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Three-dimensional analysis of the pharyngeal airway space and hyoid bone position after orthognathic surgery

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A B S T R A C T

Purpose: The aim of this study was to evaluate changes in the pharyngeal airway space (PAS) and hyoid bone position after orthognathic surgery with cone-beam computed tomography (CBCT).

Material and methods: This study was conducted with the tomographic records of 30 patients with skeletal class II or III deformities submitted to two different types of orthognathic surgery: Group 1 ($n = 15$), maxillary advancement, and mandibular setback; and Group 2 ($n = 15$), maxillomandibular advancement. CBCT scans were acquired preoperatively (T_0); and at around 1.5 months (T_1) and 6.7 months (T_2) postoperatively. PAS volume, minimum cross-sectional area (min CSA), and hyoid bone position changes were assessed with Dolphin Imaging 3D software, and results analyzed with ANOVA and a Tukey–Kramer test ($p < 0.05$).

Results: The hyoid bone was significantly displaced in the horizontal dimension, moving posteriorly in Group 1, and anteriorly in Group 2. Although PAS volume and min CSA increased after both surgeries, these measurements were significantly larger only in Group 2. The significant differences that existed between groups preoperatively no longer existed after the surgeries.

Conclusions: Both orthognathic surgeries assessed resulted in changes in hyoid bone position and increased PAS volume and min CSA, particularly after maxillomandibular advancement surgery.

1. Introduction

Dentomaxillofacial deformities may not only compromise the masticatory function and the facial profile of patients (Li et al., 2014), but it may also lead to the narrowing of the pharyngeal airway space (PAS) and respiratory sleep disorders (Grauer et al., 2009; Claudino et al., 2013; Castro-Silva et al., 2015). When orthodontic treatment alone cannot reach satisfactory results in patients with severe bone deformities, orthognathic surgery may be required not only to enhance facial harmony and occlusion, but also to improve breathing (Hong et al., 2011; Raffaini and Pisani, 2013; Li et al., 2014; Al-Moraissi et al., 2015; Hatab et al., 2015). As a result, much attention has been paid to alterations of the PAS structures after orthognathic surgery in recent years (De Souza Carvalho et al., 2012; Gokce et al., 2014; Li et al., 2014).

Orthognathic surgery procedures (maxillomandibular advancement and setback) can modify the relationships between bone structures and soft tissues, such as the soft palate, uvula, palate, base of the tongue and suprahyoid muscles, epiglottis, and hyoid bone (De Souza Carvalho et al., 2012; Panou et al., 2013; Raffaini and Pisani, 2013; Gokce et al., 2014; Christovam et al., 2016). These structures are anatomically and functionally associated with the PAS and, depending on the magnitude and direction of skeletal correction, their movement may lead to alterations in the area (Hong et al., 2011; De Souza Carvalho et al., 2012). When surgery is considered, it is advisable that potential changes in the hyoid bone position and PAS be studied for each patient in order to evaluate treatment changes and to predict postoperative stability (Kim et al., 2013; Christovam et al., 2016).

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Technological advances in computer graphics as well as in imaging diagnosis are becoming a common reality in dental care routines. In contrast to two-dimensional lateral cephalograms, which do not permit the precise evaluation of the PAS (Hatab et al., 2015), cone beam computed tomography (CBCT) can reproduce different sections of the body in multiplanar images (axial, sagittal, and coronal), and assess all the structures in layers with adequate definition (Kim et al., 2014). The evaluation of CBCT images with the use of software allows specific anatomic features to be three-dimensionally delimited in real size (1:1) (Hong et al., 2011), permitting the accurate and reliable analysis and measurement of the PAS morphology and hyoid bone position (Claudino et al., 2013; Schendel et al., 2014; Castro-Silva et al., 2015). However, the evidence available on alterations of hyoid bone position and airway volume after maxillomandibular advancement, and maxillary advancement and mandibular setback surgery, based on 3D images, is still scarce (Christovam et al., 2016).

Therefore, the aim of this study was to analyze the changes in hyoid bone position and in the PAS volume in a group of patients with angle class II and class III deformities submitted to orthognathic surgery, using CBCT scans and Dolphin Imaging 3D software.

2. Material and methods

2.1. Ethical approval

This study was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki), and was approved by the Permanent Ethics Committee for Experiments Involving Humans at the State University of Maringá (UEM), Brazil (CAAE 13862413.7.0000.0104). The study was a cross-sectional observational study performed in conformity with the recommendations of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines (von Elm et al., 2008). Due to the retrospective nature of this study, a signed informed consent was not required by the Committee.

