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Pharyngeal Airway Changes after Bimaxillary Orthognathic Surgery – Preliminary Results

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SUMMARY

Introduction Dentofacial deformity, a deviation from normal facial proportions and dental relationships, is corrected by jaw repositioning in all three spatial planes, which changes the position and tension of the surrounding tissues, bones and muscles. These changes may also affect the dimensions of the pharyngeal airways (PA).

Objective The aim of this study was to evaluate and compare three-dimensional PA changes in patients treated by a combination mandibular set-back/maxillary advancement versus patients that had bimaxillary advancement with genioplasty.

Methods The sample consisted of 7 patients treated by combined mandibular set-back/maxillary advancement and 7 patients treated with bimaxillary advancement surgery. Nasopharyngeal (NP) volume, oropharyngeal (OP) volume and the area of maximum constriction (AMC) in the OP were measured on CBCT scans (2 mA/120 kV/12″ FOV) taken before (T1) and 3 months after surgery (T2). Paired samples t-test was used for analyzing statistical significance of changes ($p \leq 0.05$).

Results OP volume and AMC increase after bimaxillary advancement was statistically significant, while for the mandibular set-back group the increase was non-significant. NP volume was not reduced in any of the two groups. No significant differences in PA dimensions were found between groups at neither T1 nor T2 time points.

Conclusion Results suggest that the combination of mandibular set-back/maxillary advancement did not reduce airway dimensions, while bimaxillary advancement surgery led to a statistically significant increase in the OP dimensions.

Keywords: cone beam CT; bimaxillary orthognathic surgery; pharyngeal airway

INTRODUCTION

Dentofacial deformity is defined as a handicapping deviation from normal facial proportions and dental relationships. Treatment of such deformity is complex and involves orthodontists, maxillofacial surgeons and other dental specialists. Aesthetic and functional problems are corrected by jaw repositioning in all three spatial planes [1]. Skeletal movements change the position and tension of the surrounding soft tissues, tongue, soft palate, hyoid bone and muscles, which are directly or indirectly connected to the upper and/or lower jaw. These changes may also affect the dimensions of the oral and nasal cavities, as well as the pharyngeal airway space (PAS) [2, 3]. The most commonly preformed bimaxillary orthognathic surgeries are mandibular set-back combined with maxillary advancement and maxillo-mandibular advancement.

Mandibular set-back combined with maxillary advancement is a procedure used to treat class III malocclusions. It has been shown that class III correction by mandibular set-back only can cause a reduction in pharyngeal airway dimensions, therefore additional maxillary advancement is suggested in order to prevent potential breathing problems [4, 5].

Maxillo-mandibular advancement (MMA) combined with genioplasty was first described as a procedure for treating the obstructive sleep apnea (OSA) syndrome [6]. It is performed by means of the Le Fort I and bilateral sagittal split (BSS) osteotomies, after which both jaws are moved anteriorly. This leads to anterior repositioning of the soft palate, tongue and pharyngeal tissues.

OBJECTIVE

The aim of this study was to analyze and compare three-dimensional (3D) pharyngeal airway changes in surgical patients treated by mandibular set-back and maxillary advancement and patients that had bimaxillary advancement with genioplasty.

METHODS

The sample of the study consisted of 14 nongrowing subjects who underwent combined orthodontic-surgical treatment at Case Western Reserve University in Cleveland, OH, USA. The sample was divided into two groups according to the type of bimaxillary surgery.

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Group A consisted of 7 patients treated by combined mandibular set-back/maxillary advancement, and group B consisted of 7 patients treated by maxillo-mandibular advancement (MMA) with genioplasty. Groups were matched for age and gender.

