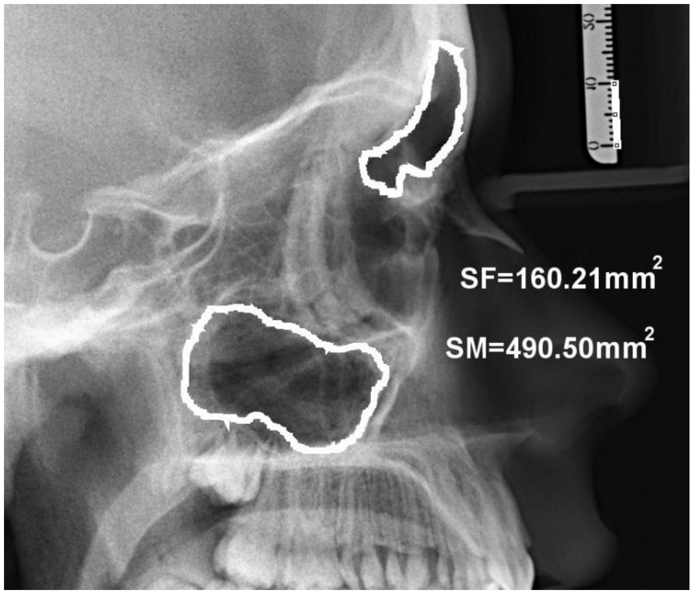

Figure 4 - Measurement of the areas of the maxillary [12] and frontal sinuses. [23]

Statistical Analysis

Statistical analysis was performed using SAS (*The SAS System, release 9.2. SAS Institute Inc., Cary: NC, 2008*). Intraclass correlation coefficient (ICC) was used to assess the intra-examiner reliability: for a minimum period of 30 days, 20% of the sample were randomly selected and measured again. Before starting calculations, the sample was divided in groups according to gender and skeletal patterns. Numerical variables were summarized using basic statistics (mean, standard deviation and limits of the confidence interval), and subsequently by appropriated models of analysis of variance (ANOVA) for each variable. The normality of residuals was assessed by the Akaike Information Criterion (AIC) and the means were compared by Tukey test at 5% probability. Multiple linear regression was performed to analyze the effect of the measures of the pharyngeal airway space at the mean of the pharynx. The Pearson correlation analysis was used to assess the association between skeletal patterns (length of line AO-BO) and other variables. The significance level for all analyses performed was $\alpha < 0.05$.

Results

The intra-examiner reliability test showed excellent reproducibility between the two readings (ICC>0.99) for all measurements.

Women's Wits analysis presented: Class I, 24 subjects, Class II, 9 subjects, Class III, 22 subjects. For men: Class I, 21 subjects, Class II, 21 subjects, Class III, 19 subjects. From this division by sex and skeletal patterns, results were associated with the other variables.

The distance between the pterygomaxillary point and the posterior pharyngeal wall (pm-ad2) was the most closely correlated with the dimensions of the pharyngeal airway space, presenting in multiple regression analysis, R-Squared = 0.56. This measure associated with the distance between the apex of the uvula and the posterior pharyngeal wall (uv-puv) achieves an R-Squared of 0.85, explaining more than 85% of the anteroposterior diameter of the pharynx (Table 2). In contrast, the measure tu-ad3 did not reach significance for enter in the model.

Table 2 – Multiple linear regression analysis to predict the outcome of the pharyngeal airway space from the set of independent variables.

Step	Measurement	Partial R-Square	Model R- Square	P value
1	pm-ad2	0.5585	0.5585	<.0001
2	uv-puv	0.2948	0.8534	<.0001
3	rl-prl	0.0404	0.8938	<.0001
4	pm-ad1	0.0428	0.9366	<.0001
5	ve-pve	0.0125	0.9491	<.0001

Figure 5 shows that males had higher pharyngeal airway sizes compared to the females for all skeletal patterns, but only on Skeletal Class III the difference was statistically significant ($p<0.001$).

