Computerized Cephalometric Study of the Pharyngeal Airway Space in Patients Submitted to Orthognathic Surgery

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Abstract

Introduction Pharynx is a muscular organ with is sustained by craniofacial bones. It is divided into nasal, oral and hypopharynx, and can be considered as a tube that serves both respiratory and digestive systems. Its anatomical morphology permits that factors facilitate its obstruction, leading to the sleep apnea syndrome. One of the treatment consists of surgical mandibular advancement, increasing pharyngeal dimensions. The aim of this study was evaluate the cephalometric changes in the pharyngeal airway space after orthognathic surgery procedures for correction of mandibular prognathism.

Materials and Methods Pre and post-operative cephalometric analysis was performed on 19 patients submitted to mandibular setback by mandibular bilateral sagittal split osteotomy associated with maxillary advancement by Le Fort I osteotomy, using the Dolphin Imaging 10.0 software. **Results** Results did not reveal statistically significant changes in the upper (nasopharyngeal), middle (oropharyngeal) and lower (hypopharyngeal) airway spaces, but showed increase in the nasal pharynx due the maxillary advancement and a lower position of the hyoid bone due the mandibular setback.

Discussion Maxillomandibular orthognathic surgery for correction of mandibular prognathism does not seem to statistically significantly change the pharyngeal airway space, but it increases the maxillary airway.

Conclusion It seems to be important to consider the double jaw surgery in cases of mandibular prognathism, aiming prevention of a possible reduction of whole upper airway.

Keywords Airway space · Sleep apnea · Maxillary advancement · Mandibular setback

Introduction

The upper airway participates in several physiological functions, including breathing, swallowing and speech, and is divided into three anatomical segments: (a) nasopharynx (between the turbinates and hard palate), (b) oropharynx, which may be divided into retropalatal (velopharynx) and retrolingual portions; and (c) hypopharynx (from the tongue base to the larynx) [1].

Acting as a collapsible tube [2], the pharynx may be considered a unique respiratory and digestive via, whose opening and closure during swallowing is regulated by a sophisticated mechanism to protect the airway [3].

Muscles of the biodynamic system that regulate respiration, mastication, swallowing and speech are inserted on the hyoid bone [4]. This is a single bone and does not articulate with other bones; thus, it is suspended in the soft tissue by tendons and muscles, its position is changed according to head and body positioning and other physiological states, and it is moved during several oral functions, in combination with the activity of the tongue, due to the interrelationship of fibers of the geniohyoid and genioglossus muscles [5].

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In patients with maxillomandibular deformities, excessive horizontal growth is expected to increase the airway, whereas poor horizontal growth is expected to decrease it; similarly, orthognathic surgery for correction of maxillo-mandibular deformities is expected to influence the airway, increasing it when maxillary or mandibular advancement is performed and reducing it in case of mandibular setback.

This study aimed to evaluate the changes in cephalometric measurements of the pharyngeal airway space in patients submitted to orthognathic surgery for correction of mandibular prognathism by combined mandibular setback and maxillary advancement.

Materials and Methods

This study was approved by the Ethical Committee of Bauru Dental School, University of São Paulo, Brazil (Protocol 42/2004), and comprised retrospective computerized cephalometric analysis of 19 white Brazilian individuals, without obstructive sleep apnea (OSA), submitted to maxillomandibular orthognathic surgery for correction of mandibular prognathism by mandibular bilateral sagittal split osteotomy for mandibular setback and Le Fort I osteotomy for maxillary advancement. All surgical procedures were performed by the same team, with utilization of rigid internal fixation and transoperative maxillomandibular fixation. The patients were submitted to preoperative orthodontic preparation and to post-operative orthodontics for finalization. Analyses were performed by cephalometric analysis of the airway space on the Dolphin Imaging® 10.0 software (Dolphin/3 M—USA), registered for Bauru Dental School, University of São Paulo. To obtain the lateral cephalometric radiograph, patients were positioned in the cephalometric unit by the use of a standard appliance positioner for lateral cephalometric radiograph, with median sagittal plane perpendicular to the ground and Frankfurt horizontal plane parallel to the ground, teeth in centric occlusion and lips in rest position.

