Int. J. Morphol.,
41(5):1575-1579, 2023.

Effect of Bimaxillary Orthognathic Surgery on Pharyngeal Airway Volume

Efecto de Cirugía Ortognática Bimaxilar en el Volumen de la Vía Aérea Faríngea

Marcelo Parra[1,2,3]; Luis Araneda[4,5]; Héctor Torres[6] & Sergio Olate[2,3,7]

PARRA, M. ; ARANEDA, L.; TORRES, H. & OLATE, S. Effect of bimaxillary orthognathic surgery on pharyngeal airway volume. *Int. J. Morphol., 41(5)*:1575-1579, 2023.

SUMMARY: Subjects with maxillary skeletal classes II and III not only express alterations in the hard and soft maxillofacial tissues, but also in the morphology and dimensions of the upper airway. A small space in the upper airway has been associated with sleep disorders, such as snoring and mainly obstructive sleep apnea/hypopnea syndrome (OSAHS). Consequently, interest has increased due to the influence of orthognathic surgery in the airway space. Although there are studies in the literature that have compared upper airway spaces, most have evaluated the changes using two-dimensional images, mainly lateral skull X-rays. The present study aimed to determine the airway volume in subjects with skeletal classes II and III who underwent bimaxillary orthognathic surgery. 80 CBCT exams from 40 subjects obtained before and 6 months after surgery were used. There were 20 class II and 20 class III subjects. For the volumetric analysis, a 3D rendering of the upper airway was made in previously established segments, and then the airway volume was calculated using the 3D Slicer® software version 4.11 (Slicer, USA). The statistical analysis by t-test of related samples revealed statistically significant volumetric increases in the nasopharynx, laryngopharynx, and total volume in class II patients. However, in class III patients, there were significant increases in the nasopharynx and total volume, while the volume was maintained in the oropharynx and laryngopharynx.

KEY WORDS: Upper airway space; Orthognathic surgery; Pharyngeal airway volume.

INTRODUCTION

The maxillo-mandibular discrepancies associated with growth and bone development produce significant functional alterations. Skeletal class type II is characterized mainly by a posterior position of the mandible compared to the maxilla, due to a lack of mandibular growth, or excessive growth of the maxilla (Nath *et al*., 2019). In class III subjects, the opposite occurs, with the mandible in a more protruded position than the maxilla, associated with mandibular hyperplasia or maxillary hypoplasia (Chen *et al*., 2015). These discrepancies not only express alterations in the hard and soft maxillofacial tissues, but also in the morphology and dimensions of the upper airway, where spaces in the upper airway are frequently observed to be reduced in class II subjects. (Nath *et al*., 2019)

A smaller space in the upper airway and the resulting lower mobilized air volume is strongly associated with sleep disorders, such as snoring and mainly obstructive sleep apnea (OSA) (Zhang *et al*., 2021), which is a common disorder, with a prevalence from 9 % to 38 % in the general population (Senaratna *et al*., 2017). This syndrome is characterized byperiods of apnea and/or hypopnea while sleeping. Apnea is the cessation of airflow by the nose or mouth, whereas hypopnea is a reduction in the airflow that enters by the nose or mouth, which causes oxygen saturation and/or ends in arousal. Epidemiological studies have repeatedly confirmed that the severity of OSA plays an important role in the development of cerebrovascular diseases, including stroke (Redline *et al*., 2010). Although the reduction in the

[1] Departamento de Odontología Integral Adulto, Facultad de Odontología, Universidad de la Frontera, Temuco, Chile.
[2] Programa de Doctorado en Ciencias Morfológicas, Facultad de Medicina, Universidad de La Frontera, Temuco, Chile.
[3] Centro de Excelencia en Estudios Morfológicos y Quirúrgicos (CEMyQ), Facultad de Medicina, Universidad de La Frontera, Temuco, Chile.
[4] Programa de Especialización en Imagenología Oral y Maxilofacial, Universidad San Sebastián, Chile.
[5] Departamento Patología y Medicina Oral, Facultad de Odontología, Universidad de Chile.
[6] Escuela de Odontología, Facultad de Odontología, Universidad de la Frontera, Temuco, Chile.
[7] División de Cirugía Oral y Maxilofacial, Universidad de La Frontera, Temuco, Chile.

Received: 2023-07-16 Accepted: 2023-08-22

diameter of the upper airway is not the only triggering factor of OSA, since it is a multifactor disorder, it is an anatomical factor important to consider.