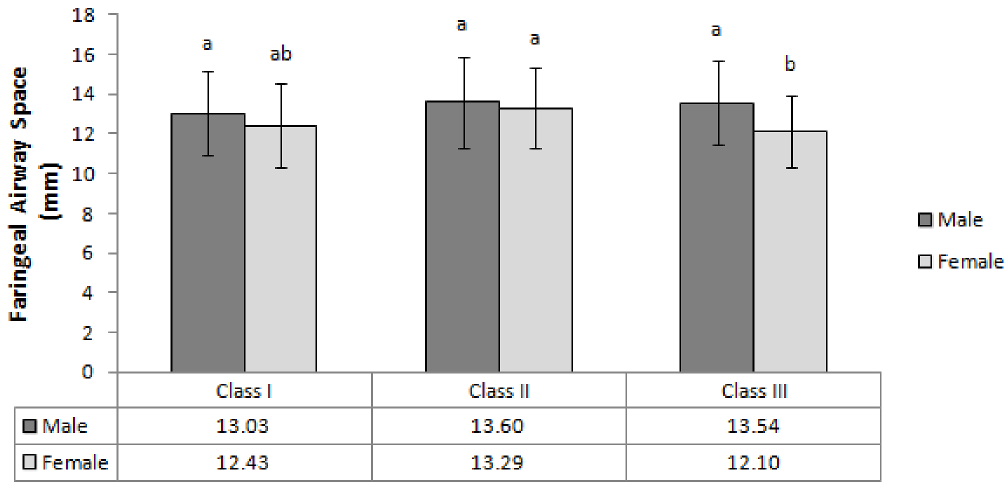

Figure 5 - Pharyngeal airway space (mm) by gender and skeletal pattern. Different letters indicate statistically significant differences at $\alpha = 0.05$.

Figure 6 illustrates the data for the height of the palate which revealed a statistically significant difference between genders for skeletal classes I and III ($p<0.001$).

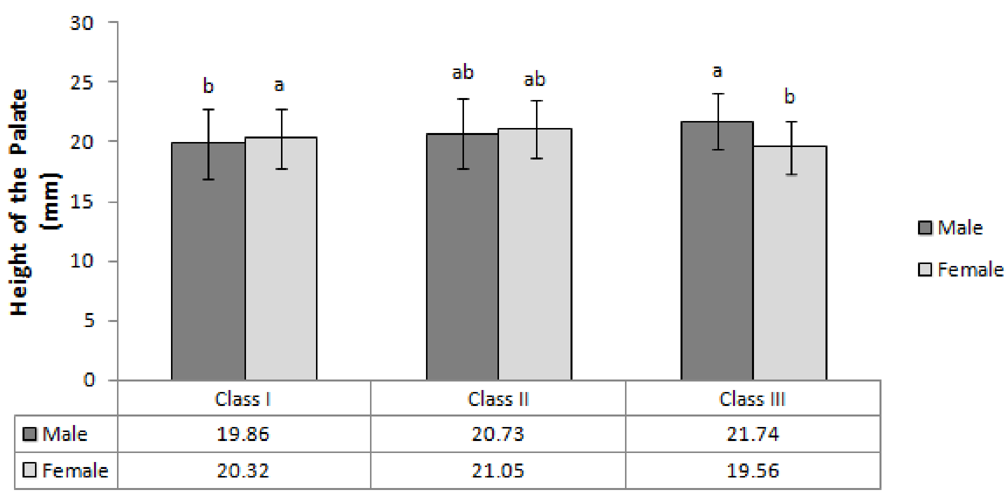

Figure 6 - Height of the palate (mm) by gender and skeletal pattern. Different letters indicate statistically significant differences at $\alpha=0.05$.

Figure 7 revealed the area of the maxillary sinus. Although the males of the class III had higher areas than that of the females, there was no statistically significant difference between the groups ($p=0.0814$). Figure 8 shows the data of the area of the frontal sinus which revealed a statistically significant difference between genders for skeletal classes II and III ($p<0.001$).

