Cephalometric changes of upper airway dimensions following orthognathic surgery in patients with skeletal class III deformity

Amirfarhang Miresmaili [a], Nasrin Farhadian [a], Sanaz Soheilifar [b]

Abstract:
Aim: Class III skeletal deformity may be the result of mandibular prognathism and/or maxillary deficiency. In adult patients , orthognathic surgery is used for treatment. Historically, the surgical correction of class III deformities was achieved just by mandibular setback, but nowadays other methods of surgery are used. Orthosurgery treatments, in addition to improvement in masticatory function, occlusion and esthetics, may lead to changes in upper airway dimensions, position of hyoid, tongue and soft palate. The purpose of this study was to evaluate cephalometric changes in upper airway dimensions of skeletal class III patients following orthodontic treatment and bimaxillary surgery.
Material and methods: In this retrospective study, pre-treatment and post-treatment (6-12 months after surgery) lateral cephalograms of skeletal class III patients were used for analysis. All of the patients of a private office in Hamadan who had the inclusion criteria were selected. Cephalograms were traced manually. All the measurements were done with ruler.Then paired t test was used for analysing the data.
Results: Changes in upper airway linear measurements, position of hyoid, base of tongue, soft palate size and angle, and craniocervical angle, were not statistically significant ($p>0.05$). But there was a significant increase in nasopharynx and oropharynx surface area ($p<0.05$).
Conclusion: Orthodontic treatment with bimaxillay surgery in surgical class III cases can increase surface area of oropharynx and nasopharynx, and it seems that there is no risk factor for breathing disorders.
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Skeletal Cl III malocclusion results from mandibular prognathism and/or maxillary deficiency. The pharynx and dentofacial structures have close relationship. Some studies have been designed to evaluate this relationship. Cakarn et al. who evaluated the cephalograms af Class III patients revealed increased nasopharyngeal and decreased hypopharyngeal sagittal dimensions relative to class I patients.[1]

[a]Associate professor, Orthodontic department,Hamedan University of Medical Science
[b]postgraduate student, Orthodontic department, Hamedan University of Medical Sciences

Corresponding author:
Dr. Nasrin Farhadian
Email: nasrinnc@yahoo.com

On the other hand, Alves et al. who used computed tomography scans reported that in normal nasal breathing patients the majority of airway measurements are not affected by their malocclusion. [2]
Skeletal Cl III malocclusion can be treated through orthognathic surgery. Orthosurgery treatment can improve occlusion, masticatory function and esthetics. Upper airway dimensions may also change due to this treatment. [3] Some of the studies have shown narrowing of airway dimensions after orthognathic surgery.[3,4,5,6] Narrowing of pharyngeal airway space may lead to obstructive sleep apnea (OSA), which is a risk factor for respiratory and cardiac problems. [3,7]

Studies have shown that orthognathic surgery could change the position of hyoid, tongue and soft palate.[4,5,8] The changes in position and size of soft palate and tongue could change the space occupied by them in the upper airway area and therefore may lead to narrowing of airway space and respiratory problems. Changes in tongue position and size can be analyzed more precisely by measuring the changes in hyoid bone position.[4] Furthermore; horizontal position of vallecula suggested to be the best predictor of hypopharyngeal depth. [9] On the other hand, narrowing of the airway may cause some compensatory mechanisms in the craniocervical area in order to maintain the airway patency, such as a change in position and size of tongue and soft palate [4] ,or cervical hyperflexion which is reported in some studies after mandibular setback surgery. [5,8]
Among several studies that tried to investigate the effects of orthognathic surgery on pharyngeal space, most of them have evaluated the effect of mandibular setback surgery. [5,6,8] The effect of maxillary advancement and bimaxillary surgeries on the upper airway variables have not been studied sufficiently. In addition, there are controversies about the changes in upper airway dimension after the bimaxillary surgery in the literature. Samman et al. who evaluated the presurgery and 6-months post-surgery cephalometrics found reduction in airway space [4], Chen et al. found reduction in short term (3-6 months after surgery), although no changes in long term(at least 2 years after surgery)[3] were noticed. Cakarne found a significant increase in nasopharyngeal airway space after 8 months follow up.[1]
The aim of this study is to investigate the effect of orthodontic treatment with bimaxillary surgery on upper airway dimensions in skeletal cl III patients.