For these reasons, during the past few years, interest has increased due to the influence of orthognathic surgery on the airway space. Several authors indicate that orthognathic surgery leads to an increase in upper airway space. (Chen *et al*., 2015; Von Bremen *et al*., 2021) This, of course, is very favorable, especially in class II cases where the volume of posterior air space tends to be significantly reduced (Xiang *et al*., 2017).

Although studies exist in the literature that have compared upper airway spaces, most have evaluated the upper airway changes using two-dimensional images, mainly lateral skull X-rays. However, cephalometric X-rays in two dimensions can limit the accuracy of the measurements of the upper respiratory tract due to the disadvantages of two-dimensionally evaluating a three-dimensional space (Abé-Nickler *et al*., 2017). At the moment, cone beam computed tomography (CBCT) is widely used to evaluate the shape and volume of the respiratory tract. CBCT offers the advantages of volumetric rather than linear measurements, thereby providing a three-dimensional analysis as well as measurements without distortions (Chen *et al*., 2015). In addition to the use of CBCT, various software packages have been developed to take volumetric measurements and can be applied to estimate upper airway volumes.

Although there is no consensus in the scientific literature regarding the three-dimensional volumetric differences of the upper airway in class II and III subjects who underwent orthognathic surgery, it is necessary to know the volume obtained after maxilla-mandibular movements to guide future conditions affecting the airway.

MATERIAL AND METHOD

An experimental, comparative, and retrospective study was conducted, approved by the Scientific Ethics Committee of the Universidad San Sebastián, Chile, file number 66-22. Twenty class II and 20 class III subjects were included as follows: 80 CBCT studies were used, 40 before and 40 after the surgery, from 40 subjects over 18 years of age who underwent orthognathic surgery. All the subjects signed an informed consent for their participation, and they were told about the scope of the study. Subjects with skeletal class I, subjects with imaging signs of facial trauma who required previous surgery, and subjects with incomplete diagnostic and imaging information were excluded.

CBCT examinations: The CBCT examinations were obtained by specialized technicians with 5 years of experience with a NewTom VGi EVO 3D scanner (Verona, Italy) with a 24 ¥ 19 cm window, taken with an exposure time of 15 s at 110 kV and 8 mA. To obtain the volume, the patient was seated in a vertical position, with the lips at rest and without forced muscle contraction. The examinations were input with an ordinal number, indicating only the patient's age, sex, and skeletal class, determined previously using cephalometric analysis by the surgical team who performed the orthognathic surgery, and thus the subjects' identity was kept confidential. The presurgical imaging occurred between two and four weeks before the intervention.

Volumetric Analysis. For the volumetric analysis, the 3D-Slicer® software version 4.11 (Slicer, USA) was used. To this end, the examinations were opened in DICOM format and segmented, rendering the upper airway three-dimensional, using the following reference points (Fig 1): (1) Anterior: posterior nasal spine in the sagittal plane and choanae in the axial plane. (2) Posterior: posterior wall of the pharynx (3). Superior: highest point of the nasopharynx. (4) Inferior: below the hyoid bone at the level of the lower margin of the C4 vertebral body.

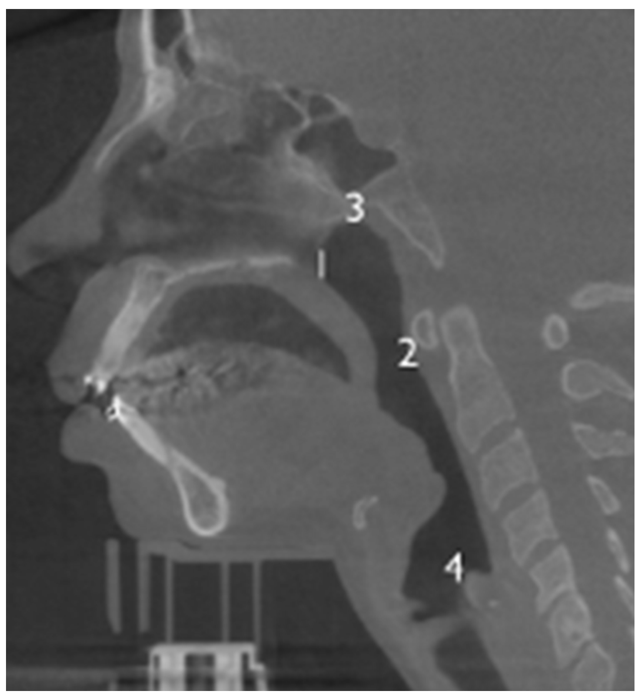

Fig. 1. Reference points for the three-dimensional rendering of the total airway.