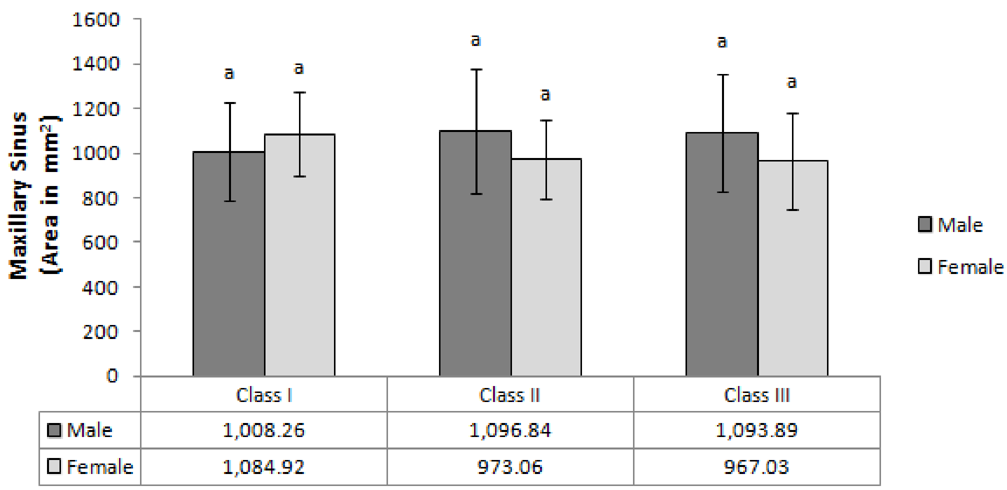

Figure 7 - Area of the maxillary sinus (mm^2) by gender and skeletal pattern. Different letters indicate statistically significant differences at $\alpha = 0.05$.

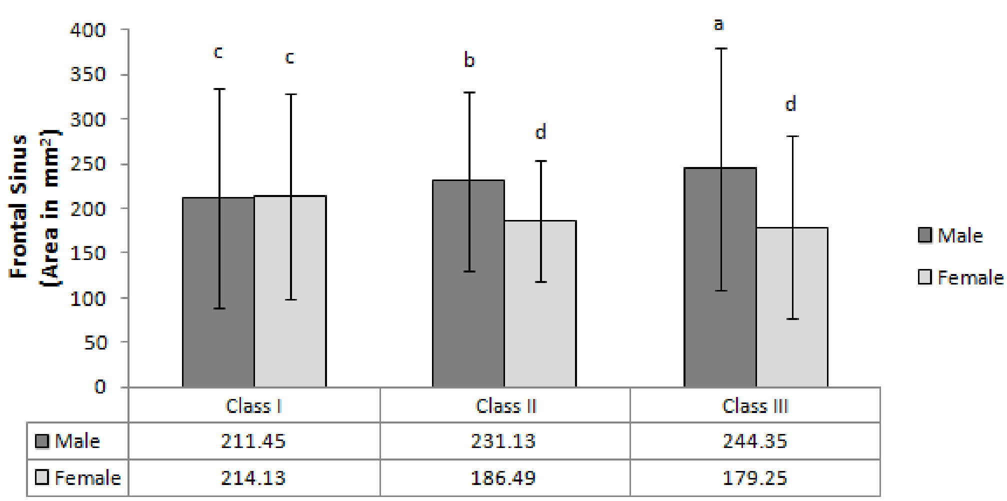

Figure 8 Area of the frontal sinus (mm^2) by gender and skeletal pattern. Different letters indicate statistically significant differences at $\alpha = 0.05$.

Pearson correlation analysis was used to assess the association between variables (Table 3). Data indicates that skeletal patterns was not related to the other variables, however a moderate positive correlation, and highly significant ($p<0.0001$), among the area of the frontal sinus, with the area of the maxillary sinus ($r=0.636$) and the height of the palate ($r=0.404$). Still considering the frontal sinus there was a weak positive correlation with the pharyngeal airway space ($r=0.209$) inside the significant level of 5% ($p<0.025$). There was a moderate positive correlation, and highly significant ($p<0.0001$), of the maxillary sinus with the height of the palate ($r=0.439$).

