Original Article - Comparative Study

Tomographic Analysis of the Impact of Mandibular Advancement Surgery on Increased Airway Volume

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Abstract

Purpose: This study aimed to quantify, using cone-beam computed tomography (CBCT) in patients who underwent a mandibular advancement surgery associated with genioplasty, three-dimensional changes in airway space and to evaluate whether these changes differ between men and women. **Materials and Methods:** Preoperative and 8-month postoperative CBCT scans of 38 patients aged 18–45 years of either sex and any ethnicity who underwent mandibular advancement surgery associated with genioplasty were analyzed using the Xoran software (Xoran Technologies, Ann Arbor, MI, USA). The linear distances gonion-gnathion (Go-Gn) and condylion-menton (Co-Me) were obtained. Airway volume was measured using the Dolphin Imaging software, version 11.0. Then, data were tabulated and analyzed using Student's *t*-test. **Results:** Mean patient age was 30.3 years; 39.47% were men and 60.63% were women. The mean Go-Gn distance was 72.05 mm before surgery and 78.56 mm after surgery, with a mean gain of 6.51 mm. The mean Co-Me distance was 113.47 mm before surgery and 119.89 mm after surgery, with a mean increase of 6.42 mm. Both differences were statistically significant. The mean volume of airway space was 17,272.92 mm^3 before surgery and 24,173.74 mm^3 after surgery, with a statistically significant mean increase of 6900.82 mm^3. There was no statistically significant difference in mean volumetric gain between men (7566.69 mm^3) and women (7456.69 mm^3). **Conclusion:** Mandibular advancement surgery results in significant increase of airway space, and there is no difference in airway volume between men and women.

Keywords: Cone-beam computed tomography, mandibular advancement, orthognathic surgery, sleep apnea syndromes

Introduction

Dentoskeletal discrepancy with mandibular retrusion may cause severe functional problems to the patient, such as obstructive sleep apnea (OSA).[1] Studies on OSA have emphasized the need to increase airway space through orthognathic surgery.[2] Orthognathic surgery can be used not only to improve facial esthetics and dental occlusion but also to optimize functional results associated with the airway. Mandibular advancement leads to increased oropharyngeal airway space and is one of the most satisfactory methods to correct upper airway deficiencies.[3]

Imaging modalities such as acoustic reflection, fluoroscopy, nasopharyngoscopy, magnetic resonance imaging, cephalometry, and computed tomography can be used to assess airway space.[4] Cone-beam computed tomography (CBCT) provides better airway assessment due to its three-dimensional nature. CBCT images can be analyzed using the Dolphin Imaging software (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA), which enables the evaluation of upper airway space in its three dimensions and volume measurement.[5]

As mandibular advancement surgery is often indicated in cases of OSA to improve airway space and thus, to treat this disease, the aim of the present study was to quantify, using CBCT, three-dimensional volumetric changes of airway space in patients undergoing mandibular advancement surgery and to determine whether these changes differed between male and female patients.

Materials and Methods

This study was approved by the Ethics Committee. All procedures were in accordance with the 1964 Helsinki

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declaration. The sample was retrospectively selected based on the medical records of patients with preoperative and 8-month postoperative CBCT scans. It consisted of 38 patients aged 18–45 years of either sex and any ethnicity who underwent mandibular advancement surgery associated with genioplasty.

Pre- and post-operative CBCT scans were analyzed using the Xoran software (Xoran Technologies, Ann Arbor, MI, USA), which provided measures of mandibular base length, such as the distance between the cephalometric landmarks gonion and gnathion (Go-Gn) [Figure 1] and condylion and menton (Co-Me) [Figure 2]. Go was considered the limit between posterior and inferior borders of the mandibular ramus; Gn was considered the most inferior and anterior point of the mandibular symphysis; Co was considered the most posterior and superior point of the mandibular condyle; and Me was considered the most inferior point of the menton.

Volume measurement of upper airway space was performed by a calibrated examiner, who marked five cephalometric landmarks on a sagittal section of the images using the Dolphin Imaging software, version 11.0. The definition of a specific area with these five landmarks enabled standardized assessment of pre- and post-operative airway space. A polygon was formed by joining these landmarks: posterior nasal spine, basion, anterior inferior border of the fourth cervical vertebra (C4), inferior border of the hyoid bone, center of the uvula, and posterior nasal spine again [Figure 3].[6] With the delimitation of the polygon, the software generated an image and measured the airway volume [Figure 4]. Data were tabulated and analyzed using Student's *t*-test.