An independent analysis of the airway segments was then performed. The previously segmented airway was divided into nasopharynx, oropharynx, and laryngopharynx, outlined in Figure 2. After segmentation, the volumetric calculations were made of each individualized segment and the total volume before and after orthognathic surgery with the corresponding modules from the previously individualized software.

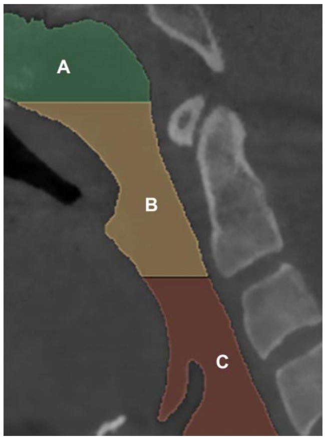

Fig. 2. Division of the upper airway studied. In which: A: Nasopharynx: highest point of the nasopharynx up to the posterior nasal spine. B: Oropharynx: from the posterior nasal spine to the lower edge of C2. C: Laryngopharynx: from the lower edge of C2 to the lower edge of C4.

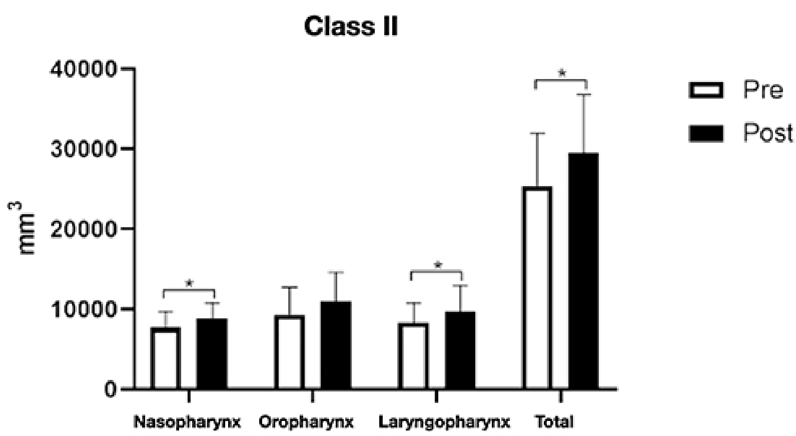

Fig. 3. Statistical results for the t-test for related samples in class III subjects.
*: Statistical significance.

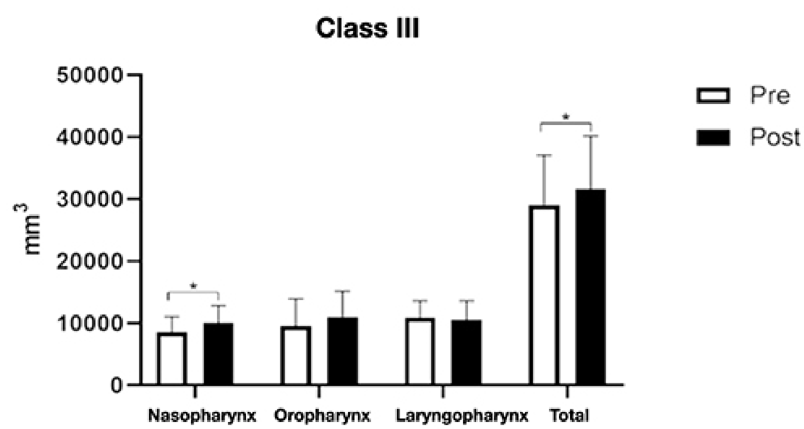

Fig. 4. Statistical results for the t-test for related samples in class III subjects.
*: Statistical significance.

Statistical analysis . First, a test of normality was done with the Shapiro-Wilk test. Then, the differences between the groups were analyzed using a t-test for related samples. $p<0.05$ was considered statistically significant. For the analysis, the SPSS version 21 statistics software was used (IBM Corp., Armonk, NY, USA).

RESULTS

The statistical analysis by t-test of related samples revealed (Fig. 3) statistically significant volumetric increases in class II patients in the nasopharynx (p=0.017), laryngopharynx (p=0.045), and total volume (p=0.015). By contrast, in the oropharynx, although the values after orthognathic surgery were higher than the presurgical condition, they were not statistically significant (p=0.062).

In class III patients (Fig. 4), statistically significant increases were noted in the nasopharynx (p=0.007) and total volume (p=0.045), whereas in the oropharynx, although the values after orthognathic surgery were higher than the presurgical condition, they were not statistically significant (p=0.060). By contrast, in the laryngopharynx, mean volumetric values were slightly lower after orthognathic surgery; however, they were not statistically significant (p=0.521).