Materials and methods

Lateral cephalograms of skeletal cl III patients from an orthodontic office in Hamadan were evaluated. The inclusion criteria were: Iranian in race, skeletal cl III , treated through combination orthodontic treatment and bimaxillary surgery (maxillary advancement , mandibular setback), having the initial and final lateral cephalograms (at the start of treatment and between 6-12 months after surgery). The exclusion criteria were: history of OSA , tonsillectomy or adenoidectomy. Sample size was calculated according to following formula:

$N=2(Z1-\alpha/2 + Z1-\beta)2 * \delta 2 / (\mu 1-\mu 2)2=24$, $\alpha=5\%$, $\beta=20\%$

($\mu 1$ and $\mu 2$: the mean upper airway dimension before and after surgery, δ: the standard deviation of change in airway dimensions) μ and δ were according to Tselnik et al. [6]
Lateral cephalograms were taken in NHP with teeth in centric occlusion. Two devices:Soredex with 1.13 magnification and Planmeca with 1.8-1.13 magnification, had been used for taking radiographs. Before and after cephalograms were traced manually and variables measured in millimeter. Then paired-t test was used for analysis. The statistical package used was SPSS version 12. A random sample of 25 tracings were measured twice by one month interval for analysis of systematic error.
Upper airway was evaluated at 4 levels: nasopharynx, oropharynx, and hypopharynx , and region of minimal airway space (PASmin).
The length, thickness and angle of soft palate, position of the base of tongue, position of hyoid bone relative to several landmarks , and the craniocervical angle were evaluated.
Cephalometric variables of the airway ,soft palate and tongue were evaluated according to the Samman et al.[4], except for the measurements of nasopharynx which was modified. Hyoid was evaluated according to the measurements collected by Athanasiou et al.[10] For craniocervical angle the method of measurement was the one used by Muto et al.[5] (Fig 1).
The airway surface area was devided into 5 trinagles: 3 for nasopharynx and oropharynx (upper pharyngeal surface area) and 2 for hypopharynx (lower pharyngeal surface area) (Fig 2).

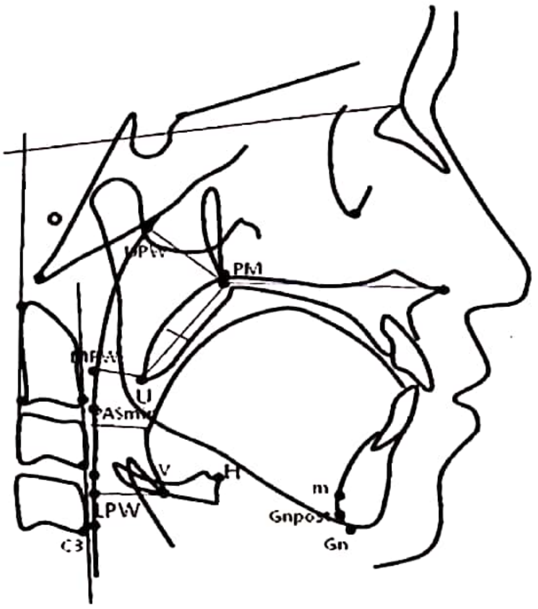

Fig 1: A) Landmarks

PM :pterigomaxillare, the point at intersection of posterior contour of maxilla and nasal floor, equivalent to PNS , CV:cervical vertebra, the line overlying the anterior surface of 2nd and 3rd cervical vertebra, H: anterior hyoid, the most anterior and superior point on the body of hyoid bone, U: Uvula, the tip of uvula, V: Vallecula, the intersection of the epiglottis and base of tongue, UPW: upper pharyngeal wall, intersection of line between posterior pharyngeal wall and perpendicular from PNS to Ba-N , MPW: middle pharyngeal wall, intersection of a perpendicular line from U to posterior pharyngeal wall, LPW: lower pharyngeal wall, intersection of a perpendicular line from V to posterior pharyngeal, NL:nasal line , line between ANS and PNS, C3: the most inferior anterior point on third cervical vertebrae, H': intersection point between the perpendicular from H to line connecting the point C3 and Gnpost, GnPost: the most inferior posterior point on the mandibular symphysis , M: the most posterior point on mandibular symphysis, PPW: the most inferior point of the pharyngeal wall along a parallel line on point H to the NL line