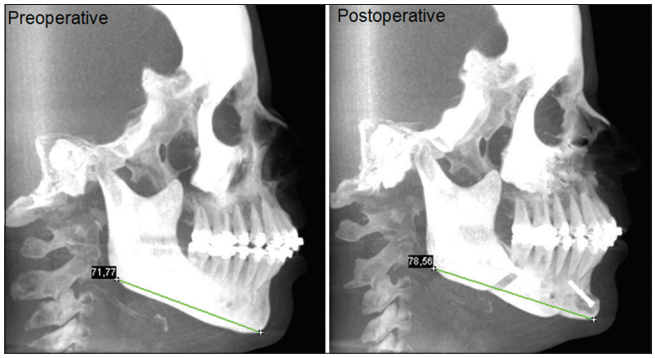

Figure 1: Pre- and post-operative measurements of gonion to gnathion distance using the Xoran software with XSTD files

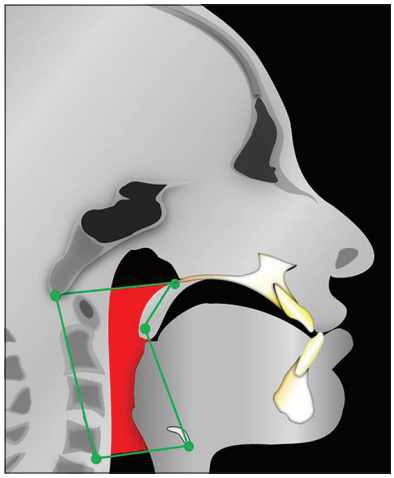

Figure 3: The polygon that defines the airway region analyzed in this study was obtained by joining the following landmarks: posterior nasal spine, basion, anterior inferior border of the fourth cervical vertebra (C4), inferior border of the hyoid bone, center of the uvula, and posterior nasal spine again

Results

Thirty-eight pre- and post-operative CBCT scans of patients who underwent mandibular advancement surgery associated with genioplasty were analyzed. Mean patient

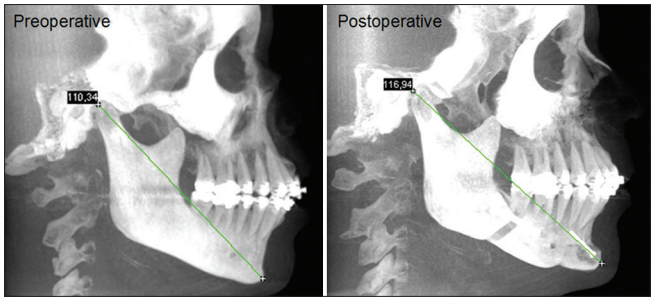

Figure 2: Pre- and post-operative measurements of condylion to menton distance using the Xoran software with XSTD files

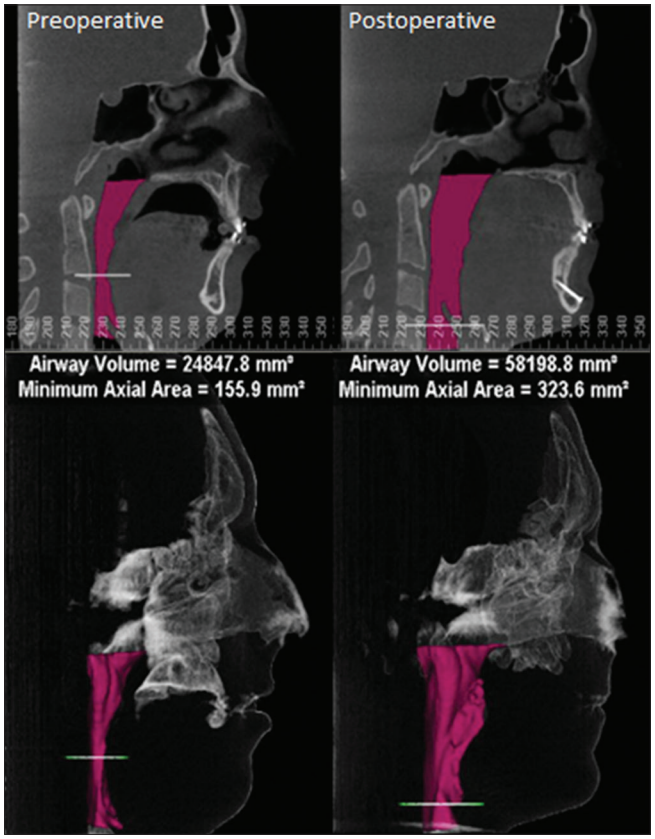

Figure 4: Pre- and post-operative measurements of airway volume using the Dolphin Imaging software, version 11.0, with DICON files

age was 30.3 years (range: 19–45 years), and there were 15 men (39.47%) and 23 women (60.63%).

The comparison between pre- and post-operative Go-Gn and Co-Me distances showed a linear millimetric increase in all CBCT scans. The mean Go-Gn distance was 72.05 mm before surgery and 78.56 mm after surgery, with a mean linear gain of 6.51 mm. This between-group difference was statistically significant ($P < 0.001$). The mean Co-Me distance was 113.47 mm before surgery and 119.89 mm after surgery. There was a mean linear increase of 6.42 mm, showing a statistically significant difference ($P < 0.001$) [Table 1].

Volumetric assessment (mm^3) of pre- and post-operative CBCT scans showed increased airway space in all 38 patients. The mean volume was 17,272.92 mm^3 before surgery and 24,173.74 mm^3 after surgery, with a mean volumetric gain of 6900.82 mm^3. This corresponds to a statistically significant increase of 39.95% in airway space ($P < 0.001$) [Table 1].

