Comparison of Different Orthognathic Surgeries Impact on Pharyngeal Airway Space in CL III Patients

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Introduction: This study sought to compare the changes in the pharyngeal airway space, hyoid bone position, tongue, soft palate, and retro-lingual soft tissues following three different orthognathic surgeries on class III patients. **Materials and Methods:** This quasi-experimental study was conducted on 75 skeletal class III patients. The predictor variable was the type of orthognathic surgery namely mandibular setback, maxillary impaction & mandibular setback and maxillary advancement & mandibular setback (25 patients in each group). The primary outcome variables were the dimensions of the pharyngeal airway space and retrolingual region, measured preoperatively and at least one year postoperatively. Cephalometric landmarks were also measured. Pre- and post-operative cephalograms were superimposed based on the S-N line with registration at the S-point. **Results:** When considering the changes in the whole sample (75 cases), significant changes were found in oropharyngeal length (UMPW, VLPW), tongue height (H-VT), horizontal position of vallecula (V_C3) and horizontal position of the hyoid bone. The only significant difference noted, was the tongue height and vertical position of hyoid between the three groups. **Conclusion:** Orthognathic surgery significantly affects the oropharyngeal space and position of the tongue and hyoid bone. The three types of Orthognathic surgeries on class III patients caused different effects on oropharyngeal space, tongue and hyoid position with a significant impact on tongue height in maxillary advancement plus mandibular setback.

Keyword: Orthognathic Surgery; Malocclusion, Angle Class III; Pharynx

Introduction

Although severe class III malocclusion has a low prevalence in different populations (less than 5% in white population and approximately 12% in Chinese and Japanese populations), it accounts for a substantial proportion of orthognathic surgeries (1). Although it has been proposed that after mandibular setback surgery, the mandibular bone, tongue, soft palate, hyoid bone, and associated musculature move backward, resulting in narrowing of the pharyngeal airway space (PAS) but due to different results from studies investigating the effects of mandibular setback on posterior airway, more research is needed to better understand the effect of mandibular setback on airway structures (2-5).

Adequate airway space is pivotal to maintain vital functions of the body. Patients may require postural adaptations (for example deviation of head posture) to get accustomed to a narrow airway space secondary to surgery (6,7). Therefore, enhanced understanding of the airway and related structural changes may assist the clinician in precise treatment planning and selection of the most appropriate surgical technique. In the past two decades, considerable attention has been paid to changes in the airway space and retrolingual and retropalatal soft and hard tissues following orthognathic surgery (8-11).

Most previous studies focused on mandibular setback surgery and yielded contradictory results. To the best of the authors' knowledge, no data is available on this topic in Iranian population. Furthermore, limited studies have compared different surgical approaches in terms of their impact on the airway space in class III patients. Therefore, this study sought to evaluate the changes in the airway space, hyoid bone position, tongue, soft palate and retrolingual soft tissues following three commonly performed orthognathic surgeries on class III patients.

Table 1. Descriptions of the abbreviations for the hard and the soft tissue landmarks

Variable	Definition
Or	Orbitale, the lowest point on the average of the left and right inferior borders of the bony orbit
AH	Anterior hyoid, the most anterior and superior point on the body of the hyoid bone, representing the inferior part of the tongue
Ho	The point where the posterior border or choanal crest of the vomer meets the pharyngeal outline of the cranial base, assumed to be in the median plane.
Po	the most superior point of each external acoustic meatus
Me	Lowest point of mandibular symphysis
Pog	Most anterior point on the osseous contour of the chin
Gn	Lowest anterior point of the chin
LPW	Linear measurement of the lower pharyngeal wall: Intersection between perpendicular line of V and the posterior pharyngeal wall
MPW	Linear measurement of the mid-pharyngeal wall: Intersection between perpendicular line of Ptm-Ba at U and the posterior pharyngeal wall
UPW	Linear measurement of the superior pharyngeal wall: Intersection between line Ptm-Ba and the posterior pharyngeal wall
V	Vallecula: the intersection of the epiglottis and the base of the tongue
U	Most postero-inferior point (tip)of the uvula
A point	The innermost point on the concavity of the maxilla between the incisor tooth and bone
B point	The innermost point on the concavity of the mandible between the incisor tooth and bony chin
ANS	Anterior nasal spine
PNS	Posterir nasal spine
N	Nasion
S	Sella
Ba	Basion
Ptm or Pm	The point of the intersection of the image of the anterior surface of the pterygoid process of the sphenoid bone and the posterior margin of the maxilla
AA	Anterior Arch of Atlas
H	The most superior point of the tongue in relation to the line from vallecula to the tip of the tongue
FH	A line connecting porion to orbitale
ML	T2(the most inferioposterior point on the mandible) to menton
NL	Nasal line, line between the anterior nasal spine (ANS) and the posterior nasal spine (PNS)
T	Tip of the tongue
SN	A line connecting Sella to Nasion

