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Volumetric Evaluation of the Upper Airways in Relation to the Gonial Angle

Avaliação Volumétrica das Vias Aéreas Superiores com Relação ao Ângulo Goníaco

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Abstract

The upper airspace is essential to understand the physiology and pathogenesis of its obstruction, complementary exams based on images have been used to evaluate the upper airspace. The objective of this study was to evaluate, by means of computed tomography, the upper airways (UAS), in relation to anatomical variables, emphasizing the gonial angle and comparing it with volume in mm³, sex and age. A total of 124 computed tomography scans were analyzed using DICOM files (digital image communication in medicine) made available by a radiology clinic using the ITK-snap program (version 3.6.0), upper airway volumes, sex, age and gonial angle values on both the right and left sides were tabulated in a table in the Excel 2010 program of the Microsoft Office 2010 package, and subsequently analyzed in the SPSS software with statistical analysis using the Levene Test and also the ANOVA test, to obtain of the results. The values found for the gonial angle did not indicate a significant difference. However, the present work confirms that within each of these groups there is a homogeneity of variances, corroborating the results reported in the literature. However, regarding the volume of the upper airways, we found that in men and in individuals aged over 34 years, the volume is greater.

Keywords: Orthognathic Surgery. Computed Tomography. Cephalometry.

Resumo

O espaço aéreo superior é essencial para compreender a fisiologia e a patogênese de sua obstrução, exames complementares baseados em imagens têm sido empregados para avaliar o espaço aéreo superior. O objetivo desse estudo foi avaliar por meio de tomografia computadorizada, as vias aéreas superiores (VAS), com relação a variáveis anatômicas, dando ênfase ao ângulo goníaco e comparando com volume em mm³, sexo e idade. Foram analisados 124 exames de tomográfica computadorizada, por meio dos arquivos DICOM (comunicação de imagens digitais em medicina) disponibilizados por uma clínica radiológica, através do programa ITK-snap (versão 3.6.0), os volumes das vias aéreas superiores, o sexo, a idade e os valores do ângulo goníaco tanto do lado direito como do lado esquerdo foram tabulados em tabela no programa Excel 2010 do pacote Microsoft Office 2010, e analisados posteriormente no software SPSS com análise estatística pelo Teste de Levene e também teste ANOVA, para obtenção dos resultados. Os valores encontrados para o ângulo goníaco não indicaram diferença significativa. Contudo, o presente trabalho confirma que dentro de cada um desses grupos há uma homogeneidade das variâncias e corroborando com os resultados relatados na literatura. No entanto com relação ao volume das vias aéreas superiores encontramos que em homens e em indivíduos com idade superior a 34 anos o volume é superior.

Palavras-chave*: Cirurgia Ortognática. Tomografia Computadorizada. Cefalometría.*

1 Introduction

It is considered that the dentofacial deformity refers to significant deviations of the normal proportions of the maxillomandibular complex, being one of the main problems of oral health of the world population, affecting self-esteem and quality of life[1]. In this context, orthognathic surgery is the procedure performed to correct skeletal deformities by surgical displacement of the maxilla and/or jaw, and may lead to changes in the volume of the upper airways[2]. This procedure aims to successfully correct the dentofacial deformities of congenital and acquired etiology[3]. For the planning of this surgery, all data obtained in the patient evaluation , including facial analysis and imaging exams are used [4].

Computerized Tomography (CT) is an examination that allows the evaluation of the airways and related structures, defining three-dimensionally (height, width and depth) the measurements of the spaces of the nasopharynx, oropharynx and hypopharynx, as the region of maximum narrowing, the volume and minimum anteroposterior and lateral dimension of the pharynx[5]. Computed tomography can accurately measure areas with low density, such as air and soft tissues, on the other hand, cone beam computed tomography (CFC) has proven to be superior and an excellent tool for measuring airway volume, as reported in the literature[6-8]. However, it is known that this examination has a higher cost and the patient is subjected to a higher radiation index.