All patients were treated with standard edgewise appliances and orthognathic surgery. CBCT scans were taken before (T1) and 3 months after surgery (T2) using a custom Hitachi CB MercuRay scanner (Hitachi Medical Systems America Inc., Twinsburg, OH). The scanner settings were adjusted in order to fully comply with the ALARA (As Low As Reasonably Achievable) standards, while maintaining acceptable diagnostic image quality [7, 8]. Images were taken at 2 mA, 120 kV, and a 12-inch field of view (F Mode) setting, with the scanning time of 9.6 seconds. Image data for each patient consisted of 512 slices, with isometric voxels sized 0.377 mm. Image resolution was 1024×1024 pixels and 12 bits per pixel (4096 grayscale). Patients were scanned in the sitting position with head in the natural head posture and teeth in maximum intercuspation. Scanning was performed at the end of the exhalation period when the patient was not swallowing. The images were taken during the regular diagnostic procedures of obtaining orthodontic records. Patients have signed the informed consent form that allows the use of their records for research and publication purposes. The research was also approved by the Human Research Ethics Committee of the University of Belgrade Faculty of Dental Medicine (resolution number 36/20 from December 14, 2009).

DICOM (Digital Imaging and Communication in Medicine) images were analyzed using the InVivo Dental Software (Anatomage Inc., San Jose, CA, USA). Image orientation was performed in the Section view according to the axial, coronal and sagittal slices (Figure 1). *Foramen incisivum* served as a reference point for determining the midsagittal plane on the axial slice. On the sagittal slice palatal plane was oriented so that it coincided with the True Horizontal Plane and on the coronal slice *Infraorbitale* points were aligned. Images were further worked on in the Volume Render view where orientation was transmitted automatically. Grayscale view images with maximum intensity reconstruction were moved upward or downward with the Patient Orientation tool when needed, so that the palatal plane coincided with the central horizontal line of the grid. Slice view and the Volume Render view were then matched.

Positive airway creation and volume calculation was also performed in the Volume Render view. Grayscale images were put in top orientation, with volume rendering reconstruction, and were then inversed. Opacity was decreased in order to visualize internal structures. Sculpting tool was used to cut away unnecessary parts (Figure 2A) and the partly sculpted images were then oriented to Right Lateral view where sculpting was continued (Figure 2B). Images were then reoriented back to Top view and maxillary sinuses were removed (Figure 2C). After obtaining the desired airway, opacity was increased, brightness and contrast were readjusted and a solid airway was created for calculating the final airway volume (Figure 2D).

Nasal passages (NP)

Inferior border of the NP was defined using the horizontal line through the palatal plane (Figure 3). The superior border was determined in the Section view by moving the axial reference plane on the sagittal slice until reaching the axial slice on which the nasal septum first fuses with the posterior wall of the pharynx (Figure 3). Distance measuring tool was used to measure the distance between the superior and inferior borders.

The 3D Volume Clipping Tool in the Volume Render view was used to cut the airway along the axial plane. Clipping plane was moved when needed to concur with the inferior NP border by scrolling the mouse wheel. Distance Measuring Tool was used to measure the distance between the borders obtained earlier, and using the Clipping Tool the part above the superior border was eliminated. Maxillary sinuses were cut away in Top view orientation, and the definite NP volume was obtained.

Oropharyngeal airways (OP)

Inferior NP border (palatal plane) was used as the superior OP border (Figure 3) and the horizontal line through the most anteroinferior point of the second cervical vertebrae as the inferior OP border (Figure 3). The distance between OP borders was measured in the same way as the NP borders.

The NP airway volume was flipped to the side underneath the palatal plane using the Flip option of the 3D Volume Clipping Tool. The distance between the OP borders was transferred to the airway volume and the part below the inferior border was cut with the Sculpting Tool. OP volume was measured using the Volume Measuring Tool.

All volumes were calculated using automatic segmentation, i.e. the Volumetric Measuring Tool, which calculates and displays the desired volume measurement in cubic millimeters (mm^3) and cubic centimeters (cc).

Area of maximum constriction in the OP

The area of maximum constriction (AMC) in the OP was measured on the axial slices in the Sectional view by means of the Area Measuring Tool. The maximum constriction slice was identified by moving the axial reference plane on the sagittal slice while observing the airway area on the corresponding axial slice.

Cephalometric analysis

Cephalograms generated from DICOM files were analyzed using the Dolphin Imaging software version 11 (Dolphin Imaging, CA, USA). Sagittal jaw positions and relationships were determined according to the SNA, SNB and ANB angles and A-Nperp and B-Nperp linear measurements.