2.2. Patients

The criteria for the selection of the tomographic images to be included in our study were patients >18 years, diagnosed with Class II and Class III skeletal deformities, who were submitted either to maxillary advancement and mandibular setback, or to maxillomandibular advancement orthognathic surgery. Patients with craniofacial syndromes (lip and palate clefts), or a history of previous surgeries in the head and neck region, were excluded from the study (Uesugi et al., 2014; Shin et al., 2015; Kochar et al., 2016).

Selected records were divided into two groups according to the type of orthognathic surgery: Group 1 – maxillary advancement and mandibular setback ($n = 15$); and Group 2 – maxillomandibular advancement ($n = 15$) (Brunetto et al., 2014; Gonçales et al., 2014). Mandibular setback and advancement were achieved with bilateral sagittal split osteotomy and the use of functionally stable fixation; while Le Fort I osteotomy was used for maxillary advancement (Brunetto et al., 2014; Li et al., 2014; Schendel et al., 2014; Butterfield et al., 2015; Hatab et al., 2015). All surgical procedures were performed by the same team of experienced buccal-maxillofacial surgeons at the Orthognathic Surgery Outpatient Unit (UEM), between 2013 and 2014. During the course of treatment, all patients also received multidisciplinary care by a speech therapist, a nutritionist, and a social worker.

2.3. Acquisition of tomographic images

All CBCT scans were conducted by the same dental radiology and imaging specialist at the Clinical Research Imaging Laboratory (UEM) using the i-CAT® Next Generation (Imaging Sciences International, Hatfield, PA, EUA). Volumes were reconstructed with isometric voxel size of acquisition of 0.30 mm, FOV (field of view) of 17 × 23 cm, tube tension of 120 kVp, and tube current of 3–8 mA. CBCT scans were obtained at three intervals as part of the surgical protocol: preoperatively – 1–2 months before the surgery (T_0), to assist diagnostics and surgery planning; early postoperatively – 1–2 months after the surgery (T_1); and late postoperatively – 5–8 months after the surgery (T_2), to ascertain surgery outcome (Jakobsone et al., 2011; De Souza Carvalho et al., 2012; Kim et al., 2013; Burkhard et al., 2014; Shin et al., 2015).

During acquisition, patients were instructed to remain seated on a chair and adopt a natural head position by looking at their own eyes in a mirror on the opposite wall (Kim et al., 2014; Dalmau et al., 2015; Shin et al., 2015; Canellas et al., 2016). Patients were also instructed to maintain maximum intercuspation with their tongues and lips at rest, to breathe lightly, and avoid swallowing during image acquisition (Kim et al., 2014; Kochar et al., 2016; Canellas et al., 2016). No support for the chin and head were used during image acquisition, as these could be confused with the soft tissues in the region, and negatively affect orthognathic surgery virtual planning.

2.4. Tomographic scan analysis

Measurements on all CBCT images acquired at T_0, T_1, and T_2 were conducted by the same examiner, who was trained and calibrated by a Dolphin Imaging Company representative. Calibration was performed with the use of 10 randomly chosen images. The CBCT images were exported using the DICOM (Digital Imaging and Communications in Medicine) extension and were imported into Dolphin Imaging software (version 11.9) (Dolphin Imaging & Management Solutions®, Chatsworth, CA, USA). To transfer the acquired images to the virtual environment, spatial orientation was performed in order to reposition the axial plane coincidently with the FHP, and the midsagittal plane coincidently with the midline perpendicular to the FHP, passing through the cephalometric point of the nasion (foremost point of the frontonasal suture). In case of asymmetry, orientation was conducted so that these planes were as close as possible to the original orientation planes (Fig. 1). This virtual orientation achieved the correct rotation of the head, in which the bilateral structures were coincident (Brunetto et al., 2014; Uesugi et al., 2014; Canellas et al., 2016).

After image standardization, the landmark S (sella turcica) on the sagittal plane was used as a reference point for outlining the horizontal reference line (parallel to the FHP) and the vertical reference line (perpendicular to the FHP). Hyoid bone position was then determined in relation to these two lines (Fig. 2). Vertical (HBV) and horizontal (HBH) measurements were taken by drawing a line from the most anterosuperior point of the hyoid bone to the reference lines (Kim et al., 2013; Shin et al., 2015).

To analyze PAS volume, the 'sinus/airway' tool was used on the sagittal reconstruction (Fig. 3). Total PAS volume (Fig. 3A) had the following cephalometric limits: i) upper limit – horizontal line connecting posterior nasal spine to the basion (PNS–Ba); ii) lower limit – horizontal line passing through the uppermost point of the epiglottis to the most anteroinferior point of the third cervical vertebra (epiglottis–C3); iii) posterior limit – vertical line delimiting the posterior pharyngeal wall (C3–Ba); and iv) anterior limit – a line delineating the soft palate, tongue, and the anterior wall of the pharynx (epiglottis – soft palate – PNS) (Valladares-Neto et al.,