Materials and Methods

This study was conducted on 75 non-growing patients (50 females and 25 males) with a mean age of 24 years and four months. The patients were divided into three groups according to the type of surgical procedure:

1. Mandibular setback (Man S)

2. Mandibular setback and maxillary advancement (Max Adv+Man S)

3. Mandibular setback and maxillary impaction (Man S+Max Imp)

The patients were selected based on the following inclusion and exclusion criteria

1. Adult patients with dental and skeletal class III malocclusion who had undergone combined orthodontic-surgical treatment in the School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran and five private offices.
2. Patients with lateral cephalograms taken in natural head position as the baseline (prior to surgery) and at least one year after surgery subsequent to removal of the orthodontic appliances. The one-year period was selected because the post-surgical edema and possible transient changes of the healing soft tissue are expected to eliminate by this time and the one-year time period was sufficient for the changes to take place.
3. Only patients who had undergone routine orthognathic surgery were included. Patients suffering from trauma, syndromes or congenital defects, cleft lip or plate and those who underwent soft tissue surgery (e.g. rhinoplasty) were not included.
4. The patients who had undergone chin surgery were excluded because it could have affected the anterior facial height and probably the head position.

Cephalograms were scanned by a radiographic scanner (ScanMaker i800, MicroTek International, Inc., Cerritos, CA, USA). The magnification of cephalograms was adjusted by matching their dpi. Also, the length of a ruler or nasal length was used to match the magnification of scanned cephalograms.

Table 2. Descriptions of the abbreviations for the hard and the soft tissue landmarks

Variable	Group	Definition
Pm-UPW	Pharynx	distance from pm to UPW (nasopharyngeal airway space length)
U-MPW	Pharynx	The distance from tip of the soft palate to middle pharyngeal wall (oropharyngeal airway space length)
V-LPW	Pharynx	The distance from Vallecula to LPW
Pm-AA	Pharynx	Pm to AA connecting line (The length of the lower bony nasopharynx)
V-T	Tongue	Indicates long axis of mandibular symphysis(tongue length)
H⊥VT	Tongue	Tongue height, measured as perpendicular distance from H to VT line
V⊥FH	Tongue	The perpendicular distance from V to FH (vertical position of vallecula)
V-C3	Tongue	The distance from V to the third cervical vertebra (C3) (Horizontal position of vallecula)
Pm-U	Soft palate	Pm to U connecting line(soft palate length)
NL/Pm-U	Soft palate	The inclination of the long axis of the soft palate relative to the nasal line
AH-C3 HOR	Hyoid bone	AH to C3 connecting line(hyoid horizontal position)
AH-C3 VER	Hyoid bone	AH to C3 connecting line(hyoid vertical position)
AH⊥FH	Hyoid bone	AH to FH connecting line(hyoid vertical position in relation to FH line)
AH-ML	Hyoid bone	AH to ML connecting line(hyoid vertical position in relation to mandible)
AH-S VER	Hyoid bone	The distance from perpendicular line to FH from AH-Sella

The landmarks were traced and marked on the pre- and postsurgical (T1 and T2) lateral cephalograms (Tables 1 and 2, figure1). The second radiograph was superimposed on the first radiograph, based on the true vertical line or the ruler (considered as parallel in the two images), and superimposition was performed along the S-N line with registration at the S-point. After superimposition, the variables were measured. Measurements were made using Orthosurger X software. Next, changes in cephalometric variables were analyzed using the Sollow analysis. All the cephalograms were evaluated by the same examiner. The differences in the measured cephalometric variables were recorded as the changes attributable to the surgical procedure.