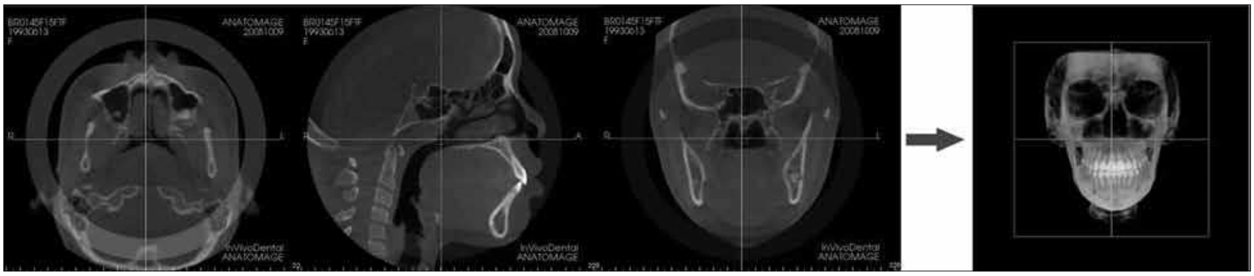


Figure 1. Image orientation according to the axial, sagittal and coronal slices

Figure 2. Image orientation, views and reconstruction during positive airway creation

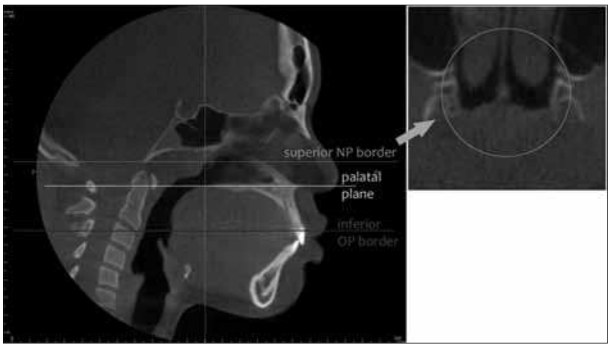


Figure 3. Determining upper and lower pharyngeal airway borders

The methodology used has been previously applied with success [3, 9]. All measuring has been performed and repeated for reliability testing by a single operator (NLjS) trained by an expert (JMP).

Statistical analysis

Data processing and descriptive statistics (means, standard deviations and ranges for pretreatment (T1) and post-treatment (T2) records) was done using the Microsoft Office Excel 2010 package (Microsoft Corporation, Redmond, WA). SPSS software package (version 12, SPSS Inc., Chicago, IL) was used for further statistical analysis. Intraoperator reliability for each measurement was determined using the intraclass correlation coefficient (ICC). The Kolmogorov–Smirnov test revealed the normality of distribution for all data, therefore parametric tests were used. Statistical significance of changes between T1 and T2 was analyzed using paired samples t-test, with the level of significance set at $p<0.05$.

RESULTS

The intraclass correlation coefficient for all measured parameters showed high reliability and reproducibility of measurements (r>0.95).

Mean ages and cephalometric measurements at T1 and T2 for both groups are presented in Table 1, while Table 2 contains pharyngeal airway measurements. Postoperative OP and NP volumes, as well as the AMC, increased in both groups. OP volume and AMC increase after bimaxillary advancement (group B) was statistically significant (Table 2). No significant differences were found between groups at T1 and T2 (Table 3).

Distribution of NP volume values before and after surgery is presented in Graph 1 for group A and in Graph 2 for group B. Distribution of OP volume values before and after surgery is presented in Graph 3 for group A and in Graph 4 for group B. Distribution of AMC values before and after surgery is shown in Graph 5 for group A and in Graph 6 for group B.