Table 3 – Results of Pearson's correlation analysis.

	AO-BO reading (Wits)		Pharyngeal airway space		Height of the palate		Maxillary sinus (area)		Frontal sinus (area)	
	r	p	r	p	r	p	r	p	r	p
AO-BO reading (Wits)	1.000	-	0.120	0.1979	-0.012	0.897	0.039	0.675	-0.030	0.749
Pharyngeal airway space	0.120	0.198	1.000	-	-0.123	0.187	0.088	0.349	0.209	0.025*
Height of the palate	-0.012	0.897	-0.123	0.187	1.000	-	0.439	<.0001**	0.404	<.0001**
Maxillary sinus (area)	0.039	0.675	0.088	0.349	0.439	<.0001**	1.000	-	0.636	<.0001**
Frontal sinus (area)	-0.030	0.749	0.209	0.025*	0.404	<.0001**	0.636	<.0001**	1.000	-

r: correlation coefficient; p: P value.
* correlation is significant at the 0.05 level
** correlation is significant at the 0.0001 level

Discussion

The measurements pm-ad2 and uv-puv were the more significant among the pharyngeal airway space. This can be explained because the point ad2 is located at pharyngeal tonsil so that the diameter pm-ad2 is directly associated with lymphoid tissue morphology in this region [21]. Individual factors such as susceptibility to allergies and infections can increase or decrease the size of this area. [24]. The diameter uv-puv is closely related to the morphology of the soft palate whose length is potentially influenced by body constitution [25]. A soft palate longer, for example, bears the point uv (apex of the uvula) closest to the posterior pharyngeal wall (point puv). The remaining measurements (rl-prl, pm-ad1, ve-pve and tu-ad3) are located in regions whose tissues have less morphological variability, which may explain why these diameters were less significant in predicting the pharyngeal airway space (Table 2). It is clinical important to know the areas that may affect the dimensions of the pharyngeal airway space because they are related to diseases or abnormalities of the respiratory system such as snoring and apnea-hypopnea syndrome [25].

For all three skeletal classes studied the male group showed greater pharyngeal airway space when compared with females of the same skeletal class (Figure 5), although the statistical test has shown gender differences only for class III. The upper airway is a complex structure and the soft tissues who forms the nasopharynx and oropharynx are delimited by constituent bones of the facial skeleton [26]. Due to this bone fixation it is normal that men have higher values for the pharyngeal airway space from adolescence because most linear measurements of the face, together with the craniofacial development, becomes greater in males [21] [27]. In addition, inferior pharyngeal airway space is surrounded by mandible and soft tissues which determine major or minor increase in the pharyngeal airway dimensions [18] [28].

Comparing the measure of the pharyngeal airway space among the different skeletal classes in the same gender it was found a significantly greater value for female II compared to female III (Figure 5). However, studies have reported no significant differences in the size or shape of the pharyngeal airway space between young men and women [29] or among the skeletal patterns [3]. This results suggests that other factors of individual variation, as mandibular length, type of breathing and facial growth patterns can be as important as the skeletal patterns in the evaluation of pharyngeal airway space, so that the airway constriction does not represents the only factor associated with malocclusions [30].

For the height of the palate the data were controversial: while for males there was a significant increase in values from class I to class III, for the females there was a significant decrease when comparing these same classes. There is a tendency to higher values for men class III and for women class II (Figure 6).

Knowing the height of the palate is a way to estimate the position of the tongue in the oral cavity. Although not clearly established, it is known that there is a relationship among the position of the tongue, the dimensions of the palate and the facial morphology [9] [31] [32]. Bourdiol [9] has measured the space between the tongue and palate and found lower values for women class II, and the highest values were obtained for men class III. These data confirm that the skeletal pattern is not the only feature that determines the changes in the dimensions of the palate. Should be investigated the habit of breathing, tongue position, tone of the jaw elevator muscles and facial type [33]. These variables did not were evaluated in this study.

