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Original Research Article

Volumetric analysis of pharyngeal airway dimensions and hyoid bone position following orthognathic surgery in skeletal class III patients: a cross sectional cephalometric study

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ABSTRACT

Background: Objective of the study was to determine linear and volumetric changes in pharyngeal airway dimensions in class III patients treated by different modalities of orthognathic surgery and to compare the results of different orthognathic surgical modalities, and determine the change at the position of the hyoid bone.
Methods: Pre and Post-treatment lateral cephalogram of 53 class III adult patients who were treated by different modalities of orthognathic surgery studied to assess the changes in pharyngeal airway dimensions and hyoid bone position after orthognathic surgery. 28 patients were treated with mandibular set back, and 25 patients were treated with Bijaw surgery. Lateral cephalogram records were taken before treatment (T1), after surgery (T2), the end of the fixed treatment (T3) and 1 year after debonding (T4).
Results: Interception of both surgical modalities has significant impact on various skeletal and pharyngeal parameters i.e., BMeH (0.00), PNS (0.009), MPS (0.13), GOP (0.001), IPS (0.007), SAS (0.006), and MAS (0.00). OJ (overjet) and OB (overbite) was significant especially after time interval of one year. In Bijaw groups, PPST4 parameter was significantly increased (0.0000), SPST4 (0.000), GOP (0.000), EPS (0.000) and IPS parameter was significantly decreased (0.045). Significant difference was observed in T4 time interval in superior pharyngeal airway space, posterior airway space and middle airway space with ($p<0.05$).
Conclusions: Pharyngeal airway is significantly altered following orthognathic surgery in class III patients and it depends on the type of surgical modality employed were Bijaw surgery has significant impact on oropharyngeal and hypopharyngeal airway space.

Keywords: BSSO, Pharyngeal airway, Bijaw, Class III

INTRODUCTION

The presence of a normal airway and the proper functioning of its various components play a crucial role in the growth and development of craniofacial structures. Various authors in their studies have quoted significant relationships between oro-pharyngeal airway dimensions and development of dentofacial and craniofacial structures.[1,2]

Both hereditary and environmental factors contribute to the morphology of the human face and consequently, the airway. Environmental factors can have a significant impact on airway development and function such as rhinitis and asthma, environmental irritants and infections have often been associated with a vertical growth pattern along with obstruction of the upper and lower pharyngeal airways. Narrow pharyngeal airway is one of the

predisposing factors for mouth breathing and obstructive sleep apnoea (OSA).[3-5]

A skeletal class III malocclusion may arise from a prognathic mandible, a retrognathic maxilla or a combination.[6] The ortho-surgical approach for the management of skeletal Class III deformity involves various surgical procedures like mandibular set-back, maxillary advancement and bi-jaw surgeries. Functional orthopaedic therapy like use of facemask/reverse pull headgear is used in growing individuals. The orthognathic surgeries influence tongue posture and volume of oral cavity hence influencing the posterior airway space. Bijaw surgical procedures are frequently performed for the surgical correction of this deformity in contrary to past when majority of these patients were treated by mandibular set back surgeries. According to a study, Bijaw surgery is now a preferred approach in 40% of Class III patients, while mandibular setback is preferred in 10%, and maxillary advancement in 50%.[7,8]

The mandibular set back surgery can significantly reduce the volume of the pharyngeal airway and change the position of the hyoid bone and tongue. The movement of the jaws affects the soft palate, tongue, hyoid bone and associated tissues that are attached directly or indirectly to the maxilla and mandible, causing alterations in the pharyngeal dimensions. The narrowing of the pharyngeal airway due to set back surgeries can predispose the patient to obstructive sleep apnoea (OSA) syndrome.[9-15] Maxillary advancement surgeries have often been performed in conjugation with mandibular advancement operations for the treatment of OSA syndrome because of the positive effect on breathing.[16,17] When the maxilla and mandible are protruded, widening occurs in the velopharyngeal airway with the elevation of the tissues attached to the maxilla, mandible and hyoid bone. The reduced tension in the oropharyngeal and nasopharyngeal soft tissues following maxillary advancement improves airway, thus reducing the adverse effect of mandibular set back operations on breathing.[18]

