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Volumetric and cephalometric evaluation of the upper airway of class III patients submitted to maxillary advancement

Avaliação volumétrica e cefalométrica da via aérea superior em pacientes classe III submetidos a avanço de maxila

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Resumo

Introdução: A deficiência anteroposterior da maxila pode estar associada com a diminuição do volume da via aérea superior. O avanço de maxila por resultar em um aumento do espaço aéreo superior. **Objetivo:** Correlacionar mensurações cefalométricas (2D) e volumétricas (3D) da via aérea superior em pacientes classe III tratados por meio de avanço maxilar. **Material e método:** Este estudo retrospectivo transversal foi realizado em dez pacientes adultos submetidos ao avanço de maxila para correção de deficiência anteroposterior de maxila e deformidade classe III. Foram incluídos os dados de tomografias computadorizadas Cone beam em dois períodos: pré-operatório (T1) e pós-operatório de 6 a 8 meses (T2). Os arquivos DICOM foram importados e reconstruídos para avaliação volumétrica e cefalométrica da via aérea superior, dividida em nasofaringe, orofaringe e hipofaringe (Arnett & Gunson FAB Surgery). **Resultado:** A idade variou de 26 a 55 anos, com média de 36,3±9,2 anos. Não foram verificadas diferenças estatisticamente significantes para os parâmetros cefalométricos e volumétricos das três regiões da faringe entre os períodos T1 e T2. Este resultado ocorreu devido à pequena quantidade de avanço maxilar (4,7±1,89mm) necessário para a correção da deformidade na amostra. A correlação entre área e volume não foi estatisticamente significante apenas para as mensurações pré-operatórias da nasofaringe (r=0,30; p=0,40). Nas outras regiões e períodos a correlação foi estatisticamente significante (p<0,05). **Conclusão:** Avanços maxilares de pequenas dimensões não resultam em um aumento significativo das dimensões da via aérea superior.

Descritores: Cirurgia ortognática; remodelação das vias aéreas; maxila.

Abstract

Introduction: Anteroposterior maxillary deficiency can be associated with a decrease of upper airway volume. Maxillary advancement can improve the upper airway space. **Aim:** To correlate cephalometric (2D) and volumetric (3D) measurements of the upper airway in class III patients treated by maxillary advancement. **Material and method:** This retrospective transversal study was performed in ten adult patients submitted to maxillary advancement for correction of class III deformity secondary to maxillary anteroposterior deficiency. The Cone beam tomography files included in the medical records were used: (T1) pre-operative and (T2) 6 to 8 months postoperative. The DICOM files were imported and reconstructed for volumetric and cephalometric evaluation of the upper airway, as divided into nasopharynx, oropharynx and hypopharynx (Arnett & Gunson FAB Surgery). **Result:** Age ranged from 26 to 55 years with a mean of 36.3±9.2 years. There were no statistically significant differences for cephalometric and volumetric parameters of the three pharyngeal regions between T1 and T2 periods. This was due to the small amount of maxillary advancement necessary to correct the maxillary deformity in the studied patients (4.7±1.89mm). The correlation between area and volume was not statistically significant only for preoperative measurements of the nasopharynx (r=0.30, p=0.40). It was significant for the other regions and evaluation periods (p<0.05). **Conclusion:** Small maxillary advancements do not result in significant increases in airway dimensions.

Descriptors: Orthognathic surgery; airway remodeling; retrognathia.

INTRODUCTION

Anteroposterior maxillary deficiency can be associated with obstructive sleep apnea syndrome (OSA) as a result of the improper positioning of soft tissues and decreased volume of the upper airway (UA)[1]. Orthognathic surgery is used as adjunctive treatment for OSA through large maxillomandibular advancements of at least 10 mm, aiming to increase the space of the UA by repositioning the soft tissues[2,3].