DISCUSSION

In this study of the airway, only CBCT after orthognathic surgery with a post-operative minimum of 6 months were included. Before this time, according to reports in the literature, edema could produce a reduction in initial volume, which would mask the real volumetric increases (Brunetto *et al*., 2014).

It is important to note that there is no standardization in the literature to determine the anatomical limits of the upper airway, which could make a comparison of the results difficult. However, the projection of the hard palate and posterior nasal spine has been described frequently in the literature (Pereira *et al*., 2021, Yoshino *et al*., 2021).

The clinical importance of the relation between the surgical movement of the maxilla and/or mandible and the size of the upper airway is based on the effects of its positional change. In this respect, planning orthognathic surgery is a complex procedure that involves different components and variables. Apparently, class II patients generally benefit in terms of an increase in the upper airway space; class III patients tend to remain relatively constant (Von Bremen *et al*., 2021).

In class II patients, most studies on the airway show volume increases due to the advancement of the mandible, which produces an early increase in air volume, especially in the oropharynx and nasopharynx. In this respect, in a study with 11 class II patients with follow-up for up to four years, Pereira *et al*., (2021) found a significant and sustained increase in the upper airway volume. In the present study, significant volume increases were reported in the nasopharynx, laryngopharynx, and total volume, which may be related to what is described in the literature.

In the case of class III patients, maxillary advancement leads to an increase in the upper airway (Souza *et al*., 2019), whereas a mandibular setback usually results in a reduction of the upper airway (An *et al*., 2019). In a study with 30 patients who underwent orthognathic surgery, Li *et al*. (2022) reported a significant increase in air volume of the nasopharynx, which agrees with the results of the present study. However, they reported a significant decrease in volume in the oropharynx, which differs from our results, where there were no differences in the pre- and postoperative conditions.

The results of the present study are clear concerning the early condition of the airway volumes before and after orthognathic surgery. However, new studies with other diagnoses, surgical techniques, and therapeutic strategies are needed, correlating the volumetric differences in the airway with related factors.

Even considering the limitations of the present study, the findings make it possible to conclude that there is a significant increase in air volume in the nasopharynx, laryngopharynx, and total volume in class II patients, and a significant increase in the nasopharynx, and maintaining of the pharyngal air volume in the other segments in class III patients who underwent bimaxillary orthognathic surgery.

PARRA, M. ; ARANEDA, L.; TORRES, H. & OLATE, S. Efecto de cirugía ortognática bimaxilar en el volumen de la vía aérea faríngea. *Int. J. Morphol., 41(5)*:1575-1579, 2023.

RESUMEN: Sujetos con clases esqueletales II y III maxilares, no solamente expresan alteraciones en los tejidos duros y blandos maxilofaciales, sino también en la morfología y dimensiones de la vía aérea superior. Un espacio reducido a nivel de la vía aérea superior se asocia a trastornos del sueño como ronquidos y principalmente el síndrome de apnea/hipoapnea obstructiva del sueño (AOS); debido a esto, ha aumentado el interés por la influencia de la cirugía ortognática en el espacio de la vía aérea. Si bien existen en la literatura estudios que han comparado los espacios de la vía aérea superior, la mayoría de los estudios han evaluado los cambios utilizando imágenes bidimensionales, principalmente radiografías laterales de cráneo. El objetivo del presente estudio fue determinar el volumen de la vía aérea en sujetos con clases esqueletales II y III sometidos a cirugía ortognática bimaxilar. Se utilizaron 80 exámenes CBCT pertenecientes a 40 sujetos obtenidos previo a la cirugía y 6 meses después de realizada. Veinte sujetos clase II y 20 clase III. Para el análisis volumétrico se realizó un renderizado 3D de la vía área superior en segmentos previamente establecidos y posteriormente se calculó el volumen de dicha vía aérea con la utilización del software 3D Slicer ®versión 4.11 (Slicer, USA). El análisis estadístico realizado por t-test de muestras relacionadas, arrojó en pacientes clase II aumentos volumétricos estadísticamente significativos en nasofaringe, laringofaringe y volumen total. Mientras que en pacientes clase III, se observó aumentos significativos en Nasofaringe y volumen total y mantención de volumen en orofaringe y laringofaringe.

PALABRAS CLAVE: Vía aérea superior; Cirugía Ortognática; Volumen aéreo faríngeo.

REFERENCES

Abé-Nickler, M. D.; Pörtner, S.; Sieg, P. & Hakim, S. G. No correlation between two-dimensional measurements and three-dimensional configuration of the pharyngeal upper airway space in cone-beam computed tomography. *J. Craniomaxillofac. Surg., 45(3)*:371-6, 2017.