Various studies have been conducted to investigate the effect of orthognathic surgery on posterior airway space in class III patients.[19,20] This study is a composite study with large surgical sample size evaluating changes in hyoid bone position and various linear pharyngeal dimensions along with volumetric changes in class III orthognathic surgery patients. The aim of this study was to evaluate pharyngeal airway change after mandibular set back and Bijaw surgical operations and comparing the results for each surgical procedure.

METHODS

Pre and post-treatment cephalometric records of patients who were treated in the department of orthodontics and maxillofacial surgery, AFMC, Pune from March 2018 to April 2020 were used for this cross sectional cephalometric study. Pre and post-treatment cephalometric records of patients who were treated in the department of orthodontics and maxillofacial surgery, AFMC, Pune were used for this study. The inclusion criteria were adult patients who were skeletally and dentally class III, those treated by orthognathic surgical treatment consisting of mandibular set back, or bi-jaw surgery, good quality and standardised lateral cephalogram taken from the same source. Exclusion criteria included history of previous orthognathic surgery, genioplasty, OSA, cleft, syndromes and any other craniofacial anomalies. A written consent was obtained from each patient selected for this study. Approval from the departmental ethical committee was obtained. 28 patients were treated with MS and 25 patients were treated with the Bijaw surgical procedure. The distribution of patients with respect to surgical technique and gender is shown in Table 1.

Table 1: Patients categorization based on surgical technique and gender.

Surgical technique	Male	Female	Total
Mandibular setback (MS)	16	12	28
Bijaw (BJ)	15	10	25
Total	31	22	53

Bilateral sagittal split ramus osteotomies with semi-rigid fixation were done for mandibular set back and Le Fort I osteotomy with rigid fixation were used to advance the maxilla forward.

Cephalometric analysis

The lateral cephalometric radiographs were taken by the same operator on the same machine before treatment (T1), after surgery (T2), at the end of the fixed treatment (T3) and one year after debonding (T4). The cephalogram were standardized by keeping the natural head position and the mandibles in centric relation. The lateral cephalograms were traced using x-ray viewer with a standardised source of light and cephalometric reference points were determined by using a lead pencil and acetate paper. Five skeletal and dental, three craniocervical and hyoidal, seven pharyngeal linear and three pharyngeal area measurements were used in the study. Linear and angular measurements were done and area measurements of the pharyngeal airway were done with digital planimeter (Sokkia Placom, KPM80N, Tokyo, Japan) (Figures 1-4).

The pharyngeal airway measurements were chosen similar to the investigations done previously.[21,22]

Statistical analysis

The statistical analysis of the study was performed by using repeated intragroup comparisons skeletal parameters ANOVA and Bonferroni post hoc test in both MS and Bi Jaw patients. Multivariate analysis was done to see the effect of interception in both the surgical modality at time

period one year after surgery and also to intercept whether surgical modality is better in such cases or not.

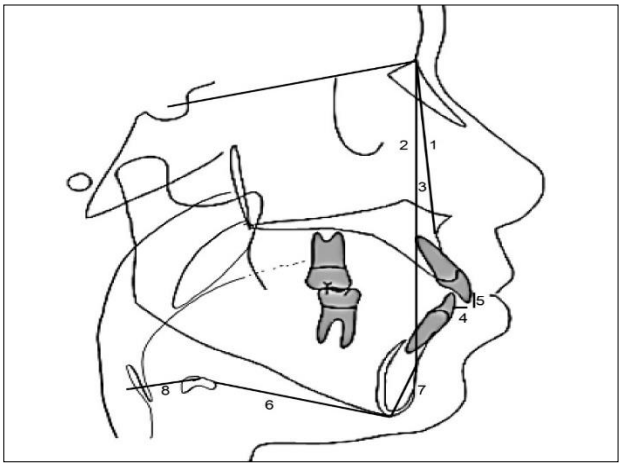

Figure 1: Skeletal parameters (a) SNA (b) SNB (c) ANB (d) Overjet (e) Overbite (f) MPH (g) BMeH (h) C3H.