B)linear(mm) and angular (deg) measurements

PM-U: length of soft palate, distance from H to VT line,SPT: soft palate thickness, represents the maximal thickness of soft palate measured perpendicular to PM_U line, PM-UPW: depth of nasopharyngeal airway space from PM to UPW ,U-MPW: depth of oropharyngeal airway space from V to LPW,V-LPW⊥ depth of hypopharyngeal airway space from V to LPW, PAS-Min: the shortest distance between base of tongue and posterior pharyngeal wall, the narrowest sagittal airway space,V FH : position of vallecula in vertical plane, a perpendicular line from V to FH ,V CV: position of vallecula in horizontal plane, a line from V to CV and parallel to FH ,H FH: position of hyoid bone in vertical plane, from AH perpendicular to FH, H-CV: position of hyoid bone in horizontal plane , from AH to CV and parallel to FH ,NL/PM-U: inclination of long axis of the soft palate relative to the nasal line, C3-H: anteroposterior position of hyoid,linear distance berween C3 and H, H-H': vertical position of hyoid ,distance from H to H', Hy-GnPost: horizontal position of hyoid ,distance from H to Gnpost, H-APW2: linear distance of hyoid to anterior pharyngeal wall on point APW2 ,H-APW4: linear distance of hyoid to anterior pharyngeal wall on point APW4, H-m: anteroposterior position of hyoid ,distance of H to m , H-NL: vertical position of hyoid , distance from H to NL , H-ML: vertical position of hyoid , distance from H to ML , H-NSL: vertical position of hyoid, distance from H to NSL ,H-PPW: horizontal position of hyoid distance from H to PPW ,OPT-NSL: craniocervical angle, angle between lines OPT and NSL.

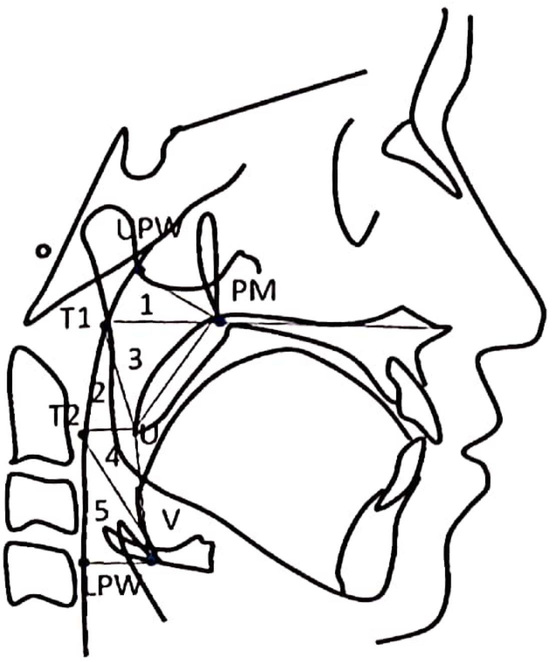

Fig 2: Surface area of upper and lower pharyngeal space(mm^2)

The surface of triangles 1 ,2 and 3 represents the upper pharyngeal surface, and triangles number 4 and 5 represent the lower pharyngeal surface. T1:intersection of NL line with posterior pharyngeal line, T2: intersection of line parallel to NL line with posterior pharyngeal wall

Results:

The data for the sample before and after treatment are shown in Table 1.

Table 1: The mean of the measurements before and after treatment

Variable	Before treatment	After treatment	P value	Number
Pm-UPW	24.02	25.10	.220	24
U-MPW	12.98	13.34	.620	24
V-LPW	20.24	21.07	.224	24
Pas-min	13.86	13.44	.680	24
Airway surface area	1351.29	1486.52	.014*	24
Upper pharynx surface area	735.04	821.64	.013*	24
Lower pharynx surface area	607.97	663.78	.062	24
PM-U	35.72	37.32	.053	24
SPT	9.95	9.30	.117	24
NL/PM-U	128.83	129.24	.752	24
V-FH	91.60	92.96	.216	24
V-CV	23.44	24.13	.404	23
H-FH	91.42	91.11	.841	24
H-CV	36.05	36.10	.927	23
C3-H	37.80	38.74	.154	22
H-H'	1.87	1.24	.520	20
H-APW2	18.78	19.28	.595	24
H-APW4	18.06	17.94	.742	17
H-Gn post	49.21	45.79	.070	21
H-m	47.75	44.36	.073	24
H-NL	64.80	65.90	.307	24
H-NSL	110.41	112.17	.106	24
H-PPW	33.46	34.03	.405	24
OPT-NSL	107.56	105.66	.309	24

Systematic error was not siginificant (P value<0.01) , so the results were highly reproducible.

There wasn't any significant difference in the variables evaluated before and after treatment except for the variables related to total airway surface area and upper pharyngeal surface area that increased significantly after treatment.