Class III dentoskeletal deformity usually results from anteroposterior maxillary deficiency and/or mandibular excess. The correction of this deformity by mandibular setbacks alone may cause narrowing of the UA and predisposition to the occurrence of OSA[1,4]. Therefore, the treatment is preferably performed by isolated maxillary advancement or bimaxillary surgery, aiming for the anterior repositioning of the soft palate tissues and velopharyngeal musculature, facial deformity correction, and increased UA space[1,5,6].

The evaluation of facial structures and UA can be accomplished using cephalometric radiographs and CT scans. However, the examination of the airways by radiographs has limitations because only basic and permeability measurements can be visualized, and specifically, the size and shape of the UAs can be changed by the head and patient position[7,8]. Computed tomography is the gold standard of examination to visualize the facial skeleton and airspace structures, allowing the measurement of the size and volume of UA and location of the narrowing areas[9,10].

The objective of this study was to correlate (2-dimensional (2D)) cephalometric measurements to (3-dimensional (3D)) volumetric measurements of the preoperative and postoperative upper airways in Class III non-OSA patients treated with maxillary advancement.

MATERIAL AND METHOD

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara - University of Sao Paulo State, Brazil, under the registration number CEP 1.363.419.

Sample Selection

A retrospective analysis was performed on the image database of patients submitted to orthognathic surgery, and they were selected in descending chronological order. Included in the sample were medical records of patients with Class-III skeletal deformities submitted to maxillary advancement surgery by Le Fort I osteotomy and fixation with plates and screws and pre- and postoperative cone beam computed tomography (CBCT) scans. Syndromic patients, those presenting orofacial clefts, and patients who underwent bimaxillary or segmental surgery or other procedures in addition to the maxillary advancement were excluded.

Data Collection

To evaluate the UA, a single appropriately trained researcher collected data including the medical records and CBCT scans obtained in in two periods as follows: (T1) immediate preoperative and (T2) postoperative from 6 to 8 months. Data were included in a specific study table for analysis purposes.

CBCT scans were obtained using a volumetric CT scanner for dentofacial images (I-Cat, KaVo do Brasil Ind. Com. Ltda. - Joinville, SC), for which patients were positioned with the head in a neutral position and told not to swallow during imaging. Data were imported and reconstructed with the software Dolphin Imaging 11 (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) for volumetric (3D) and cephalometric (2D) analysis of the UA, and the 3D volume was positioned according to the anatomical references, allowing the same position for all measurements.

Volumetric Evaluation (3D) of the UA

The images of sagittal sections of the airway were selected, and planes were formulated to define the upper and lower limits. Using anatomical references, the limits of the upper airway (Figure 1) were determined, and the volumes were split into the following:

- Nasopharynx: The upper limit was determined by a straight line parallel to the Frankfurt plane passing through point A to a point on the posterior pharyngeal wall. The lower limit was given by a straight line, also parallel to the Frankfurt plane, passing through the upper incisor edge to a point on the posterior pharyngeal wall.
- Oropharynx: The upper limit was determined by a straight line parallel to the Frankfurt plane passing through the central upper incisor edge to a point on the posterior pharyngeal wall. The lower limit was a straight line, also parallel to the Frankfurt plane, passing through point B to a point on the posterior pharyngeal wall.
- Hypopharynx: The upper limit was determined by a straight line parallel to the Frankfurt plane passing through point B