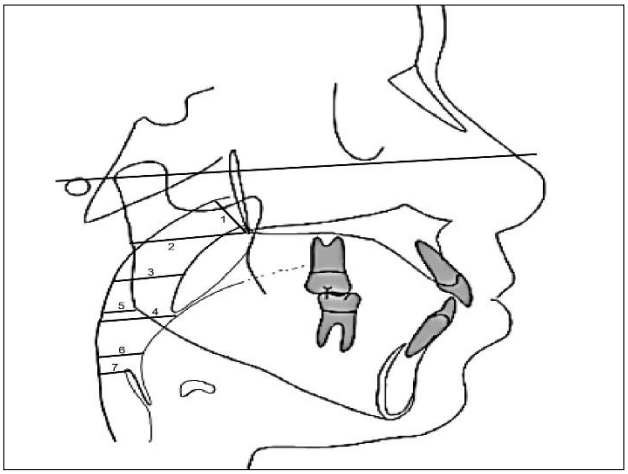

Figure 2: Pharyngeal linear parameters (a) PNS-R (b) PPS (c) SPSS (d) MPS (e) GoP (f) IPS (g) EPS.

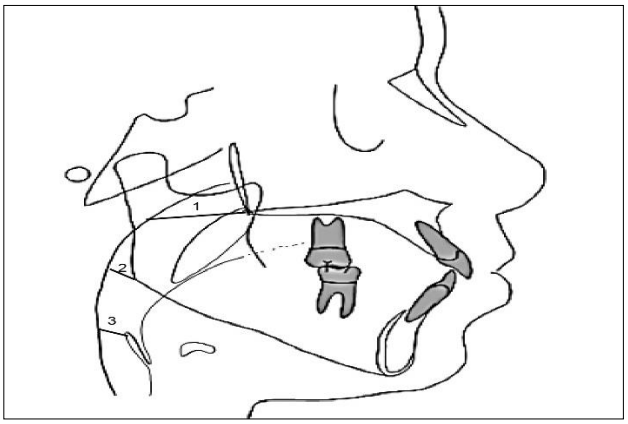

Figure 3: Pharyngeal area (a) SAS, superior pharyngeal airway (b) PAS, posterior airway space (c) MAS, minimum airway space.

Error study

A research methodology where digitizing points and measurements were performed on 20 randomly selected radiographs. Cephalometric landmarks of the radiographs were digitized twice, area measurements were repeated three times by the same investigator, and the average values of three measurements were calculated to eliminate errors in measurements.

Figure 4: Digital planimeter.

RESULTS

The mean values and standard error of the means of the variables at each time interval for two surgery groups are depicted in Table 2.

The mean amounts of maxillary advancement in the Bijaw are 4.32 mm. The mean backward movements of the mandible in the MS and Bijaw groups were 5.92 and 5.1 mm respectively. Intergroup comparisons of hyoid parameters showed highly significant changes after surgical intervention is more in Bijaw after T4 i.e., MPHT4 (0.00), BMeHT4 (0.00), C3HT4 (0.00).

Pharyngeal parameters showed highly significant changes in Bijaw compared to MS at T3 and T4 time interval after surgical intervention. Parameters showing significant changes after surgical intervention in both groups are evaluated in Table 2. Interception of both surgical modalities has significant impact on various skeletal and pharyngeal parameters i.e, BMeH (0.00), PNS (0.009), MPS (0.13), GOP (0.001), IPS (0.007), SAS (0.006), and MAS (0.00) (Table 3) shows significant interaction between various parameters on other skeletal, hyoid and skeletal parameters which showed OJ interaction significant to GOP at time interval T4 (0.010), OB showed significant interaction with parameters after completion of treatment are C3H (0.42), MPS (0.040), EPS (0.009) and MAS (0.490). Surgical modality has significant interaction at time period after completion of treatment mainly on MPHT4 (0.000), BMeHT4 (0.000), C3HT4 (0.003), PPST4 (0.000), SPST4 (0.000), MPST4 (0.000), GOPT4 (0.000), IPST4 (0.045), EPST4 (0.000), SAST4 (0.000), SST4 (0.000), PAST4 (0.001), MAST4 (0.000).