Discussion:

In the present study, lateral cephalogram was used for evaluating the changes in the airway dimensions. Although a cephalogram provides only a 2-dimensional image of the pharyngeal airway space, it has been used extensively in the assessment of sleep apnea and craniofacial form because of advantages such as its wide availability, simplicity, low cost and ease of comparison with normative data and other studies.[3,11] Furthermore; Good correlation between airway dimensions measured on lateral cephalogram and 3-D computed tomography has been reported.[12]

Present study evaluated the changes of the airway dimensions from two aspects: the distances (linear measurements), and the surface area of the upper airway. No significant difference was revealed during 6-12 months after surgery in upper airway distances, on the other hand a siginificant increase was found in the pharyngeal surface area after the treatment ($p<0.05$). When this total surface was divided into upper (oropharynx plus nasopharynx) and lower (hypopharynx) area, it was found that increase in total surface area of the upper airway is related to increase in upper pharyngeal surface area.

Change in upper airway distances after orthognathic surgery have been studied extensively in recent decades. A main reason is that airway narrowing may be a risk factor for developing obstructive sleep apnea(OSA).[3,7] Athanasiou et al. found no significant changes in measurements representing pharyngeal depth at the level of second and fourth cervical vertebra after mandibular setback surgery.[8] But Tselnik et al. [6], Samman et al .[4] , Chen et al.[3] and Muto et al. [5] reported a reduction in airway size after this type of surgery. Only one study has documented 2 cases of developing OSA after mandibular setback13 ,and currently available literature concludes that sleep-related breating disorders as a consequence of mandibular setback is rare. [13]

After bimaxillary surgery, in contrast with the present study, Samman et al. who evaluated the preoperative and 6-months postoperative cephalograms found reduction in airway space distances. [4] The difference may be due to time of taking the records. Adaptive changes are likely to occur in the soft and hard tissues after osteotomies.[3] Some muscular adaptation may occur in long term after surgery which compensate any anatomic changes that have been made in the airway area.[4] Furthermore postsurgery inflammation may be responsible for the immedaite postsurgery changes in some of the studies.

Chen et al. found a reduction in short term (3-6 months after surfery) although no changes in long term (at least 2 years after surgery) was found[3] and Marsan et al. who evaluted the cephalograms taken before, one week post-operatively, and 1.3+/-0.2 years after a bimaxillary surgery of class III patients, found an increase in upper retropalatal airway space, together with posterior and inferior movement of hyoid bone, one week postoperatively,[14] but some relapse was found in these changes over one year . These results are consistent with the present study's results.

Cakarne who evaluated the effect of bimaxillary surgery, found a significant increase in nasopharyngeal airway space after an 8- month-follow up, but no change in hypopharyngeal and oropharyngeal level.[1] In the present study, despite no change in nasopharyngeal distances, a significant increase was found in nasopharyngeal and oropharyngeal surface area which may be related to an advancement of the maxilla in this type of surgery. Area of the pharyngeal space may be more precisely indicative of the upper airway volume than linear measurements.

Tselnik et al. used a 3-mm^2 grid for calculating the airway surface and found significant increase in airway surface area immediatly after mandibular setback surgery, but observed reduction at long term follow-up.[6] Samman et al. used computer software for calculating the upper airway area in 35 male patients after surgery, and found a decrease in this variable after surgery.[4] This result was related to a group of class III patents with three different types of surgeries.

The present study revealed no significant difference in soft palate dimensions, position of hyoid and base of tongue after the treatment. Samman et al. reported posterior movement of hyoid after bimaxillary surgery [4] and found that the soft palate moved posteriorly and the angle increased. They didn't find any significant changes in the variables related to base of tongue.[4] Athanasiou et al. found significant changes in distance of hyoid to maxilla and mandible after setback surgery but no significant changes in distance of hyoid to anterior cranial base, vertical column and the anterior pharyngeal wall.[8] Muto et al. found that after setback surgery the angle of soft palate to palate inceased and the length increased too.[5]

Craniocervical angle is evaluated only after setback surgery in the literature.[5,8] Wenzel et al.[8] and Achilleos et al.[5] reported hyperflexion after this surgery to compensate decrease in pharyngeal airway space. In the present study, there was no reduction in the upper airway dimensions and no significant changes were revealed in this angle.

In this study, as mentioned before, the radiographs were taken at the start and 6-12 months post-surgery. Combination of orthodontic treatment and surgery take part in producing the results. Although it seems that orthodontic treatment has little or no impact on airway measurements.

Conclusion:

In the present study it was concluded that:

- Upper airway distances didn't change significantly.
- Position of hyoid, base of the tongue, length, thickness, angle of soft palate, and craniocervical angle didn't change significantly
- The surface area of nasoharynx and oropharynx increased sifnificantly.($p<0.05$)
- Orthodontic treatment and bimaxillary surgery do not seem to be a risk factor for breathing disorders.

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