The following inclusion criteria were adopted:

- Previous presence of mandibular prognathism;
- Accomplishment of orthognathic surgery for correction of prognathism by the same surgical team;
- Availability of a preoperative (initial) lateral cephalogram and a post-operative (final) lateral cephalogram that were obtained from the preoperative (initial) and postoperative (final) lateral cephalometric radiograph. There was a period not less than 6 months between the preoperative (initial) and post-operative (final) lateral cephalometric radiograph;

- The lateral cephalometric radiographs should allow clear visualization of anatomical structures of the face and skull necessary for cephalometric tracing.

The lateral cephalograms were digitized on a scanner UMAX® (model Astra 2600) with transparency adapter, at 600 dpi, and saved in TIFF format, always with the presence of the specific ruler of the Dolphin Imaging® 10.0 software (Dolphin/3 M—USA), to allow the cephalometric analysis Quas/Airway by utilization of the Dolphin Imaging® 10.0 software (Dolphin/3 M—USA) (Figs. 1, 2). Only one examiner examined the x-rays and performed 1 evaluation with all the x-rays, and other evaluation (second assessment) with part of the x-rays for the analysis of the error.

After recording of linear and angular measurements on the initial and final lateral cephalograms of all patients, data were tabulated and submitted to statistical analysis by the paired t test for determination of significance, and ten radiographs of five individuals (one preoperative and one post-operative) were randomly selected among the 19 patients for evaluation of systematic and/or casual error [6]. To calculate the means, to perform the statistical analysis, we used the software Statistics 7 (State Soft Inc, Tulsa, EUA).

Fig. 1 Cephalogram digitized with the specific transparent ruler of the Dolphin Imaging 10.0 software

Fig. 2 Schematic representation of cephalometric points employed

Results

The study sample composed of 19 individuals (nine men and ten women), with mean age 25.58 years (SD = 6.81 years) and mean post-operative period of 28.47 months (SD = 15.64 months).

Among the measurements investigated, the difference between the initial and final means of measurements of facial angle (NBa-PtGn), angle formed by Frankfort horizontal plane and line Nasion/Pogonion (FH-NPog), angle formed by mandibular plane and facial plane (FT), angle between intersection line through Sella-Nasion and Nasion-A-point (SNA), intersection of S–N line (Sella-Nasion) and N–B line (Nasion-deepest anterior point in concavity of anterior mandible, B-point) (SNB), angle formed by N–A line (Nasion-A point) and N–B line (Nasion- B point) (ANB) showed statistically significant variations ($p < 0.05$).

In addition to the above mentioned, the overjet, line through posterior nasal spine and vallecule (PNS-V), line through posterior nasal spine and most posterior point of soft palate (PNsPa), angle formed by most anterosuperior point of hyoid-mandibular plane line and most anterosuperior point of hyoid/Menton line (H-Me-MP), perpendicular line

mandibular plane leaving most anterosuperior point of hyoid (H-MP Perp) and line through most anterosuperior point of hyoid and Sella (HS) revealed statistically significant variations ($p < 0.05$) too. The FT, ANS, ANB, overjet, PNS-V, PNsPa, H-Me-MP, H-MP Perp, and HS-exhibited increase, whereas NBa-PtGn, FH-NPog and SNB decreased. All the others measurements did not present statistically significant variations ($p < 0.05$).

Tables 1 and 2 show the initial and final means, difference between final and initial means, as well as the initial and final standard deviations and the difference between them, the result of the paired t test and p value of measurements of 19 individuals submitted to orthognathic surgery for correction of mandibular prognathism. The statistical analysis of random and systematic error in this study showed no statistically significant differences.

Discussion

Airway obstructions may be caused by dentofacial skeletal deformities, which are defined as defects in the growth and development of facial bones (especially the maxilla and mandible) that lead to changes in these bones and incorrect positioning of teeth and their relationships; changes in masticatory function, swallowing, speech, temporomandibular joint, respiration, and in facial harmony and esthetics [7]. Also, it should be highlighted that the pharynx is a muscular organ supported by insertion on bones; thus, developmental changes of the maxilla and mandible may cause or predispose the patient to pharyngeal obstruction in some situations, e.g. during sleep, when muscle tonus is reduced [8].