Table 2: The mean values and standard error of the means of the variables at each time interval for two surgery groups.

Parameters	Maxillary setback (n=20)				Bijaw (n=22)			
Skeletal and dental	**T1 (X±Sx)**	**T2 (X±Sx)**	**T3 (X±Sx)**	**T4 (X±Sx)**	**T1 (X±Sx)**	**T2 (X±Sx)**	**T3 (X±Sx)**	**T4 (X±Sx)**
SNA, degree	81.2±2.8	80.6±2.4	80.0±3.2	80.0±3.2	80.4±2.6	79.9±2.1	82.4±2.0	82.2±2.1
SNB, degree	85.4±2.4	84.9±2.4	78.8±1.8	78.9±2.3	87.8±2.4	87.8±2.1	80.2±2.1	80.7±1.9
ANB, degree	-4.4±0.9	-4.6±1.2	1.6±0.6	1.5±0.6	-7.4±0.9	-8.1±1.3	2.1±0.7	1.9±0.7
OJ, mm	-3.6±0.8	-4.8±0.5	2.0±0.8	1.7±0.7	-7.0±1.2	-7.8±2.3	2.7±0.5	2.3±0.6
OB, mm	-1.4±0.5	-2.3±0.8	2.3±0.5	2.3±0.5	-3.3±1.4	-3.8±0.9	2.1±0.4	2.0±0.3
Hyoid								
MPH	8.9±3.2	10.8±1.8	15.8±3.8	13.6±3.7	14.3±3.4	15.8±3.8	21.7±3.5	21.3±3.2
BMeH	88.8±2.3	89.6±3.1	100±4.3	100±4.3	99.0±6.3	101.2±6.2	110.1±4.2	109.8±3.8
C3H	31.3±2.8	31.6±2.9	36.3±2.4	35.8±2.3	33.8±2.0	36.2±2.1	39.1±1.7	38.7±1.7
Pharyngeal								
Nasopharyngeal								
PNS-R, mm	23.2±2.9	23.5±3.3	24±2.8	24.1±2.8	23.8±3.1	24.0±3.3	27.7±3.2	27.3±3.0
Oropharyngeal								
PPS mm	31.0±2.1	31.0±2.1	29.8±0.8	29.6±0.9	21.7±1.4	23.0±2.5	27.5±1.4	26.9±1.3
SPSS mm	13.3±1.9	11.9±1.4	8.7±0.6	8.4±0.7	17.1±1.8	17.5±2.0	20.3±2.1	20.3±2.1
MPS mm	11.3±1.9	9.7±1.7	8.0±1.4	7.9±1.4	15.5±2.4	13.5±1.9	10.2±0.7	10.2±0.7
Hypopharyngeal								
GOP, mm	9.6±1.0	8.6±0.6	5.7±1.0	5.8±1.0	14.0±1.9	14.7±2.3	16.2±3.7	16.2±3.2
IPS, mm	11.3±3.4	10.0±2.5	6.6±2.06	6.6±2.06	13.2±1.7	13.5±2.1	9.2±1.3	9.2±1.2
EPS, mm	10.3±1.9	10.0±1.9	6.3±0.5	6.3±0.5	12.2±1.7	12.2±1.7	9.5±1.0	9.3±0.8
Area								
SAS, mm	257.6±7.3	254.9±7.3	253.5±7.6	252.8±7.5	261.1±7.0	270.1±8.0	2947±6.6	291.7±7.8
PAS, mm	401.3±6.8	380.6±7.5	341.6±6.1	341.2±6.0	402.6±8.4	401.7±6.3	391.3±36.5	390.3±38.2
MAS, mm	262.5±3.8	251.5±3.1	221.5±8.3	221.5±8.0	351.7±7.0	367.0±7.3	311.4±6.3	311.9±7.95

Table 3: Tests of between subjects' effects.