DISCUSSION

Jaw repositioning by orthognathic surgery changes the position and tension of the surrounding structures, therefore affecting the dimensions of the pharyngeal airway space. The quantity of PAS dimension changes depends on the intensity and direction of skeletal movement [2]. This study was designed to assess PAS changes in patients treated by a combination of orthodontic treatment and bimaxillary orthognathic surgery. Using the information from the DICOM images provided by a single CBCT scan, we were able to analyze the PAS of our patients easily and

Table 1. Average age and sagittal parameters for groups A and B

Parameter	Age (years)	SNA		SNB		ANB		A-Nperp		B-Nperp	
	T1	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Group A (n=7)	18.18±1.2	82.36±4.37	85.56±3.86	83.11±2.49	81.01±2.43	-0.74±4.14	4.49±3.23	-0.33±5.24	2.94±3.88	0.20±4.26	-3.37±4.06
Group B (n=7)	19.75±3.79	79.94±3.9	83.99±4.64	77.19±5.95	80.16±4.52	2.76±2.72	3.86±0.8	-2.77±4.32	-2.21±10.79	-6.30±7.67	-5.07±7.57

SNA – sagittal position of the maxilla relative to the cranial base; SNB – sagittal position of the mandible relative to the cranial base; ANB – intermaxillary sagittal relation

Table 2. Descriptive statistics and comparison of pharyngeal airway measurements at T1 and T2 for groups A and B

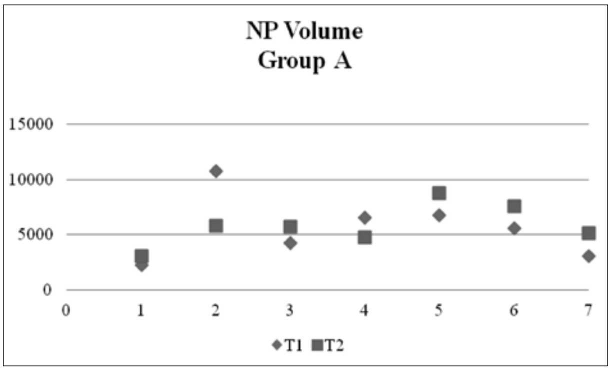
Parameter		T1				T2				p	Δ (T2–T1)
		Mean	SD	Min	Max	Mean	SD	Min	Max		Mean±SD
Group A (n=7)	NP volume (mm³)	5,590.43	2,835.66	2,238	10,737	5,827.14	1,844.55	3,082	8,722	0.821	236.71±2,652.08
	OP volume (mm³)	8,620.71	6,156.43	2,890	18,463	8,962.14	6,367.22	2,870	19,528	0.593	341.43±1,600.51
	AMC (mm²)	200.42	156.42	65.11	464.76	202.96	144.74	86.81	439.85	0.843	2.54±32.48
Group B (n=7)	NP volume (mm³)	6,342.29	3,262.56	2,280	12,167	6,642.71	2,907.42	2,482	11,982	0.609	2,993.83±1,471.54
	OP volume (mm³)	5,344.29	3,806.64	680	11,775	8,166.43	3,292.97	4,076	12,996	0.047*	2,822.14±300.43
	AMC (mm²)	121.43	69.91	37.54	237.28	174.64	73.83	71.23	284.55	0.041*	53.21±54.13

* p<0.05
NP – nasal passage; OP – oropharyngeal; AMC – area of maximal constriction in the OP; SD – standard deviation; Min – minimum value; Max – maximum value

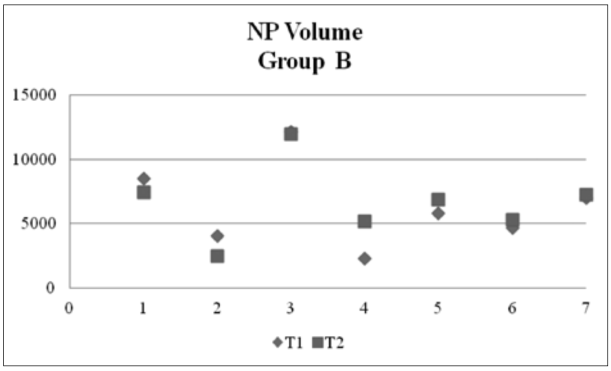
Table 3. Mean differences for pharyngeal airway measurements between groups A and B at T1 and T2