An, J. H.; Park, S. B.; Choi, Y. K.; Lee, S. H.; Kim, K. B. & Kim, Y. I. Cone-Beam Computed Tomography Evaluation of Pharyngeal Airway Space Changes After Bimaxillary Orthognathic Surgery in Patients With Class III Skeletal Deformities: A 6-Year Follow-Up Study. *J. Oral Maxillofac. Surg., 77(12)*:2534-44, 2019.

Brunetto, D. P.; Velasco, L.; Koerich, L. & Araújo, M. T. Prediction of 3-dimensional pharyngeal airway changes after orthognathic surgery: a preliminary study. *Am. J. Orthod. Dentofacial Orthop., 146(3)*:299-309, 2014.

Chen, X.; Liu, D.; Liu, J.; Wu, Z.; Xie, Y.; Li, L.; *et al*. Three-Dimensional Evaluation of the Upper Airway Morphological Changes in Growing Patients with Skeletal Class III Malocclusion Treated by Protraction Headgear and Rapid Palatal Expansion: A Comparative Research. *PLoS One,10(8)*:e0135273, 2015.

Li, H.; Sun, C.; Chen, Y.; Sun, Z. & Gao, X. Quantitative changes of upper airway in class III patients undergoing bimaxillary surgery after one-year follow-up: a retrospective study. *Head Face Med., 18(1)*:14, 2022.

Nath, M.; Ahmed, J.; Ongole, R.; Denny, C. & Shenoy, N. CBCT analysis of pharyngeal airway volume and comparison of airway volume among patients with skeletal Class I, Class II, and Class III malocclusion: A retrospective study. *Cranio., 39(5)*:379-90, 2021.

Pereira, PKN.; de Castro Rocha, V.; Degan, VV.; Garib, DG.; Vedovello. SAS. & de Menezes, CC. Upper airways after mandibular advancement orthognathic surgery: A 4-year follow-up. *Am. J. Orthod. Dentofacial Orthop., 159(6)*:743-9, 2021.

Plaza, S.P.; Reimpell, A.; Silva, J. & Montoya, D. Relationship between skeletal Class II and Class III malocclusions with vertical skeletal pattern. *Dental Press J. Orthod., 24(4)*:63-72, 2019.

Redline, S.; Yenokyan, G.; Gottlieb, DJ.; Shahar, E.; O'Connor, GT.; Resnick, HE.; *et al*. Obstructive sleep apnea-hypopnea and incident stroke: the sleep heart health study. *Am. J. Respir. Crit. Care Med., 182(2)*:269-77, 2010.

Senaratna, CV.; Perret, JL.; Lodge, CJ.; Lowe, AJ.; Campbell, BE.; Matheson, MC.; *et al*. Prevalence of obstructive sleep apnea in the general population: A systematic review. *Sleep Med. Rev., 34*:70-81, 2017.

Souza, Pinto, GN.; Iwaki, Filho, L.; Previdelli, I.; Ramos, AL.; Yamashita, AL.; Stabile, GAV.; *et al*. Three-dimensional alterations in pharyngeal airspace, soft palate, and hyoid bone of class II and class III patients submitted to bimaxillary orthognathic surgery: A retrospective study. *J. Craniomaxillofac. Surg., 47(6)*:883-94, 2019.

Von Bremen, J.; Lotz, JH.; Kater, W.; Bock, NC. & Ruf, S. Upper airway changes following high oblique sagittal split osteotomy (HSSO). *J. Craniomaxillofac. Surg., 49(2)*:146-53, 2021.

Xiang, M.; Hu, B.; Liu, Y.; Sun, J. & Song, J. Changes in airway dimensions following functional appliances in growing patients with skeletal class II malocclusion: A systematic review and meta-analysis. *Int. J. Pediatr. Otorhinolaryngol., 97*:170-80, 2017.

Yoshino, N.; Nishii, Y.; Kamio, T.; aki, T.; Shibahara, T. & Sueishi, K. Three-Dimensional Evaluation of Pharyngeal Morphology in Bimaxillary Surgery with and without Horseshoe Osteotomy in Skeletal Class III Cases. *Bull Tokyo Dent. Coll., 62(4)*:215-26, 2021.

Zhang, Z.; Qi, M.; Hügli, G. & Khatami, R. Predictors of changes in cerebral perfusion and oxygenation during obstructive sleep apnea. *Sci. Rep., 11(1)*:23510, 2021.

Corresponding author:
Prof. Sergio Olate
Universidad de La Frontera
Claro Solar 115
Temuco
CHILE

E-mail: sergio.olate@ufrontera.cl