The distribution of the obtained data was assessed using One-Sample Kolmogorov-Smirnov test. P-value less than 0.05 was considered statistically significant. The equality of variances was confirmed using Levene's test. Considering the normal distribution of the data and equality of the variances, the mean, SD, minimum and maximum values before and one year after the surgery were calculated for each group of the patients and their significance was analyzed using paired t-test. All tests were carried out using SPSS version 21 (SPSS Inc., IL, USA). The changes were calculated and One-way ANOVA was used to compare inter-group changes. The Tukey's HSD test was used for multiple comparisons.

Method error

Reliability of the measurements was analyzed using the Dahlberg's Formula (12). The error of the method was no greater than 0.5 degrees for angles and 0.5 millimeters for distances.

Results

One-Sample Kolmogorov-Smirnov test showed that the data passed the normality test and the distribution of the data obtained in this study followed a Gaussian pattern. The equality of variances was confirmed using Levene's test. The mean and SD of the airway and retrolingual soft tissue changes before and after surgery are summarized in Tables 3.

- Comparison of changes between different orthosurgical groups :
- **Pm-UPW**: which shows the inferior border of the nasopharynx is increased in Max adv+Man S and decreased in Man S and Man S+Max Imp but these changes are not statistically significant.
- **U-MPW**: which shows the middle part of the oropharynx is increased in all three surgeries with no statistically significant changes.
- **V-LPW**: which shows the inferior border of the oropharynx is increased in all three surgeries but this increase is not statistically significant.
- **Pm-AA**: which shows the length of the lower bony nasopharynx is increased in all three surgeries although this increase is not statistically significant. The least increase is seen in Man S surgery.
- **V-T length**: tongue length is decreased in Man S and Man S+ Max Imp but is not statistically significant. Reduction of tongue size is pronounced more in Man S than Man S+ Max Imp. Tongue size was nearly the same before and after Max Adv+Man S surgery.

Table 3. The mean and standard deviation of changes of cephalometric variables in each surgical group and the p-value of comparison of the mean changes of the three surgical groups (One-way ANOVA)

Cephalometric variables (mm)	Man S Mean (SD)	Max Imp & Man S Mean (SD)	Max Adv & Man S Mean (SD)	Comparison of the three groups *P-value*
Pm-UPW	-0.17 (4.20)	-0.11 (4.06)	0.93 (2.46)	0.48
U-MPW	1.24 (2.57)	1.18 (2.53)	0.47 (2.21)	0.46
V-LPW	1.18 (2.25)	0.25 (2.50)	1.29 (3.36)	0.34
Pm-AA	0.44 (4.20)	1.30 (4.74)	1.26 (2.77)	0.69
V-T	-1.63 (6.85)	-1.31 (5.68)	0.42 (5.57)	0.43
H-VT	1.01 (4.71)	1.93 (6.83)	2.46 (3.70)	0.61
VT-FH	-2.61 (6.70)	0.34 (6.41)	2.11 (7.02)	0.04*
V-C3	0.68 (3.61)	0.99 (4.05)	1.86 (3.88)	0.54
Pm-U	-0.39 (4.36)	1.27 (5.14)	-0.10 (4.19)	0.39
NL-Pm-U	-2.54 (6.02	-1.64 (8.10)	0.38 (7.44)	0.34
AH-C3 HOR	2.81 (5.06)	2.79 (2.86)	2.11 (4.30)	0.77
AH-C3 VER	1.40 (18.67)	1.29 (11.14)	0.61 (9.63)	0.97
AH-FH	-1.25 (8.71)	1.94 (6.64)	2.99 (7.80)	0.048
AH-ML	-1.19 (3.85)	-0.49 (4.05	1.77 (3.56)	0.021*
AH-S VER	-1.72 (8.74)	2.44 (7.14	4.40 (8.35)	0.029*