Knowledge of the morphology and functioning of skeletal and soft tissue structures that make up the upper airspace is

essential to understand the physiology and pathogenesis of its obstruction. However, its evaluation is complex, since its location does not allow direct viewing. Different forms of complementary imaging tests have been used to evaluate the upper airspace, skeletal structures and adjacent soft tissues. Each method has inherent advantages and disadvantages, and there is no consensus regarding the gold standard procedure for its evaluation[5].

The gonial angle is a complex factor of craniofacial parameters, giving a signal on vertical parameters and symmetry of the facial skeleton, playing a role in growth prediction and age estimation[9]. However, the gonial angle suggests the intersection point of the lower edge of the mandibular body with the posterior edge of the branch, an important factor that determines the mandible rotation direction[10].

Whereas the cephalometric radiography provides numerous information, however, it stirs in the ability to provide only two-dimensional image of a three-dimensional structure, not allowing an accurate assessment of the complexity of this structure and its dimensions[5]. One of the variables observed in cephalometry is the gonial angle that is directly related to mandibular morphology. Considering that the main characteristic of Standard I patients is facial balance, it is expected that they do not present important changes in the jaw, with variations of this angle related to the facial type[11].

Currently there are new forms of diagnosis, and in the present study our objectives were to build three-dimensional airway models and from mapping the different groups of patients (volume in mm³, sex and age), correlating the volume of the airways with the gonial angle, so that we could analyze what could bring better predictability to the operative movements of orthognathic surgery.

In the literature, there are few studies about the existence of a relationship between the upper airway volumes of skeletal facial patterns classes I, II and III with the patient's age, sex and gonial angle. Thus, this study is necessary in order to evaluate these other methods, so that there is a reduction in the requests for computed tomography scans and the patient can be submitted with lower radiation. The correct diagnosis and operative planning make the surgical technique more accurate in the routine of treatment, not only an alternative, but a goal currently.