Parameter	T1			T2			Δ		
	Group A (n=7)	Group B (n=7)	p	Group A (n=7)	Group B (n=7)	p	Group A (n=7)	Group B (n=7)	p
NP volume (mm³)	5,590.43±2835.66	6,342.29±3,262.56	0.654	5,827.14±1844.55	6,642.71±2907.42	0.543	236.71±2652.08	2,993.83±1471.54	0.957
OP volume (mm³)	8,620.71±6156.43	5,344.29±3,806.64	0.254	8,962.14±6367.22	8,166.43±3292.97	0.774	341.43±1600.51	2,822.14±300.43	0.077
AMC (mm²)	200.42±156.42	121.43±69.91	0.246	202.96±144.74	174.64±73.83	0.653	2.54±32.48	53.21±54.13	0.055

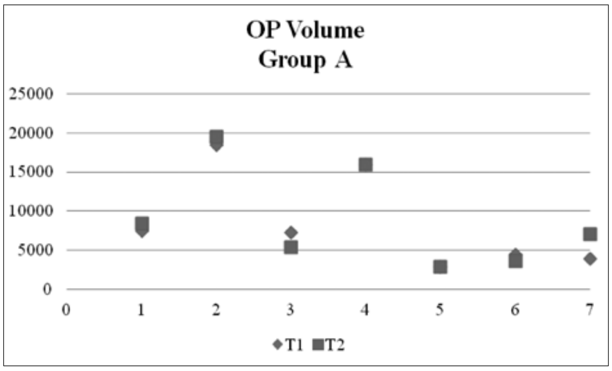
NP – nasal passage; OP – oropharyngeal; AMC – area of maximal constriction in the OP



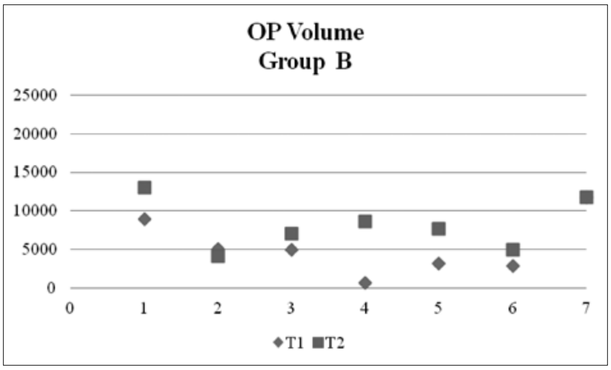
Graph 1. Nasopharyngeal (NP) volume values distribution for group A



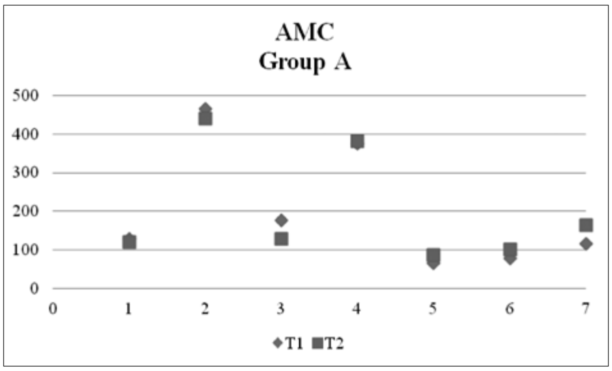
Graph 2. Nasopharyngeal (NP) volume values distribution for group B



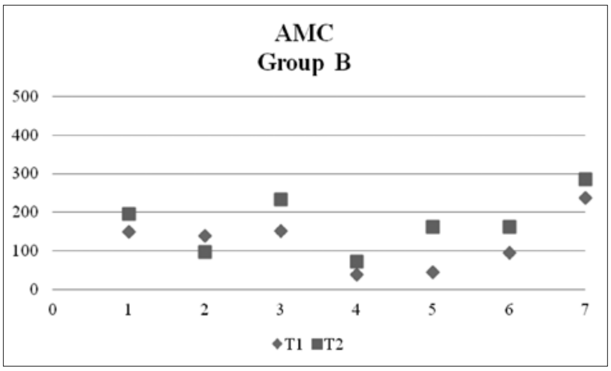
Graph 3. Oropharyngeal (OP) volume values distribution for group A



Graph 4. Oropharyngeal (OP) volume values distribution for group B



Graph 5. Area of maximum constriction (AMC) values distribution for group A



Graph 6. Area of maximum constriction (AMC) values distribution for group B

in detail [10]. NP and OP volumes and the AMC were calculated for all patients at T1 and T2.

