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≤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 non-growing 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.
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 Infraorbital 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 inverted. 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.

**Ororharyngeal 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 (mm³) 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.
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Age (years)</th>
<th>SNA</th>
<th>SNB</th>
<th>ANB</th>
<th>A-Nperp</th>
<th>B-Nperp</th>
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<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T1</td>
<td>T2</td>
<td>T1</td>
<td>T2</td>
<td>T1</td>
</tr>
<tr>
<td>Group A</td>
<td>18.18±1.2</td>
<td>82.36±4.37</td>
<td>85.56±3.96</td>
<td>83.11±2.49</td>
<td>81.01±2.43</td>
<td>-0.74±4.14</td>
</tr>
<tr>
<td>Group B</td>
<td>19.75±3.79</td>
<td>79.94±3.9</td>
<td>83.99±4.64</td>
<td>77.19±5.95</td>
<td>80.16±4.52</td>
<td>2.76±2.72</td>
</tr>
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</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>T1 Mean</th>
<th>T1 SD</th>
<th>T1 Min</th>
<th>T1 Max</th>
<th>T2 Mean</th>
<th>T2 SD</th>
<th>T2 Min</th>
<th>T2 Max</th>
<th>p</th>
<th>Δ (T2–T1) Mean</th>
<th>Δ (T2–T1) SD</th>
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</thead>
<tbody>
<tr>
<td>Group A</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NP volume (mm³)</td>
<td>5,590.43±2,835.66</td>
<td>5,827.14±1,844.55</td>
<td>5,082.71</td>
<td>6,367.22</td>
<td>0.654</td>
<td>1.87±5.24</td>
<td>2.94±3.88</td>
<td>3.082</td>
<td>8,722</td>
<td>0.593</td>
<td>236.71±2,652.08</td>
</tr>
<tr>
<td>OP volume (mm³)</td>
<td>8,620.71±6,156.43</td>
<td>8,962.14±6,367.22</td>
<td>8,096.43</td>
<td>8,396.27</td>
<td>0.593</td>
<td>144.74</td>
<td>174.64</td>
<td>86.81</td>
<td>439.85</td>
<td>0.843</td>
<td>2.54±32.48</td>
</tr>
<tr>
<td>AMC (mm²)</td>
<td>200.42±156.42</td>
<td>202.96±144.74</td>
<td>237.28</td>
<td>73.83</td>
<td>0.047*</td>
<td>71.23</td>
<td>284.55</td>
<td>0.041*</td>
<td>53.21±54.13</td>
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<tr>
<td>Group B</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>NP volume (mm³)</td>
<td>6,342.29±3,262.56</td>
<td>6,642.71±2,907.42</td>
<td>6,121</td>
<td>7,292.97</td>
<td>0.047*</td>
<td>11,982</td>
<td>19,528</td>
<td>0.609</td>
<td>2,993.83±1,471.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP volume (mm³)</td>
<td>5,344.29±3,806.64</td>
<td>8,166.43±3,292.97</td>
<td>680</td>
<td>8,294.13</td>
<td>0.077</td>
<td>12,996</td>
<td>341.43±1,600.51</td>
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<td></td>
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<tr>
<td>AMC (mm²)</td>
<td>121.43±69.91</td>
<td>174.64</td>
<td>73.83</td>
<td>71.23</td>
<td>53.21±54.13</td>
<td>284.55</td>
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*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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group A (n=7)</th>
<th>Group B (n=7)</th>
<th>p</th>
<th>Group A (n=7)</th>
<th>Group B (n=7)</th>
<th>p</th>
<th>Group A (n=7)</th>
<th>Group B (n=7)</th>
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<td>6,642.71±2,907.42</td>
<td>0.543</td>
<td>236.71±2,652.08</td>
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<td>0.957</td>
</tr>
<tr>
<td>OP volume (mm³)</td>
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<td>5,344.29±3,806.64</td>
<td>0.254</td>
<td>8,962.14±6,367.22</td>
<td>5,344.29±3,806.64</td>
<td>0.774</td>
<td>341.43±1,600.51</td>
<td>2,822.14±300.43</td>
<td>0.077</td>
</tr>
<tr>
<td>AMC (mm²)</td>
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<td>174.64±73.83</td>
<td>0.653</td>
<td>202.96±144.74</td>
<td>284.55</td>
<td>0.041*</td>
<td>53.21±54.13</td>
<td>284.55</td>
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</tr>
</tbody>
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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
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 setback/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.

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...
Pharyngeal Airway Changes after Bimaxillary Orthognathic Surgery – Preliminary Results

This paper is a part of Dr. Neda Stefanović’s doctoral thesis.

REFERENCES


Промене фарингеалних ваздушких 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, меких ткива, кости и мишића. Ове промене могу да утичу на величину фарингеалних ваздушких путева. Циљ рада Циљ студије је био да се процене и упореде тродимензионалне промене фарингеалних ваздушких путева код особа са легеном ретропозиционирањем мандibuле уз померање максиле унапред у односу на енапрезе ваздушких путева не намерно уланторукти.
Методе ради Испитане су експерименталне фарингеалне области максиларне и антерниорног позиционирања максиле и седам пацијената са ваздушких путева, радећи максиларним антерниорног позиционирањем. За примење напона, ортодонтска хирургија и површина најужег дела ортофракиска вере у СВС снимцима (2 mА/120 kV/12° FOV) направљаних пре операције (T1) и три месеца након хирурске корекције (T2). Статистички t-тест за упарате узорци коришћен је за анализу статистичке значајности промена (p≤0,05). Резултати Запремина дофракиска и површина најужег дела ортофракиска повећале су се у обе групе, а статистички значајно код истипаната лечене бимаксиларним антерниорном позиционирањем, а статистички невизначно код истиптаната лечене комбинацијом ретропозиционирања мандibuле и антерниорног позиционирања максиле. Ни у једној групи није дошло до смањења запремине нозофракиска. Ни пре ни после терапије нису уочене значајне разлике у величини ваздушких путева између група. Закључак Резултати указују на то да ретропозиционирање мандibuле антерниорно позиционирања максиле није смањило димензију ваздушких путева, док је бимаксиларно антерниорно позиционирање довело до статистички значајног повећања величине ортофракиска. Кључне речи: СВС; бимаксиларна ортогнатска хирургија; фарингеални ваздушки путеви