2 Material and Methods

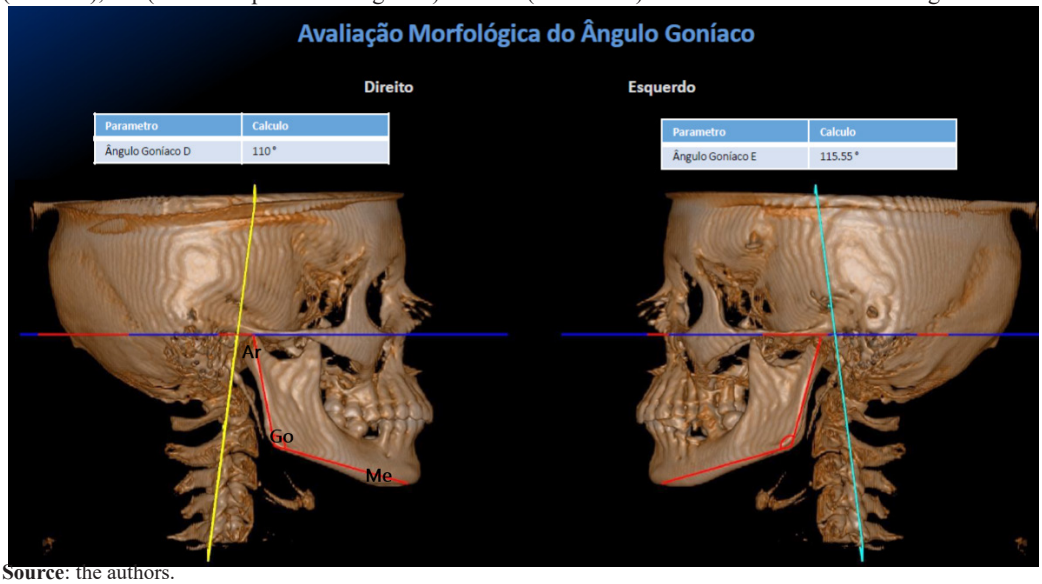
2.1 Universe of research

This is a retrospective study of the database analysis of a dental radiological clinic in the city of Passo Fundo, with the survey of 124 full face computed tomography scans in DICOM format, dated from 2015 to 2018. After evaluation of inclusion and exclusion criteria, the examinations were divided into three groups: Group 1 patients with skeletal pattern class I; group 2 patients with skeletal pattern class II; and group 3 patients with skeletal pattern class III, grouping according to sex and age.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria were performed according to full face examinations in patients between 15 and 58 years of age, of both sexes, and had the value related to the gonial angle on both sides (Figure 1). The exclusion criteria were examinations of young people under 15 years old and older people over 58 years old, repeated examinations or with absence of files in DICOM format (Communication of Digital Imaging in Medicine) and absence of values of the gonial angle, tests that presented morphological alterations, neoplastic or traumatic lesions that could create bias in the research, and tests that presented signs of previous bone correction surgery.

Figure 1 - Reference points for the measurements of the gonial angle. Gonial angle is formed between the points **Ar** (articular), **Go** (built or cephalometric gonial) and **Me** (mentonian). The normal value for this angle is 130 degrees



Source: the authors.

2.3 Acquisition of tomographic taking

All the TCFC exams were performed with full face in the same radiological clinic, using the same equipment and configurations, with acquisition parameters at 120 kVp, 37.1 mA, 17.8 seconds, volume size rendered in 17 x 23 cm and resolution of 0.3 mm³ voxel, using ICAT *Imaging Sciences International LLC, Hatfield, PA*, *USA*.

2.4 Images manipulation and analysis

To obtain the values of the gonial angle, the images contained in the medical reports were used, through the morphological evaluation.

2.5 Software for analysis

The files in DICOM format have been examined by the ITK-SNAP application version 3.6.0 (Figure 3), an integration between the SNAP and ITK tools (*Insight Toolki*) by *Cognitica Corporation* under NIH / NLM PO 467-MZ-202446-1 (*US National Institutes of Health*), with validation study supported by NIH/NIBIB P01 EB002779, NIH *Conte Center* MH064065, and UNC *Neurodevelopmental Disorders Research Center, Developmental Neuroimaging Core*) a free-of-charge 3D anatomical segmentation processor of medical images (Yushkevich and Gerig 2006).

2.6 Ethical issues

The project was submitted and approved to the Research Ethics Committee of the Universidade de Passo Fundo, under opinion number 3.414.871/14903119.8.0000.5342. The agreement to participate in the study was obtained through a letter to the clinic that provided the exams. There was no identification of the patients.

2.7 Data analysis

The values defined were tabulated in a table in the *Excel* 2010 program of the *Microsoft Office* 2010 suite, and analyzed later in the SPSS software with statistical analysis by the Levene Test, estimating the variables of interest and their respective confidence intervals.

3 Results and Discussion

124 full face tomographies were analyzed, immediately after inclusion and exclusion criteria, these tomographies were divided into three groups, according to the skeletal facial pattern (I, II and II): group 1 with 57 exams; group 2 with 46 exams; and group 3 with 21 exams. Regarding sex, we observed that the female was more frequent, with 87 tests (70.2%) and the male with n = 37 (29.8% of the tests). The division of the groups according to the skeletal facial pattern can be observed in Table 1.

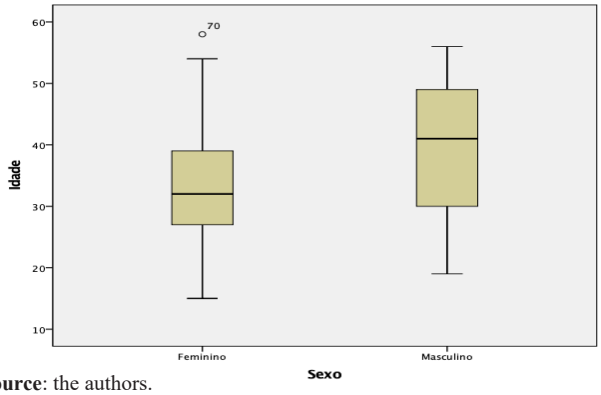
Table 1 - Description of the groups according to sex, facial pattern and frequency

Sex	Group	Frequency	%
Female	1 (Standard I)	43	47.8
	2 (Standard II)	36	40.0
	3 (Standard III)	11	12.2
	Total:	**90**	**100**
Male	1 (Standard I)	17	43.6
	2 (Standard II)	12	30.8
	3 (Standard III)	10	25.6
	Total:	**39**	**100**

Source: resource data.