Considering that 1/3 of obstructions occur at a single level and 2/3 affect two or more levels [9], and the main regions of obstruction are the soft palate, lateral pharyngeal wall and tongue base (hypopharynx) [10], it is clear that treatment of such obstructions should consider the possibility to unblock the airway, according to the affected sites. Within this context, obstructions may occur in patients with dentofacial skeletal deformities, especially maxillomandibular anteroposterior hypodevelopment. For these patients, surgical maxillomandibular advancement may correct the deformity and possibly also the obstruction, since it probably increases the pharyngeal airway space [11–13]. The stability of results is a matter of concern; studies demonstrate that this increase seems to be unstable over time [14–16], even though other authors demonstrated that there is no relapse [17], thus indicating stability.

Just like mandibular advancement increases the pharyngeal airway space, mandibular setback is expected to reduce it. Thus, it is clear that, in patients with mandibular

Table 1 Initial mean (IM), final mean (FM), difference between final and initial means (dif mean), initial standard deviation (ISD), final standard deviation (FSD), difference between final and initial standard deviations (dif SD), paired T test (t) and *p* value of

measurements (cranial base, maxilla, mandible, maxilla and mandible, and teeth) of 19 individuals submitted to orthognathic surgery for correction of mandibular prognathism

	Legend	Standard	IM	ISD	FM	FSD	Dif mean	Dif SD	t	<i>p</i> *
Cranial base										
SN (mm)	B	75.3	71.63	5.7	72.54	6.01	0.92	2.92	0.192	0.192
Maxilla										
FH-NA (°)	C	90.0	91.55	4.8	93.16	6	1.62	4.02	1.746	0.098
Mandible										
NBa-PtGn (°)	E	90.0	97.84	4.4	94.3	3.38	−3.54	3.28	4.707	0.000
FH-NPog (°)	F	88.6	96.31	4.1	92.8	3.78	−3.51	3.65	4.187	0.001
FT (°)	G	68.0	62.45	5.3	65.39	3.81	2.95	3.75	3.422	0.003
FMA (°)	H	23.9	21.77	7.7	21.8	6.09	0.07	9.76	0.027	0.979
Ar-Go-Me (°)	I	122.9	130.71	9.8	128.26	8.94	−2.45	7.19	1.484	0.155
Maxilla and mandible										
SNA (°)	J	82.0	87.28	4.1	89.13	4.27	1.84	3.56	2.264	0.036
SNB (°)	K	80.9	91.19	4.8	87.93	4.03	−3.26	2.29	6.184	0.000
ANB (°)	L	1.6	−3.91	4.4	1.19	4.26	5.1	3.17	7.004	0.000
Teeth										
Overbite (mm)	M	2.5	−0.31	1.6	0.34	0.76	0.65	1.78	1.588	0.13
Overjet (mm)	N	2.5	−3.46	3.2	3.14	1.29	6.59	3.58	5	0.000

SN, Measurements line through Nasion and Sella; FH-NA, angle formed by Frankfort horizontal plane and line Nasion/A-point; NBa-PtGn, measurements facial angle; FH-NPog, angle formed by Frankfort horizontal plane and line Nasion/Pogonion; FT, angle formed by mandibular plane and facial plane; FMA, angle formed by Frankfort horizontal plane and mandibular plane; Ar-Go-Me, angle formed by Ar-Go line and Go-Me line; SNA, angle between intersection line through Sella-Nasion and Nasion-A-point; SNB, intersection of S–N line and N–B line; ANB, angle formed by N–A line and N–B line

* *p* < 0.05

prognathism, surgical treatment (mandibular setback) would favor the reduction of the pharyngeal airway space, especially in the oropharynx and hypopharynx portions. This study did not reveal statistically significant variation in the upper, middle and lower pharyngeal airway spaces, despite the statistically significant reduction of measurements referring to the mandible (NBa-PtGn, FH-NPog and SNB), which demonstrate the mandibular setback. On the other hand, measurements evaluating the maxillary positioning were statistically significant and demonstrated maxillary advancement (e.g. increase of 1.84° in SNA between pre- and post-operative measurements).

Similarly, the mandibular setback performed by Athanasiou et al. [18] did not reduce the airway space, possibly due to physiological readaptation of the pharyngeal morphology, as mentioned by Saitoh [19]. In the present study, despite mandibular reduction, it was observed that maxillary advancement may have favored the airway re-adaptation, since the muscles associated with the maxilla contribute to increase the airway space, possibly neutralizing the possibility of its reduction as a consequence of mandibular setback.