- **H-VT** Height: tongue height is increased in all three surgeries, although this increase is not statistically significant. This increase in more pronounced in Max Adv+Man S.
- **V-FH**: perpendicular distance from V to FH is increased in Max Adv+ Man S and decreased in Man S and showed no changes in Max Imp+Man S surgery. The difference between three surgical groups is statistically significant.
- **V-C3:** Horizontal position of the vallecula to C3 is increased in all three surgeries. This increase is more in Max Adv+Man S.
- **Pm-U length**: The distance from uvula to ptm is increased in Max Imp+ Man S but decreased in Man S and Max Adv+Man S. Although these changes has no statistical significance.
- **NL-Pm-U**: The inclination of soft palate to nasal line is decreased in Man S and Max Imp+Man S which shows a forward displacement of the soft palate. This inclination is almost stable before and after Max Adv+Man S surgery which is not statistically significant in different groups.
- **AH-C3 HOR**: The distance between hyoid bone from C3 is increased in all three surgeries mostly in Man S which is not statistically significant in different groups.
- **AH-C3 VER**: The hyoid bone is moved upward in vertical dimension in all three surgeries which is not statistically significant in different groups.
- **AH-FH**: The distance between AH to FH line representing the inferior border of the tongue is increased in Man S and decreased in Max Adv+Man S and Max Imp+Man S. The most reduction is seen in Max Adv+Man S. The difference between three surgical groups is statistically significant.
- **AH-ML**: The hyoid vertical position in relation to mandible is increased in Max Adv+Man S and decreased in Man S. No dramatic change was observed with regard to Max Imp+ Man S surgery. The changes between different groups was statistically significant.
- **AH-S VER**: The distance from perpendicular line to FH from AH-Sella increased in Max Imp+Man S and Max Adv+Man S and decreased in Man S surgeries. The difference between groups is statistically significant.

Discussion

The current study compared the effects of three different orthognathic surgical procedures (Man. S, Max. Imp. & Man. S and Max. Adv. & Man. S) on class III patients with regard to changes in the retropharyngeal space (airway space dimensions and position of the hyoid bone, tongue and soft palate). Most literature regarding this context predominantly evaluated the changes in the retropharyngeal structures following orthognathic surgery in class III patients comparing mono-max to bi-max surgery without differentiating maxillary impaction from maxillary advancement in combination to mandibular setback. In this study we investigated what are the differences between impaction or advancement of the maxilla combined with mandibular setback on the airway, tongue and hyoid position.

In the current study, changes in the airway space and retrolingual soft tissues were assessed on cephalograms. Although cephalometry provides a two-dimensional view of three-dimensional structures, it is as reliable as computed tomography

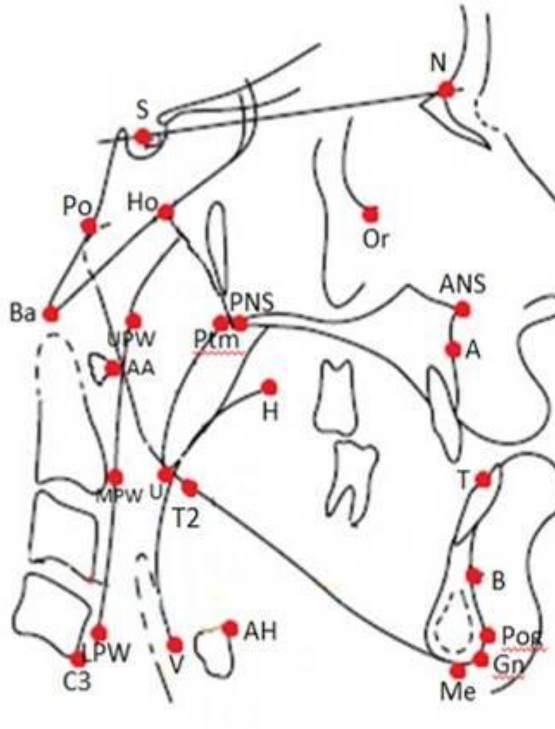

Figure 1. Cephalometric variables used in the study according to the definitions by Sollow

(CT) scan for evaluation of the posterior upper airway according to Riley and Powel. Also, a study by Miles et al, in 1995 indicated that most airway landmarks were clearly distinguishable on cephalograms irrespective of the quality of radiographs (13). Studies reporting three-dimensional CT-scan measurements mainly yielded the same results as studies performing cephalometric analyses (14); the only difference was that the patient radiation dose was lower in the latter group. We did not use CT scans for patients due to ethical considerations in terms of radiation dose accepting the As-Low-As-Reasonably-Achievable (ALARA) guideline. Based on the white paper recently published by American Association of orthodontists: "CBCT is a snapshot of a moment of breathing cycle. It provides no information on neuromuscular tone, susceptibility of collapse, or actual function of the airway. No radiographic method has been reported to have high enough sensitivity or specificity to serve as a risk assessment tool for obstructive sleep apnea."(15) In other words, the accuracy of a cephalogram compared to CBCT is the same as a diagnostic tool for assessment of sleep apnea or any other sleep related breathing disorder.