Regarding age, the mean age (±SD) of the sample was 35.4 (±10.15) years, with a minimum age of 15 years and a maximum age of 58 years. The mean age (±SD) among women was 33.5 (±9.3) years, with the lowest age in the group 15 years and the highest age among women 58 years. Regarding the men, the mean age (±SD) was 40 (±10.7) years, with the lowest age in the group 19 years and the highest age among the women 56 years (Figure 2).

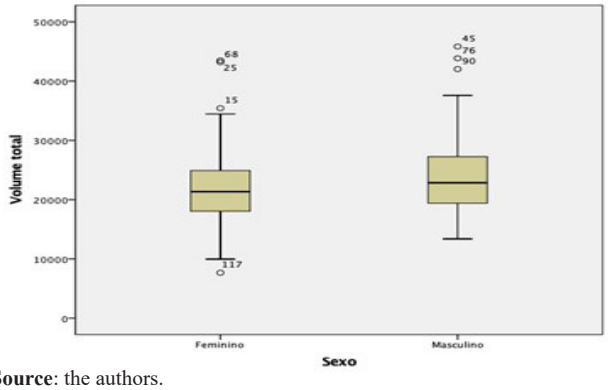
Figure 2 - Histogram sex x Age



Source: the authors.

As for the upper airways, the mean sample was 22847.4 mm³ (±SD 7192.8mm³; min: 7658.3mm³; max.:45837.1mm³). Regarding the volume of the women's airways, the mean observed was 22027.36 mm³ (±SD 6782.524 mm³; min:7658 mm³; max: 43489 mm³). In the male group, the mean volume was 24775.48 mm³ (±SD 7833.456 mm³; min:13381 mm³; max: 45837 mm³) (Figure 3).

Figure 3 - Histogram by total airway volume (mm³)

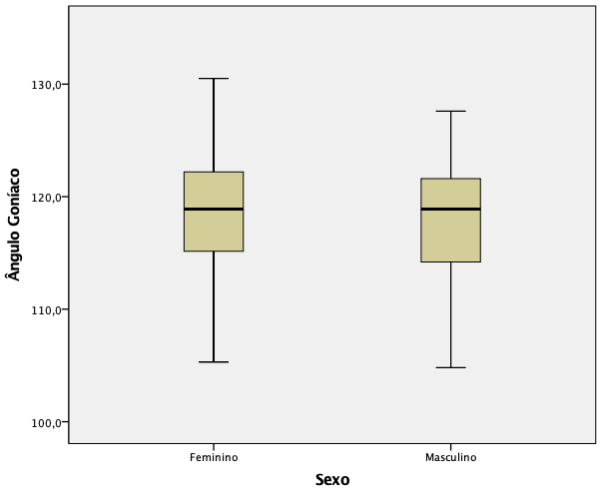


Source: the authors.

In relation to the gonial angle, the mean of the sample was 118.45º (±SD5.1-5; min:104.8-0º; max.:130.5-0º). In the female gender, the angular measurement was 118.95º (±SD 4.71º; min:105.30º; max.:130.50º) Regarding the men, the angular measurement was 117.76º (±SD 5.30º; min:104.80º; max:127.60º). We observed that 64 patients had up to 118.9º, which includes 51.6% of the exams (Figure 4).

The ANOVA test was also performed to evaluate the differences between the mean volume of the airways (mm³) according to sex, age and gonial angle (Table 2). We could observe that the Gonial angle did not change the volume of the airways (p=0.919). However, we observed a higher mean airway volume in the individuals of the male sex (Avg.± SD: 24775.5 ±7833,5mm³; p=0.049) and in individuals over 34 years (Avg.± SD: 24485.8mm³ ± 7385.5mm³; p=0.017).