Patients from our sample treated by mandibular set-back/maxillary advancement (group A) showed a non-significant increase in the NP and OP volumes and the AMC. Using lateral cephalograms Chen et al. [4] also reported a non-significant change in PAS dimensions after bimaxillary Class III correction, and a decrease after mandibular set-back only. Because of such results Chen et al. [4], as well as Degerliyurt et al. [5] suggest bimaxillary surgical Class III correction whenever possible in order to prevent PAS narrowing that could lead to the development of the obstructive sleep apnea (OSA) syndrome. This is further supported by the findings of Jakobsone et al. [11] on lateral cephalograms, who state that NP volume increases significantly in the long-term after bimaxillary Class III correction. However, some other authors who also used lateral cephalograms came to opposing conclusions – Turnbull and Battagel [12] and Foltán et al. [13] found a statistically significant decrease. On the other hand Degerliyurt et al. [5] used CT scans and noted a significant decrease after monomaxillary and non-significant decrease after bimaxillary Class III correction.

Group B of our sample, treated by maxillo-mandibular advancement (MMA) combined with genioplasty, showed a significant increase in the OP volume and the AMC (Figure 4), while the NP volume increase lacked statistical significance. These results are in line with those of Hernández-Alfaro et al. [14] who, using CBCT scans, found a significant increase of airway volume in patients treated by MMA. Group B could also be compared to the samples from studies of OSA patients that claim a 75–100% success rate in treating OSA syndrome by MMA [15-19]. Li et al. [17] (using cephalograms and fiberoptic nasopharyngoscopy), Fairburn et al. [15] (using conventional CT scans), and Ronchi et al. [20] (using cephalograms, CT scans and polysomnography) reported a significant increase in PAS dimensions, a decrease in PAS collapsibility, as well as the elimination of OSA symptoms after MMA.

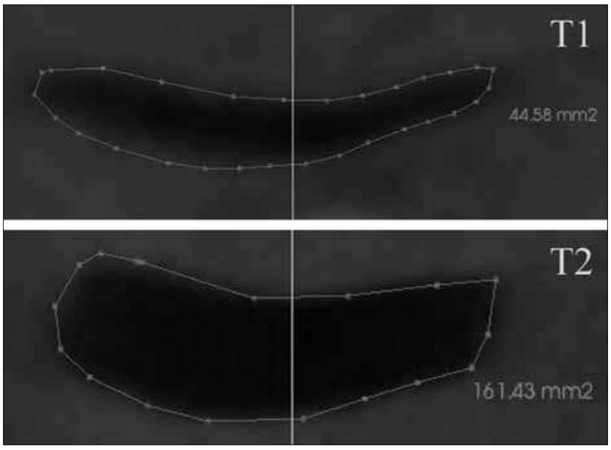


Figure 4. Area of maximum constriction in the pharynx before and after maxillo-mandibular advancement with genioplasty

Orthodontists and maxillofacial surgeons alike are frequently faced with the potential link between PAS dimensions and the sleep-induced breathing disturbances nowadays [21]. The obstructive sleep apnoea syndrome

(OSAS) is a medical condition with a growing incidence in the contemporary population [22]. Several authors [23, 24] hypothesized on the connection between the size of the mandibular region and the occurrence of OSA symptoms, but no correlation was found. However, Zucconi et al. [25] reported on a significant decrease in sagittal mandibular dimensions in habitual snorers. One study done on lateral cephalograms and study models focused on the connection between maxillary morphological features and the occurrence of the OSA symptoms in 8–10-year-old mouth-breathers reported that these children had narrow maxillas, insufficient apical base lengths and reduced palatal plane to cranial base angles [26]. El and Palomo [27, 28] found significantly smaller NP volumes in Class II compared to Class I and Class III subjects, and significantly smaller OP volumes in Class II compared to Class III subjects. Moreover, Kim et al. [29] reported mean total airway volumes to be smaller in retrognathic compared to normal sagittal skeletal relation subjects. Due to this controversy, PAS dimension assessment is slowly becoming an essential part of the diagnostic and treatment planning processes in orthodontics and orthognathic surgery.