Linear and volumetric reductions in oropharyngeal and hypopharyngeal dimensions following orthosurgical treatments in class III patients have been reported in studies based on lateral cephalograms and cone beam computed tomography scans. The results of the current study were in agreement with those of most previous relevant studies (16-19). The overall changes found in our sample indicated significant differences in oropharyngeal dimensions, tongue height and hyoid position after orthognathic surgery in class III patients. One of the strengths of our study was its sample size, which was adequately large. The other point of strength of our study is that all the horizontal and vertical measurements are based on true vertical or horizontal lines drawn to our chain indicating the true vertical. This will omit the impact of intracranial reference lines on the actual changes that happens merely because of the surgeries conducted. The other point of strength is that all measurements were performed after superimposition of the two cephalograms on true vertical considering the best fit of S-N with registration on S. This will omit the impact of head orientation and landmark identifications a lot more than measuring the two cephalograms separately and without realigning the head position.

With regard to the changes following each type of surgical procedure, the only statistically significant change was noted in the tongue height. Meanwhile, the type of the surgery affected the results. Following the setback surgery, nasopharynx experienced minor changes, oropharyngeal length increased, soft palate moved forward, tongue length decreased and hyoid bone moved upward. After the maxillary impaction and mandibular setback surgery, the length of lower part of the nasopharynx and oropharynx increased, the soft palate moved forward and its length increased, vallecula moved forward and the hyoid bone moved forward and upward. Following the maxillary advancement and setback surgery, the length of nasopharynx slightly increased; the same was seen in oropharynx. Soft palate was almost stable, Vallecula moved forward and downward, the tongue length remained constant but its height increased and it moved downward. Hyoid also moved forward and downward. The three significant differences between surgeries were in the tongue and hyoid position. It seems that because of the mobility of the hyoid, most of the adaptation to the position of the jaws after surgery takes place in the region of supra-hyoid muscles and tongue.

The inferior border of the oropharynx is increased in all three surgeries although this increase is not statistically significant. This can be attributed to adaptability of the hyoid bone position and suprahyoid muscles and other adaptable soft tissues.

In a study conducted by Park et al linear and volumetric changes of the airway space were evaluated using Cephalometry and Computed Tomography (CT) following mandibular set back surgery. Linear evaluations showed significant changes in the pharyngeal depth and hyoid backward movement but volumetric measurements showed no significant difference in the airway dimensions in CT scans. The results of the volumetric CT changes in this study is in contrast with our linear evaluations of cephalometric variables(20).

There are different reports regarding nasopharyngeal space changes after surgical procedures. Some studies showed a decrease in nasopharyngeal space (18, 21-23) whereas some revealed an increase in the nasopharyngeal dimensions following mandibular set back or bimaxillary (mandibular setback and maxillary advancement) surgeries(19, 24). Some studies showed that nasopharynx dimensions don't change following surgical procedures (25). Nimkarn proposed that maxillary advancement could increase nasopharynx dimensions just in cases of more than 10 millimeters of maxillary advancement (26).

The results of a meta-analysis conducted by E. A. Al-Moraissi et al showed a significant reduction in the posterior airway space volume in both the anterior–posterior dimension and cross-sectional area at nasopharynx, oropharynx, and hypopharynx after one-jaw surgery (mandibular setback) compared to two jaw surgery (bimaxillary)؛ thus they concluded that in patients with breathing problems bimaxillary surgery is superior to mandibular setback surgery alone for the correction of the prognathic mandible (27). This result is in contrast with the result of our study. The result of our study revealed no significant changes in linear dimensions of nasopharynx after different conducted surgeries; but the nasopharyngeal airway space decreased in Man S and Max Imp &Man S but increased in Max Adv & Man S. There was an increase in the length of the lower bony nasopharynx in all three surgical types; although in setback the mean increase was one third of the bimaxillary surgeries.

According to the results of the current study there was an increase in the linear dimension of hypopharynx (V-LPW): the least enlargement was seen in Max Imp & Man S; almost one fifth of the two other groups. Nevertheless, the difference between three experimented groups was not statistically significant. Also, an increase was observed in the oropharyngeal airway space (U-MPW): the minimum increase was in Max Adv & Man S which was one third of the other two groups. Intergroup difference was not statistically significant.