Figure 4 - Histogram of the variable gonial angle (degrees)



Source: the authors.

Table 2 - Average values (±SD; min; max) of airway volumes (mm³) according to gender, age and Gonial angle, Passo Fundo, RS/ Brazil. (n=124)

Variable	n	Average (±SD)	Min	Max	*p*
Gender					0.049
Male	37	24775.5mm³ (7833.5mm³)	13380.9mm³	45837.1mm³	
Female	87	22027.4mm³ (6784.5mm³)	7658.3mm³	43489.1mm³	
Age					0.017
Up to 34 years	66	21407.5mm³ (6750.5mm³)	7658.3mm³	43189.9mm³	
Over 34 years old	58	24485.8mm³ (7385.5mm³)	13380.9mm³	45837.1mm³	
Angle					0.919
Up to 118.9º	64	22783.1mm³ (6987.2mm³)	9955.9mm³	43849.0mm³	
Over 118.9º	60	22915.9mm³ (7464.5mm³)	7658.3mm³	45837.1mm³	

Source: resource data.

For all the measured variables, the mean and standard deviations were calculated, as well as their maximum and minimum values. The Levene test, for equality of variances, did not indicate a significant difference, which confirms that within each of these groups there is a homogeneity of the variances of the examinations with the confidence interval of 95%, a significance level of 5%, as we can see in the results in Table 3.

Table 3 - Average values of airway volumes according to sex and gonial angulation, Passo Fundo, RS/Brazil. (n=124)

Sex		Gonial Angle	n	Mean	P
Female	Total volume	Up to 118.9º	44	22258.98	0.436
		More than 118.9º	43	21790.36	
Male	Total volume	Up to 118.9º	20	23936.15	0.843
		More than 118.9º	17	25762.93	

Source: resource data.

In this study, we observed a higher mean airway volume in the individuals of the male sex (Avg.± SD: 24775.5 ±7833,5mm³; p=0.049) and in individuals over 34 years (Avg.± **SD:** 24485.8mm³ ± 7385.5mm³; p=0.017), with a significant statistical difference, however, this difference is little cited or explored in the literature. A similar study was carried out, where they were evaluated by Guijarro - Martínez and Swennen[12] (2013), where they evaluated 40 healthy individuals at the General Hospital St. Jan in Bruges, Belgium, being a preliminary validation study of the upper airway subregions based on cone beam computed tomography, which presented the volume of the Oropharynx ($p = 0.001$) and the Hypopharynx ($p < 0.001$) higher in men than in women, corroborating our results. However, we did not find, in the literature, studies that demonstrated the relation with age.

It is well known that quality sleep is fundamental to biological functions and interferes directly in our daily lives. As we sleep, body and mind recover causing the feeling of rest. It is believed that, one of the causes of sleepless nights is the Obstructive Sleep Apnea Syndrome (OSAS). With this, the study by Zinsly *et al.*[5] showed that one of the main factors of this disease is the reduction of upper airspace, the blockage of the nasal cavity, the presence and distribution of body fat (BMI), the anatomy and muscle tonicity. And for a correct diagnosis of OSAS, a rigorous and multidisciplinary evaluation should be done, and patients may present one or more obstructed locations, nasal cavity (nasopharynx), oropharynx, tongue base and hypopharynx[13].

One of the known ways to reestablish the pharyngeal airspace, in order to become less prone to collapse is through orthognathic surgery where permanent alterations are obtained, where the volume of the airspace is inevitably affected by

the skeletal mandibular movement and with the mandibular advancement and, concomitantly, the maxillomandibular advancement (bimaxillary) significantly increases the linear plane, cross-sectional and volume of VAS ($p < 0.0001$), while it reduces the apnea, hypopnea index and the respiratory impairments index ($p < 0.0001$), being beneficial to the patients who suffer from OSAS[13-15].