The reason methodology is mentioned next to the references comes from the study published by Park et al. [30] in which they examined PAS dimensions after mandibular set-back using lateral cephalograms and CT scans. They reported a difference in PAS changes depending on the diagnostic tool, namely a decrease on lateral cephalograms and a non-significant change in PAS volume and axial cross-sections on CT scans. This indicates that attention should be paid to methodology when interpreting results of different studies. Moreover, in studies involving orthognathic surgery, one should also consider different types of bony fixation, time of obtaining postoperative images and preoperative airway dimensions, as well as other factors which may influence PAS dimension changes and give a false picture of what actually happened.

Analyzing PAS using CBCT scans is becoming more popular, but even with recent technical advancements, the role of these techniques as clinical tools is limited. We are still lacking normative 3D values for PAS structures and functions, as well as standardized protocols for obtaining these images. Software reliability [31] and operators' training and experience also need to be considered.

CONCLUSION

Results of this study suggest that bimaxillary surgery had a positive effect on PA dimensions, with no statistically significant differences in the pharyngeal airway values at either T1 or T2 when comparing patients treated by mandibular set-back/maxillary advancement to those treated with bimaxillary advancement and genioplasty. Mandibular set-back combined with maxillary advancement did not cause a reduction in either the NP and OP volume or the AMC, while bimaxillary advancement resulted in significant OP volume and AMC increase. The T1 to T2 difference for AMC and OP volume was significantly larger in the bimaxillary advancement group, due to mandibular advancement. Further investigation on larger samples and post-retention records is suggested in order to better determine the significance and quantity of PAS changes.

NOTE

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Промене фарингеалних ваздушних путева након бимаксиларне ортогнатске хирургије – прелиминарни резултати

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КРАТАК САДРЖАЈ

Увод Дентофацијални деформитети представљају одступање у односу на нормалне пропорције лица и денталне односе. Лече се репозиционирањем вилица у све три равни простора, што мења положај и напетост околних меких ткива, костију и мишића. Ове промене могу да утичу на величину фарингеалних ваздушних путева.

Циљ рада Циљ студије је био да се процене и упореде тродимензионалне промене фарингеалних ваздушних путева код особа лечених ретропозиционирањем мандибуле уз померање максиле унапред у односу на оне лечене померањем обе вилице унапред уз гениопластику.

Методе рада Испитанике је чинило седам пацијената лечених комбинацијом ретропозиционирања мандибуле и антериорног позиционирања максиле и седам пацијената лечених бимаксиларним антериорним позиционирањем. Запремине назофаринкса, орофаринкса и површина најужег дела орофаринкса мерени су на *CBCT* снимцима (2 *mA*/120 *kV*/12'' *FOV*) прављаним пре операције (T1) и три месеца након хируршке корекције (T2). Студентов t-тест за упарене узорке коришћен је за анализу статистичке значајности промена ($p \le 0,05$).

Резултати Запремина орофаринкса и површина најужег дела орофаринкса повећале су се у обе групе, и то статистички значајно код испитаника лечених бимаксиларним антериорним позиционирањем, а статистички безначајно код испитаника лечених комбинацијом ретропозиционирања мандибуле и антериорног позиционирања максиле. Ни у једној групи није дошло до смањења запремине назофаринкса. Ни пре ни после терапије нису уочене значајне разлике у величини ваздушних путева између група.

Закључак Резултати указују на то да ретропозиционирање мандибуле уз антериорно позиционирање максиле није смањило димензије ваздушних путева, док је бимаксиларно антериорно позиционирање довело до статистички значајног повећања величине орофаринкса.

Кључне речи: *CBCT*; бимаксиларна ортогнатска хирургија; фарингеални ваздушни путеви

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