In the current study there was no significant difference in the soft palate length and inclination after cl III patient's surgery and also between different surgical groups. But the soft palate length had increased in Max Imp & Man S and decreased very little in the two other surgical groups. Soft palate inclination had a small increase after Max Adv& Man S (a more obtuse angle between palatal plane and soft palate) and soft palate uprighting was observed after Man S and Max Imp & Man S surgeries. In a study by Shendel and Epker, the soft palate posterior displacement and length increase was reported in cl III patients and this result was attributed to the forward maxillary displacement in Max Advancement group and the tongue backward displacement seen in Man Setback group (28). Samman et al. reported the same result as ours in cl III Chinese patients following bimaxillary surgeries; in their study soft palate inclination increased but it was not statistically significant(25). Different results reported by different studies might be related to un-similarity of post-surgical follow-up durations.

Tongue height (H-VT variable) showed significant change in the overall samples of the current study. The tongue height increased in all three groups mostly in Max Adv & Man S surgery. The only significant change between the three groups was the tongue height. The tongue length decreased in Man S and Max Imp & Man S surgeries but had a slight increase in Max Adv & Man S group. Anyhow, no significant difference was observed between three different surgical groups. Aydemire, Samman and Hwang reported no changes in the tongue position in their studies. Achilleos et al. followed 31 cl III patients after mandibular setback surgery for three years. They reported infero-posterior displacement of the hyoid bone and tongue after 6 months and complete return to the former position after three years and there was no consistent change in posterior movement of the tongue and hyoid bone (19, 25, 29, 30). The most adaptable muscle in this region seems to be the tongue. Anyhow we found a higher position of tongue in all three types of surgeries that seems logical because setback was performed in all three groups.

There are many different reports in the literature regarding the hyoid bone changes after surgery showing its merely downward (25, 29, 31), downward and backward (32-35), downward and forward displacement (36). Some studies have stated that hyoid bone ultimately returns to its initial position in order to maintain the airway resistance (29, 34, 36, 37). In the current study, horizontal distance of the hyoid bone to the third vertebra (AH-C3 HOR) increased significantly in all patients. Although, there was no significant difference among the three surgical approaches in this respect, mostly in Man S which might be an adaption to the posterior mandibular movement. In other words the hyoid bone has moved forward in order to maintain the airway patency. Although, there was no significant difference between different surgical methods. The same result was obtained by Aydemire *et al*., (18, 19). Regarding the vertical position of the hyoid bone, in set back surgery the hyoid was moved closer to vertical reference lines and mandibular plane which indicates a more superior position in contrast to the two other surgical groups that showed an inferior movement. Other studies had reported posterior and inferior hyoid bone displacement (16, 17). In our study hyoid bone moved forward in all three groups but superior in setback group and inferior in the two other groups. The differences in the hyoid position maybe due to the differences in follow-up period. In literature there has been evidence of returning to the original position of the hyoid bone overtime (18, 25, 38).

Our study compared the effect of three orthognathic surgeries(including mono- and bimaxillary surgeries) conducted on class III patients, while in some studies two bimaxillary surgeries(mandibular set-back/maxillary advancement versus bimaxillary advancement with genioplasty) were compared in terms of the effect on pharyngeal airway space (39). They concluded 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 oropharyngeal dimensions.

As the whole goal of assessing the airway is the prediction of clinical problems during sleep for the patient, it seems that radiographic evaluations have inherent limitations. We are not able to assess the function of the soft tissue by these tools. This means new diagnostic tools and methods are to be introduced to evaluate the efficacy of airway after orthognathic surgeries.

Conclusion

Considering all limitations of this research, comparison of one year post-surgical follow-up changes in the airway space, hyoid bone position, tongue, soft palate and other retrolingual soft tissues followed by three common orthognathic surgeries conducted on class III patients could suggest that:

- Orthognathic surgery has a significant effect on oropharyngeal space, tongue and hyoid position which could be followed by adaptation of head posture to cervical vertebrae.
- Type of surgery causes different changes in pharyngeal and retrolingual region with significant impact on tongue height. It seems that the tongue reduction in size after all three surgeries is compensated by increased tongue height to preserve airway patency but this increase is more significant in Max Adv+Man S surgery.

Conflict of Interest: 'None declared'.

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