Studies have found no statistically significant differences between the dimensions of the left and right maxillary sinus; therefore, the choice of left maxillary sinus to perform the evaluation of the area did not affect the results of the study [4] [14]. These authors found larger maxillary sinuses in males, corroborating with the highest absolute values found for males in classes II and III of this study (Figure 7). Other researches describe a positive relationship between the size of maxillary sinus and skull base width, as well as among other dentofacial measures as length of the face, bimaxillary width and length of the palate [12] [34].

Researches reported the relationship between craniofacial morphology and paranasal sinuses according to the masticatory biomechanics [28] [35]. This relationship is based on the dissipation of masticatory occlusal forces through the alveolar bone and afterward through three bone pillars in the maxilla [36] [37]: (1) canine and (2) zigomatic pillars that are horizontally connected along the supra and infra orbital edges, which acts as beams that resists the mechanical stresses; and (3) pterygoid pillar that is arched toward the skull base and hard palate, connecting the pillar systems on each side of the skull [38]. The traction of masticatory muscles also generates tension and compression forces which dissipate to skull, given its bone structural arrangement [36] [39].

Skeletal classes II and III determine less occlusal contacts in the region of incisors and canines which confers lower mechanical stress in canine pillars. Relationship between functional load and bone morphology states that the bone is an optimized mechanical structure which resists maximum forces with minimum weight [39]. Therefore, the canine pillars can appear thinner, since there is no major requirement of such structures in these individuals. Consequently, the maxillary sinus is slightly larger and occupies an area that would be of bone reinforcement in class I subjects. Nevertheless, for the significance level adopted in means comparison test there was no statistical difference between the skeletal classes or gender.

About the Frontal sinus, significant differences were found in classes II and III of males compared with the female groups and also in comparison with class I group (Figure 8). The literature cites higher values in the male group, regardless of skeletal patterns [4] [14]. It may be explained by the relationship of the paranasal sinuses with cranial dimensions. These dimensions are generally higher among men. As the face expands itself, the frontal and maxillary sinuses grows to occupy spaces that otherwise would not be utilized functionally [13] [40] [41]. The fact of the frontal sinus vary according to ethnic characteristics [40] can clarify the highest values recorded for females class I compared to the males of the same class, since ethnicity was not considered in this study. Despite this, there were no significant differences between males and females for the class I.

Some studies suggest that the dimensions of the frontal sinus can be used as an indicator for predicting bone maturation and mandibular growth [42] [43] [44] [45]. Probably the higher values obtained for men class III are related to dimension of mandible which decreases the number of occlusal contacts in the region of incisors and canines as well as the mechanical stress in canine pillars. In these individuals, the stress distributed to anterior maxilla, orbit and frontal is smaller. Therefore, requires remodeling of frontal sinus, as a means of prevent unnecessary bone material which would mean higher weight of the craniofacial skeleton [35]. A similar situation occurs in class II subjects, which also usually have less occlusal contacts in the region of incisors and canines.

Should be noted that among the variables investigated the area of the frontal sinus was the one that showed more variability in size and shape [13] [14] [40] [41]. Despite this morphological variability, when figures 7 and 8 are compared, it is easily observed the presence of a pattern between the groups, suggesting that the maxillary and frontal sinuses develop by a common process of pneumatization [4] [46].

Associations presented by Pearson correlation analysis (Table 3) can be explained by the interaction between the biomechanical needs of the architecture and development of the cranial sinuses that should be considered functional spaces delimited by thin walls of compact bone located between the skull bony pillars [35] [28]. Development and subsequent morphological alteration of the cranial skeletal elements is secondary to compensatory responses, and mechanically required, for the proper functioning of tissues and organs so that changes in one area affect in remote areas [47] [48].