Source	Type III sum of squares	Df	Mean square	F	Sig.
Interception					
BMeHT4	343.926	1	343.926	19.901	0.000
MPST4	3.598	1	3.598	7.041	0.013
GOPT4	57.695	1	57.695	12.553	0.001
IPST4	12.901	1	12.901	8.443	0.007
SAST4	390.938	1	390.938	9.005	0.006
MAST4	1504.245	1	1504.245	21.864	0.000
ANBT4					
MPHT4	46.321	1	46.321	4.006	0.055
OBTT4					
SPSST4	14.685	1	14.685	7.515	0.011
MPST4	4.044	1	4.044	7.914	0.009
GOPT4	34.785	1	34.785	7.569	0.010
IPST4	8.531	1	8.531	5.583	0.026
C3HT4	14.960	1	14.960	4.550	0.042
PNST4	16.864	1	16.864	4.159	0.051
MPST4	2.382	1	2.382	4.661	0.040
EPST4	2.650	1	2.650	7.856	0.009

Continued.

Source	Type III sum of squares	Df	Mean square	F	Sig.
Surgical modality					
MPHT4	334.092	1	334.092	28.894	0.000
BMeHT4	493.397	1	493.397	28.549	0.000
C3HT4	34.942	1	34.942	10.628	0.003
PNST4	27.779	1	27.779	6.850	0.014
PPST4	48.775	1	48.775	51.942	0.000
SPSST4	606.402	1	606.402	310.341	0.000
MPST4	11.704	1	11.704	22.904	0.000
GOPT4	402.645	1	402.645	87.608	0.000
IPST4	6.750	1	6.750	4.418	0.045
EPST4	27.004	1	27.004	80.048	0.000
SAST4	6584.497	1	6584.497	151.672	0.000
PAST4	10935.126	1	10935.126	13.419	0.001
MAST4	34663.862	1	34663.862	503.842	0.000
OJT4					
GOPT4	34.785	1	34785	7.569	0.010

Red <0.001 V highly significant, blue <0.01 highly significant, green <0.05 significant, alpha 5%

DISCUSSION

The pharyngeal spaces, hyoid bone, soft palate, skeletal, and dental parameters alterations after mandibular setback surgery or Bijaw surgery can vary depending on several factors, including the individual patient's anatomy, surgical technique employed, and specific treatment goals. Most of the studies evaluated only the effect of BSSO or Bijaw on airway parameters or surgical stability.[7] Effect of various treatment modalities for class III, stability and their adaptations exactly not known in any studies combine after one year. It is mandatory to compare the result of different surgical options under same standard and evaluate the effects on skeletal, dental, hyoid and pharyngeal parameters after one year. This study evaluated the effect of orthognathic surgery on the pharyngeal airway, skeletal and dental parameters after one year in MS and Bijaw patients in considerable sample.

Lateral cephalogram taken at different time interval were SNA angle did not show any changes in time interval between T1-T2, T2-T3, and T1-T4. After surgical intervention, the SNB angle was found to have mean difference of 6.4 degree on average while ANB angle has mean difference of 6.2 on average since a mandibular setback surgery was performed. No significant difference was seen from postsurgical to follow-up. These results showed that these skeletal measurements after orthognathic surgery were retained and remained stable in the long term. These results are similar to previous studies on the stability of orthognathic surgery for the correction of mandibular set back in class III deformities.[7,22,23]