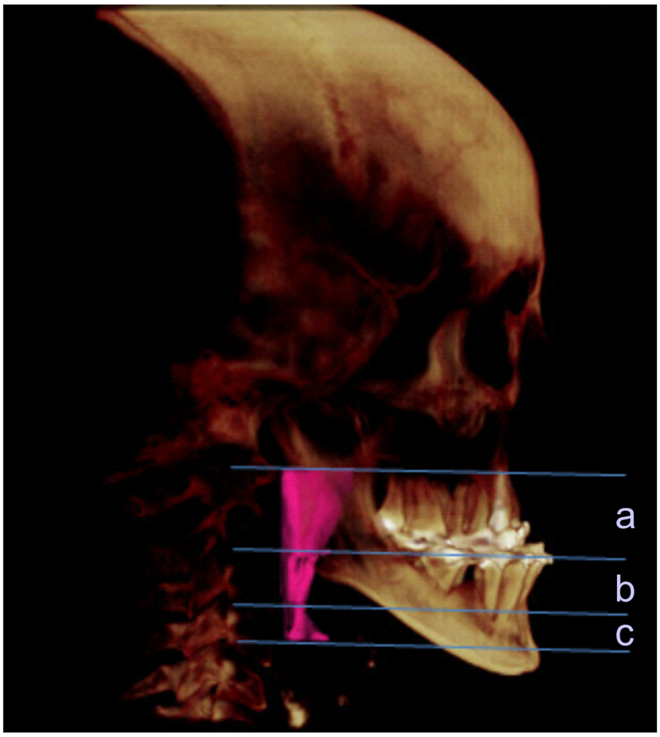

Figure 1. UA volume and limits: (a) nasopharynx; (b) oropharynx; and (c) hypopharynx.

to a point on the posterior pharyngeal wall. The lower limit was a straight line, also parallel to the Frankfurt plane, passing through point M to a point on the posterior pharyngeal wall.

From these planes, a volumetric analysis of the area configured in 3 dimensions was performed using the grey grading scale, determining the airway space. From the sum of the volumes, the software performed the 3D calculation, showing the volume in cubic millimeters of the upper airway and its regions.

Cephalometric Evaluation (2D) of the UA

After the insertion of DICOM images the CT scanner generated in the software, a lateral cephalometric radiograph was generated using the specific tool. The cephalometric points were plotted on the lateral preoperative and postoperative lateral cephalometric radiograph using the analysis of Arnett-Gunson FAB surgery (Figure 2). The demarcation of the cephalometric points was digitally performed in a low-light environment.

The cephalometric points of interest were the following:

- A/G anterior UA point A - anterior wall of the nasopharynx passing through bone point A.
- A/G posterior UA point A - posterior wall of the nasopharynx passing through bone point A.
- A/G anterior UA point S1 - anterior wall of the oropharynx passing through the central upper incisor edge.
- A/G posterior UA point S1 - posterior wall of the oropharynx passing through the central upper incisor edge.
- A/G anterior UA point B - anterior wall of the hypopharynx passing through bone point B.

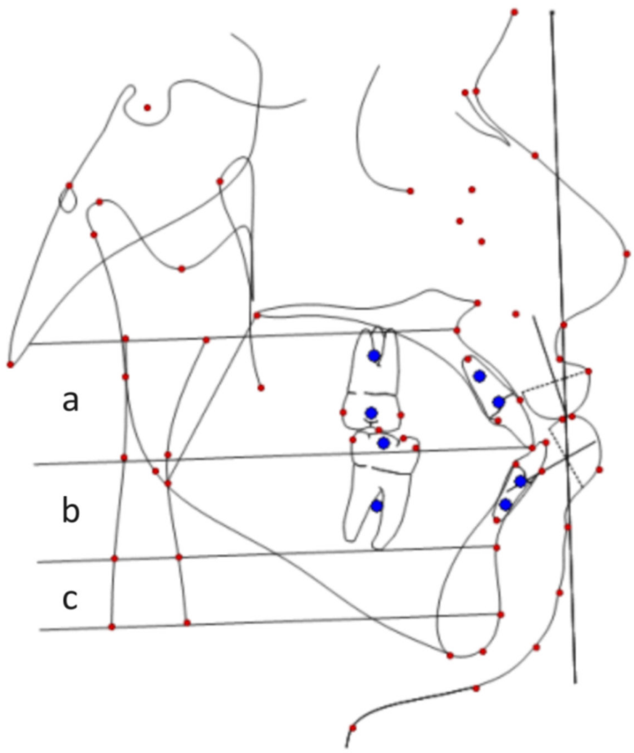

Figure 2. UA area and limits, Arnett-Gunson FAB surgery: (a) nasopharynx; (b) oropharynx; and (c) hypopharynx.