The present study describes the correlation between facial pattern with the pharyngeal airway space, height of the palate, maxillary and frontal sinuses of children and teenagers. Although the relationship between the data was considered weak and moderate this result helps to understand the interaction between these variables. A limitation of the study was the absence of data that allowed an adequate assessment of facial pattern, since different cranial configurations establishes different growth lines, resulting in interference in the craniofacial dimensions [33] [40] [49]. Lateral cephalometric radiograph is validated as a useful screening tool [15] [16] and is used routinely in clinical practice for aiding the diagnosis and clinical or surgical treatment planning of patients with skeletal malocclusion. Know the spatial interactions between the pharyngeal airway space and surrounding structures of the craniofacial skeleton help to understand the forces acting on the craniofacial skeleton that influence their morphology.

In conclusion, skeletal patterns was not related to the other variables, so it is not the main determinant of the size of the pharyngeal airway space, the height of the palate or the area of the maxillary and frontal sinuses in this stage of growth. Although the pharyngeal airway space showed weak positive correlation with the area of the frontal sinus, this correlation reveals biomechanical interaction between these structures. Moderate positive correlation was found between the area of the frontal sinus, the area of the maxillary sinus and the height of the palate. This interaction represents that the skull elements are interrelated to the dimensions of the entire craniofacial complex and must be considered a relationship of dependence.

Acknowledgments

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CONCLUSÃO

Analisando os dados obtidos neste estudo pode-se concluir que:

1. O padrão esquelético não se relacionou com as demais variáveis, portanto não é o principal determinante das dimensões do espaço aéreo faríngeo, bem como da altura do palato e da área dos seios maxilar e frontal nesse estágio de crescimento.
2. O espaço aéreo faríngeo apresentou correlação positiva fraca com a área do seio frontal revelando interação biomecânica entre essas estruturas.
3. A correlação positiva moderada recíproca encontrada entre a área do seio frontal, área do seio maxilar e altura do palato mostra que os elementos do crânio estão inter-relacionados de modo que as dimensões do complexo craniofacial devem ser consideradas como uma relação de dependência.

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ANEXO 1

Confirmação da submissão do artigo à publicação

Submission confirmation for "CORRELATION BETWEEN SKELETAL PATTERNS, PHARYNGEAL AIRWAY SPACE, HEIGHT OF THE PALATE AND AREAS OF THE MAXILLARY AND FRONTAL SINUSES OF CHILDREN AND TEENAGERS"

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ANEXO 2

Certificado do Comitê de Ética em Pesquisa

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UNIVERSIDADE ESTADUAL DE CAMPINAS

CERTIFICADO

O Comitê de Ética em Pesquisa da FOP-UNICAMP certifica que o projeto de pesquisa **"Correlação entre análise de Wits, espaço aéreo faríngeo, altura máxima do palato e áreas dos seios maxilar e frontal de adolescentes "**, protocolo nº 005/2012, dos pesquisadores Valério Landim de Almeida e Paulo Henrique Ferreira Caria, satisfaz as exigências do Conselho Nacional de Saúde - Ministério da Saúde para as pesquisas em seres humanos e foi aprovado por este comitê em 23/03/2012.

The Ethics Committee in Research of the School of Dentistry of Piracicaba - State University of Campinas, certify that the project **"Correlation among Wits appraisal, pharyngeal airway space, palate maximum high and maxillary and frontal sinuses areas in teenagers"**, register number 005/2012, of Valério Landim de Almeida and Paulo Henrique Ferreira Caria, comply with the recommendations of the National Health Council - Ministry of Health of Brazil for research in human subjects and therefore was approved by this committee at 03/23/2012.

Livia M. A. Tenuta
Profa. Dra. Lívia Maria Andaló Tenuta
Secretária
CEP/FOP/UNICAMP

Prof. Dr. Jacks Jorge Junior
Coordenador
CEP/FOP/UNICAMP

Nota: O título do protocolo aparece como fornecido pelos pesquisadores, sem qualquer edição.
Notice: The title of the project appears as provided by the authors, without editing.