Several studies have compared the measurements of pharyngeal airway dimensions obtained from lateral cephalograms with those obtained from three-dimensional CT scans. These studies have found a significant correlation between the measurements done using both imaging modalities.[24] The accuracy of cephalometric measurements in predicting the actual airway dimensions assessed by CT scans can vary depending on the specific landmarks and measurements used. However, the correlation between the two methods generally indicates that cephalograms can provide valuable information about the pharyngeal airway.[21] Many studies have evaluated the changes in pharyngeal parameters after mandibular set back surgeries and few studies recommended Bijaw surgery in prevention of upper airway narrowing during correction of class III skeletal deformities.[18] It is indispensable to compare the different surgical procedures under the same conditions and evaluate the effects on the pharyngeal airway. This is the only study with large sample evaluating the effect of orthognathic surgery on the pharyngeal dimension, hyoid bone, skeletal and dental parameters in MS and Bijaw patients.

In our study, there was significant effect on various pharyngeal parameters after various surgical interventions for correction of class III malocclusion. According to Table 3, Intergroup comparisons pharyngeal parameters T-test showed both surgical modalities showed significant 2-talied values esp for PNS at T3, T4 and PPS, SPSS, MPS, GOP, IPS, EPS, SAS, PAS and MAS. Bijaw and MS had great impact on lower pharyngeal airway but Bijaw operations effectively reduce the negative effect of MS on oropharynx with contralateral advancement of the maxilla.[25]

The measurement of the hyoid bone position using cephalometric methods can be challenging due to several factors. The position of the hyoid bone can vary within the same individual over different time periods. Factors such as head posture, tongue position, swallowing, and respiratory patterns can influence the position of the hyoid bone. This variability makes it difficult to obtain consistent and reliable measurements of the hyoid bone using cephalometric analysis. In our study, all groups showed significant change were maximal positional change was seen in certain parameters in multivariate analysis showed significant change in T4 i.e., OJ, OB and surgical modality (MS and Bijaw) (Table 4). According to the literature, after MS and Bijaw surgery hyoid bone moves inferior, both inferior and posterior.[26,27]

Table 4: Multivariate analysis showing significant changes in both the group after T4.

Effect		Value	F	Hypothesis df	Error df	Sig.
Interception	Pillai's Trace	0.935	16.487[b]	13.000	15.000	0.000
	Wilks' Lambda	0.065	16.487[b]	13.000	15.000	0.000
	Hotelling's Trace	14.289	16.487[b]	13.000	15.000	0.000
	Roy's Largest Root	14.289	16.487[b]	13.000	15.000	0.000
OJTT4	Pillai's Trace	0.785	4.213[b]	13.000	15.000	0.005
	Wilks' Lambda	0.215	4.213[b]	13.000	15.000	0.005
	Hotelling's Trace	3.651	4.213[b]	13.000	15.000	0.005
	Roy's Largest Root	3.651	4.213[b]	13.000	15.000	0.005
OBTT4	Pillai's Trace	0.770	3.854[b]	13.000	15.000	0.007
	Wilks' Lambda	0.230	3.854[b]	13.000	15.000	0.007
	Hotelling's Trace	3.340	3.854[b]	13.000	15.000	0.007
	Roy's Largest Root	3.340	3.854[b]	13.000	15.000	0.007
Surgical modality	Pillai's Trace	0.997	389.473[b]	13.000	15.000	0.000
	Wilks' Lambda	0.003	389.473[b]	13.000	15.000	0.000
	Hotelling's Trace	337.543	389.473[b]	13.000	15.000	0.000
	Roy's Largest Root	337.543	389.473[b]	13.000	15.000	0.000

The accuracy of cephalometric measurements in predicting the actual airway dimensions assessed by CT scans could have been done for our patients taken in study were margin of error is very minimal with more sensitivity.

CONCLUSION

Bijaw showed significant changes in pharyngeal parameters after surgical intervention especially in T3 and T4 time interval. MS and Bijaw cause the narrowing of pharyngeal parameters especially nasopharyngeal, oropharyngeal and hypopharyngeal airway. While planning any surgical case with skeletal deformities, we need to consider the proper evaluation of airway impact during manipulation of either jaws so that functional efficiency should not get imbalance which may cause surgical relapse over due course of time.

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