- A/G UA posterior point B - posterior wall of the hypopharynx passing through bone point B.

The UA was evaluated with linear measurements at 3 different levels: the nasopharynx, oropharynx, and hypopharynx regions. The nasopharynx corresponds to a linear measurement between points A/G anterior UA-point A and A/G posterior UA-point A; the oropharynx corresponds to a linear measurement between points A/G anterior UA-point S1 and A/G posterior UA-point S1. The hypopharynx corresponds to a linear measurement between points A/G anterior UA-point B and A/G posterior UA-point B.

Statistical Analysis

The data evaluated presented normal distribution, and parametric tests were used for inferential statistics. For intra-examiner calibration, measurements were performed in duplicate with an interval of one month between them. Reproducibility was estimated by the intra-class correlation (ICC) coefficient. For correlation analysis between the cephalometric (mm^2) and volumetric (mm^3) measurements of the oropharynx, nasopharynx and hypopharynx regions in the pre- and postoperative periods, the Pearson correlation coefficient (r) was used, and the significance was tested using a paired t-test at a significance level of 95%.

RESULT

The study included 10 patients who had been submitted to maxillary advancement surgery: 6 men and 4 women. The ages ranged from 26 to 55 years old, with an average age of 36.3 ± 9.2 years. The average anteroposterior maxillary advance was 4.7 ± 1.89 mm.

The intra-examiner reproducibility for volumetric and cephalometric analysis in T1 and T2 was high (ICC = 0.99 for volume measures; ICC = 0.96 for area measurements), so the average of the measurements was used as representative sample of each evaluation.

The cephalometric analysis of UA space between the pre-and postoperative periods showed decreased mean values of the nasopharynx; those related to the oropharynx were increased, and those related to hypopharynx were maintained. The volumetric analysis showed an average gain in the values of all regions of the UA (Table 1). However, these differences were not statistically significant.

The correlation between the two evaluation methods was high and statistically significant (p <0.05) for all parameters, except for the correlation of preoperative values for the nasopharynx (r = 0:30; p =0.40). The correlation values are shown in Table 2.

DISCUSSION

Treatment of dentoskeletal deformities is performed through orthognathic surgery. Currently, in patients with Class-III deformities, only 10% of cases are treated by mandibular setback procedure alone; in 40% bimaxillary surgery is performed, and in 50% an isolated maxillary advancement is performed[11]. One factor that can explain this distribution is the impact of such procedures on

Table 1. Mean and standard deviation of cephalometric (area) and volumetric (volume) measurements, paired T test between pre and postoperative measurements, significance level of 95%

Parameters	Nasopharynx		Oropharynx		Hypopharynx	
	T1	T2	T1	T2	T1	T2
area (mm^2)	17.7 ± 6.8	16.7 ± 4.0	11.1 ± 4.5	13.9 ± 4.9	11.6 ± 4.2	11.7 ± 3.0
p valor	0.50		0.08		0.91	
volume ($x10^3$ mm^3)	6.2 ± 3.9	7.7 ± 3.7	3.9 ± 2.7	5.4 ± 3.8	4.9 ± 2.6	5.4 ± 2.5
p valor	0.07		0.09		0.34	

Table 2. Analysis and correlation between cephalometric and volumetric measurements in UA regions pre and postoperative. Maxillary advancement according to patient