It should be highlighted that previous studies conducted by Sayinzu et al. [20] and Saito et al. [21] observed that

correction of maxillary transverse and/or anteroposterior deficiencies improves breathing and interferes with the nasopharyngeal airway (by increasing it), and Mehra et al. [11] observed smaller reduction of the nasopharyngeal airway space in patients submitted to that maxillary advancement and mandibular setback.

Riley et al. [22] related the changes in the pharyngeal airway space to the resulting inferior and posterior positioning of the hyoid bone, tongue and mandible, as corroborated by other authors [23–29] and in patients with other risk factors [30, 31] which may predispose them to obstructive sleep apnea [32–34].

In this study, notwithstanding the more inferior positioning of the hyoid bone, there was no reduction of the lower, middle and upper pharyngeal airway spaces. However, it should be highlighted that there is a tendency of reduction of the pharyngeal airway space with aging (e.g. due to elongation of the soft palate), loss of muscle tonus, possible increase in weight (especially in men) and post-operative time [35, 36] and it seems fundamental to consider such factors when planning mandibular setback. This agrees with Paoli et al. [37] who mentioned that the risk of development of obstructive sleep apnea should be included as a parameter for indication of mandibular setback, and

Table 2 Initial mean (IM), final mean (FM), difference between final and initial means (dif mean), initial standard deviation (ISD), final standard deviation (FSD), difference between final and initial standard deviations (dif SD), paired T test (t) and *p* value of

measurements (vertical proportions, airway space, and hyoid position) of 19 individuals submitted to orthognathic surgery for correction of mandibular prognathism

	Legend	Standard	IM	ISD	FM	FSD	Dif mean	Dif SD	t	<i>p</i> *
Vertical proportions										
UAFH (mm)	O	66.5	47.67	3.1	48.03	3.71	0.35	2.67	0.576	0.571
ANS-Me (mm)	P	71.5	72.24	6.4	71.74	6.15	−0.49	3.14	0.686	0.502
N-Me (mm)	Q	128.5	120.13	8.5	119.86	9.03	0.25	3.2	0.365	0.719
Airway space										
IAS (mm)	S		12.97	2.8	13.22	3.57	0.25	2.69	0.401	0.693
MAS (mm)	T		12.54	2.9	12.12	3.65	−0.42	3.07	0.598	0.557
SPAS (mm)	U		21.65	8.6	23.38	7.57	1.74	4.62	1.64	0.118
PNS-V (mm)	V		64.45	6.2	70.59	8.17	6.15	5.31	5.048	0.000
PNSPa (mm)	X		32.38	5.7	36.45	5.67	4.07	4.36	4.068	0.001
H-Me-MP (°)	Z		14.37	4.9	19.53	6.1	5.16	4.59	4.899	0.000
Hyoid position										
H-MPperp (mm)	AA		12.63	3.8	15.42	4.07	2.79	3.93	3.096	0.006
HS (mm)	DD		111.72	10	115.55	12.04	3.83	6.18	2.704	0.015

UAFH, Angle formed by intersection U–A line and Frankfort horizontal plane; ANS-Me, distance between anterior nasal spine and Menton; N-Me, distance between Nasion and Menton; IAS, inferior airway space; MAS, middle airway space; SPAS, superior-posterior airway space; PNS-V, line through posterior nasal spine and vallecule; PNSPa, line through posterior nasal spine and most posterior point of soft palate; H-Me-MP, angle formed by most anterosuperior point of hyoid-mandibular plane line and most anterosuperior point of hyoid/Menton line; H-MP Perp, perpendicular line mandibular plane leaving most anterosuperior point of hyoid; HS, line through most anterosuperior point of hyoid and Sella

* *p* < 0.05

with Ramesh et al. [38] who observed considerable reduction of the airway space in all patients, predisposing them to obstructive sleep apnea. Considering our results and accordingly with others authors [39–42], anteroposterior discrepancies may be corrected by combined maxillo-mandibular osteotomies, when this does not impair the aesthetic result of the procedure.

Thus, it may be concluded that maxillomandibular orthognathic surgery for correction of mandibular prognathism did not statistically significantly change the upper (nasopharynx), middle (oropharynx) and lower (hypopharynx) pharyngeal airway spaces.

Conflict of interest The authors declare that they have no conflict of interest.

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