Raising the success rates of orthognathic surgeries so that there is an improvement in the upper airways, especially in cases where the anatomical characteristics impose a greater degree of difficulty, is a constant scientific concern. Currently, it is not questioned the fact that one of the best ways of diagnosis and analysis of facial patterns and volume of the upper airways is the use of computerized tomography. Where with several programs available in the markets we could evaluate and count in mm^3 the total volume of the pharynx. However, there is a concern about the level of radiation that the patient is subjected to tomographic taking, not to mention its high cost.

For Pereira Filho *et al.*[16], in relation to other diagnostic methods, radiographic Cephalometry offers some advantages over other techniques, such as its low cost for examination and minimum radiation exposure, but has little reference of soft parts and because it is 2D, we were unable to analyze volume. Whereas the computed tomography is in advantage due to its ability to obtain three different types of slices (axial, sagittal and coronal) for image acquisition, besides, it has the advantage of being in 3D, allowing a more accurate evaluation of structures.

Trevisol *et al.*[17], carried out a study on the posterior airways and orthognathic surgery where he analyzed what affects long-term excellence, and concluded that orthosurgical treatment can protect the airways from unwanted alterations and be submitted to other treatment objectives. It also identified 3 variables that significantly affected the airways pre-operative dimensions, sex and extension of mandibular advancement, where the relation between airway dimensions and obstructive sleep apnea syndrome is not clarified, however, the study considerations may prove to be a useful tool to assist in the prevention and management of this disease.

Since the creation of cone beam computed tomography in 1990, there has been an expressive improvement in the diagnosis and planning of the treatment of bucomaxillofacial alterations. The volume of the upper airways, by Guijarro-Martinez and Swennen[7], was used and is still one of the most effective methods for evaluating OSAS, with images of the DICOM type (Digital Imaging Communication in Medicine) we could apply the software allowing visualization and quantification of the upper airways in an unprecedented way. Resulting in a better physiological and anatomical understanding of pharyngeal airspace.

In the present study, 124 computerized tomography scans were used to evaluate the volume of the upper airways and the patients were separated into three groups according to their facial profile, class I, II and III, according to their gender and age. Finally, the values found for the gonial angle showed no significance, corroborating the results reported in the literature[11.18].

The gonial angle is directly related to mandibular morphology and the mean obtained was 118.9°, ranging from 104.8° to 130.5°. The female patients presented the facial type tending to be longer face (118.951°, ranging from 105.3° to 130.5°), while in male patients the minimum value obtained was 104.8°, the maximum was 127.6°, and the mean was 117.765°. Whereas in the study by Reis *et al.*[11], the mean obtained for him was 121.4°± 5.3°, ranging from 109.0° to 133.0°. Repeating the results obtained for the mandibular plane angle, sexual dimorphism was observed, and the patients of the female sex presented the facial type tending to more horizontal with reduction of the angle (120.3°± 4.7°, varying between 109.0° and 128.8°), while in male patients the minimum value obtained was 115.6°, the maximum was 133.0°, and the mean was 124.6°± 6.1°. What we could notice from these values is that the difference was minimal which confirms our statistical result.

In the present study, after determining the results, we could observe a limitation that we had, where we did not evaluate the other anthropometric elements, such as BMI, physical examination and other facial classifications. However, the clinical relevance obtained that the volume of the upper airways in men and over 34 years is higher, leads us to an advantage, which in a simple clinical examination we can have an approximate idea of the volume, without the analysis of images exams. Always remembering that this does not rule out the need for complementary tests for diagnostic purposes.

Therefore, one of the possibilities analyzed is that we could have made the segmentation of the airways, where we could possibly indicate significant differences. Another way that we will be able to use in a later study is the use of new software available in the market, which allows for sharper images with greater detail, allowing the determination of volumes from surface contours and analysis of more accurate anatomies, such as E-vol, where a more realistic analysis of tomographic images is made from DICOM files, providing greater accuracy in diagnostics.

4 Conclusion

With this study, we were able to construct three-dimensional models of the upper airways and from the obtained sample, however, we could not use the gonial angle to evaluate the upper airways in healthy patients, because it did not present significant difference. New studies are suggested from innovative methods in order to obtain confirmation of this data.

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