Patient	Pre-operative						Postoperative						Maxillary Advancement (mm)
	Nasopharynx		Oropharynx		Hypopharynx		Nasopharynx		Oropharynx		Hypopharynx		
	Area	Volume	Area	Volume	Area	Volume	Area	Volume	Area	Volume	Area	Volume	
1	36.4	3.37	17.1	7.12	15.7	2.40	25.2	8.31	13.8	4.05	18.1	3.14	7
2	13.7	1.67	8.2	3.32	9.3	4.05	10.4	2.53	10.3	1.53	8.1	4.10	3
3	15.6	1.18	10.5	6.67	8.4	3.28	20.4	11.47	10.2	3.76	10.6	3.45	7
4	18.9	9.78	20.9	16.68	16.8	8.27	18.9	15.18	13.9	8.91	16.8	7.05	2
5	15.8	1.19	5.6	1.77	6.6	2.52	14.5	2.87	7.0	1.77	10.8	3.04	5
6	19.7	6.52	13.0	8.36	19.1	10.28	18.5	8.72	15.1	8.08	18.8	9.66	4
7	18.6	1.73	7.0	5.16	6.0	2.07	14.6	6.98	6.1	1.67	6.2	2.42	6
8	10.5	3.81	9.7	4.46	11.1	4.31	14.5	5.60	13.4	4.29	13.7	6.07	5
9	12.6	3.12	7.8	4.11	10.2	6.12	13.2	5.18	12.9	5.50	12.9	5.30	6
10	15.5	6.26	11.3	4.20	13.3	6.59	17.0	10.37	14.8	14.27	22.8	9.71	2
r=	0.30		0.78		0.76		0.65		0.87		0.78		
p=	0.4		0.007*		0.01*		0.04*		0.001*		0.008*		

r= Pearson's correlation test; p= Paired T test. * Statistical difference.

the UA, as the mandibular setback promotes a decrease of airway space due to anteroposterior narrowing in the oropharynx and hypopharynx regions[12] and can result in an OSA[6,13,14].

Lee et al.[13] report that the volume of the pharynx and its 3 areas – the nasopharynx, oropharynx, and hypopharynx – are influenced by changes in the jaw position at the level of the upper soft palate, posterior nose, and nasopharyngeal space regions. The maxillary advancement procedure causes an enlargement of UA in the nasopharyngeal and retropalatal areas and a subsequent increase in the dimensions and volume of the airway space[12]. Although the repositioning is anteroposterior, the increase of the UA dimensions is mainly in the transverse direction[15,16]. Per Pereira-Filho et al's[1] study, the maxillary advancement procedure, when compared to the mandibular setback and bimaxillary surgery procedures, showed the highest stability in the anteroposterior increase of the UA due to the repositioning of the soft palate tissues and muscles.

The sample evaluated in this study showed no statistically significant changes in the airway space and its regions between the pre- and postoperative periods in both the cephalometric and volumetric methods of analysis. There are two possible causes for this result. One factor is the sample size of the retrospective analysis, which may have caused a type-II error without enough statistical power to reject the null hypothesis. The second factor is the small dimension of the maxillary advancement performed in more than 30% of the sample. The patients with more than 6 mm of advancement show a quantitative incensement of UA volume in the nasopharynx region, which suggests that large movements may cause an improvement in UA. However, this result agrees with Fernández-Ferrer et al.[6] review in which the maxillary advancement procedure does not result in significant changes in the oropharynx and hypopharynx regions.

Cephalometric analysis is traditionally used for radiographic evaluation of the UA. Although this method is useful for analysis in the sagittal plane, it has limitations, including overlapping of images and difficult delimitation between the structures, and it does not capture the airway width[11,13,15]. Computed tomography is one of the best methods for evaluating 3D structures of the UA and facial skeleton[15-17]. Among its advantages is the evaluation of the regions in the coronal, axial, and sagittal planes; the visualization of soft and hard tissues; and the possibility of segmentation for volumetric analysis[8,11-13]. However, image acquisition in both methods may be impaired due to the position of the head and tongue, breathing, and time necessary for the scanning procedure[8,18,19].

In this sample, there were statistical differences between cephalometric and volumetric analysis and a positive correlation between the evaluated parameters, except for the preoperative assessment of the nasopharyngeal region. Thus, both methods can be used to evaluate the UA space. However, the reported benefits of CT allows analysis in greater detail.

In conclusion, the results showed that the UA volume and area were not modified by the maxillary advancement procedure. However, the sample size and small maxillary advancement are possible reasons for this result. The evaluation of the UA space through cephalometric and volumetric analysis shows a positive correlation.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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