The comparison of volumetric increase in airway space between men (7566.69 mm^3) and women (7456.69 mm^3) showed no statistically significant difference ($P = 0.962$) [Table 2].

Discussion

Dimensional changes in the upper airway following orthognathic surgery have been the focus of extensive scientific research.[7,8] There has been particular interest in volumetric changes in airway space following mandibular advancement surgery associated with genioplasty. This procedure considerably changes this space, which becomes more functional when the surgery is well planned and executed.[9]

Cephalometry was widely used to quantify airway space until the past decade.[10] Aboudara *et al*.[11] compared airway assessments using cephalometry and CBCT and found that cephalometric precision was low due to great variability of this region. Thus, the results of cephalometric studies are limited compared to CBCT studies as cephalometric assessment of airway space uses landmarks that change between pre- and post-operative periods.[12] This justifies the use of three-dimensional analysis of upper airway space in the present study, providing volumetric changes by comparing pre- and post-operative CBCT scans. Brown *et al*.,[13] Hwang *et al*.,[14] and Alves *et al*.[15] demonstrated the accuracy of this type of analysis.

The Dolphin Imaging software assesses airway volume with great precision. It includes tools that insert landmarks in the images and control the limits of the region where pharyngeal airway volume will be quantified.[12,16]

Li *et al*.[17] conducted a study using fiberoptic nasopharyngolaryngoscopy to evaluate the airway in the early postoperative period of 70 patients undergoing maxillomandibular advancement surgery. They reported the occurrence of moderate edema in the airway space. de Souza Carvalho *et al*.[12] found that the edema reduces gradually, and their 6-month postoperative assessments showed greater airway space compared to shorter postoperative periods. This justifies the use of 8-month postoperative CBCT scans in the present study.

There was a volumetric increase in postoperative CBCT scans of all patients included in the present study as compared to preoperative scans, which is consistent with the findings of Haskell *et al*.,[18] Achilleos *et al*.,[19] and Alves *et al*.[15] They noted that changes produced by mandibular advancement may result in widening of the airway. Furthermore, Fairburn *et al*.[20] and Goncalves *et al*.[3] found greater increase in airway space in cases of maxillomandibular advancement compared to mandibular advancement alone.

Broujerdi *et al*.[21] found that mandibular advancement leads to a mean increase of 30% in airway volume. The results of the present study are consistent with this finding as all postoperative CBCTs showed volumetric increase compared to baseline scans. However, the mean volumetric increase was 39.95% in our study. This greater mean increase may be due to the association of mandibular advancement with genioplasty. There was no statistically significant difference in mean volumetric increase between men and women, which is consistent with the findings of Kim *et al*.[22]

In the present study, mandibular advancement associated with genioplasty led to increased airway volume, which is in agreement with the findings of Ronchi *et al*.[23] They suggested the use of alternative procedures such as genioplasty, septoplasty, and turbinate reduction to improve functional results. Guijarro-Martínez *et al*.[24] compared three groups of patients: the first one underwent maxillomandibular advancement; the second one underwent maxillary advancement; and the third one underwent mandibular advancement. They found that the third group showed greater increase in pharyngeal airway volume and concluded that mandibular advancement increases airway volume more than maxillary advancement.

There are various procedures for the treatment of OSA, including mandibular advancement surgery. Several studies have shown

Table 1: Mean pre- and post-operative measurements of gonion to gnathion distance, condylion to menton distance, and airway space

	Preoperative means	Postoperative means	*P**
Go-Gn	72.05 mm	78.56 mm	0.00004717
Co-Me	113.47 mm	119.89 mm	0.00041933
Airway space	17,272.92 mm^3	24,173.74 mm^3	0.00001633

*Student's *t*-test. Go-Gn=Gonion to gnathion; Co-Me=Condylion to menton

Table 2: Mean measurements of airway volume of female and male groups and results of Student's *t*-test

	Female	Male
Mean airway volume	7456.77 mm^3	7566.69 mm^3
P	0.96209173	

that the efficacy of mandibular advancement in the treatment of OSA is due to an increase in upper airway volume. This procedure is considered the treatment of choice for this disease.[23,25] The results of the present study confirm these findings.

Abramson[26] also reported an increase in airway volume following mandibular advancement and assessing the shape of the larynx after this procedure, noted an enlargement of airway space in the cross-sectional plane. Ogawa *et al*.[27] associated airway shape with OSA and concluded that OSA patients showed a more elliptical or concave shape, while non-OSA patients showed a more round or square shape.

Schendel *et al*.[28] used three-dimensional CBCT images to calculate airway volume of 1300 patients aged 6–60 years and found that it slowly decreased after age 20. Then, after age 40, it decreased more rapidly. This report makes us believe that, even though we found an increase in airway volume in our study, a longer period of observation is required to evaluate whether patients undergoing orthognathic surgery show a decrease in pharyngeal airway volume over time. In addition to recurrence, Park *et al*.[29] showed that over the years, the decrease in airway space may reach 22% of the total increase achieved with orthognathic surgery.

Conclusion

Mandibular advancement surgery results in significant increase in airway space. There is no statistically significant difference in volumetric airway space changes between men and women.

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Conflicts of interest

There are no conflicts of interest.

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