Original Article

Assessment of the Changes in the Dimensions of the Soft Palate Following Orthognathic Surgery in Class III Patients

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KEY WORDS
Orthognathic Surgery;
Class III deformity;
Soft palate

Received July 2011;
Received in revised form Nov. 2011;
Accepted Jan. 2012

ABSTRACT

Statement of Problem: Adaptation of the soft palate and its morphological alterations do occur to some extent after different surgical strategies of class III patients including mandibular setback, maxillary advancement and bimaxillary surgery. The precise changes in soft palate morphology are not well understood yet.

Purpose: The aim of this study was to conduct a detailed cephalometric evaluation of the alterations taking place in position and morphology of the soft palate after treatment of class III skeletal deformity via different surgical procedures (i.e. mandibular setback, maxillary advancement, bimaxillary surgery).

Materials and Method: 120 consecutive patients who were diagnosed as having skeletal class III deformity were evaluated. All patients included in this study were adults who had completed their growth and had cephalograms within a month prior to operation (T1) and 1 month to 9 months post-surgery (T2) taken in the natural head position. Patients were divided according to the type of surgery undertaken in three groups: group 1 combination of mandibular and maxillary (bimaxillary), group 2 (mandibular setback) and group 3 (maxillary advancement) surgery. Soft palate length, depth and thickness were evaluated at both T1 and T2 in each group. The results were compared by paired t and one-way ANOVA tests.

Results: Soft palate length increased significantly in groups I and III (p <0.05). Soft palate depth changed significantly in group II (p <0.05). Soft palate thickness did not changed in any groups (p >0.05).

Conclusion: Soft palate morphology was changed after class III surgeries. Palatal length was increased after maxillary advancement or bimaxillary surgery whereas its depth was increased after mandibular setback or bimaxillary surgery.

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Introduction

Class III problems are those caused by some combination of maxillary hypoplasia (deficiency) and mandibular hyperplasia (excess) [1-3]. Historically, the surgical correction of class III deformities was achieved by mandibular setback alone [4-6], but as the knowledge and techniques advanced, corrective surgery progressed into combined mandibular setback and maxillary advancement procedures (i.e. bimaxillary). Treatment of class III dentofacial deformities with jaw osteotomies has an effect on oropharyngeal morphology as well as position of bony facial skeleton and hard tissue-soft tissue relationships [7-9]. One aspect of surgical treatment of class III skeletal deformity which has gained prominence over the past 20 years is the effect of skeletal movement in different surgical strategies of treatment on the pharyngeal [posterior] airway space (PAS) [1]. The soft palate and its associated muscles in pharyngeal region are attached directly or indirectly to the maxilla. Therefore, movement of the jaws will result in positional changes of the structures attached to the bone and changes in tension of the attached soft tissue and muscle [10-11]. This will result in an alteration of the nasal and oral cavities and pharyngeal (posterior) airway (PAS) dimensions depending on the direction and magnitude of the skeletal movements [10-11]. Liukkonen et al. evaluated the soft palate length of patients who had mandibular setback surgery in cephalometric films and reported that the length of uvula is unchanged following surgery [12]. Others also evaluated the cephalometries of the patients before and after surgery and found that the soft palate length increased significantly following mandibular setback surgery but the thickness remained unchanged (Saitoh [13], Muto et al. [14], Achilleos et al. [15] and Marsan et al. [16]). Samman et al. (2002) showed a decrease in length, sagittal thickness and area of the soft palate assessed radiographically following either mandibular setback or bimaxillary surgery [17]. They concluded that this was a compensatory mechanism by the soft palate to protect the airway against obstruction. Schendel et al. quantified the changes in the palatal morphology seen in cephalometry after LeFort I maxillary advancement surgery and reported a 0.5mm increase in soft palate length per millimeter of maxillary advancement [18]. Adaptation of the soft palate after surgical treatment of class III patients and its morphological alterations has not been sufficiently clarified. The aim of this study was to conduct a detailed cephalometric evaluation of the alterations taking place in position and morphology of the soft palate after treatment of class III skeletal deformity via different surgical procedures (i.e. mandibular setback, maxillary advancement, bimaxillary surgery).

Materials and Method

This was a before-after cross sectional retrospective study of 120 consecutive patients who were diagnosed as having skeletal class III deformity and randomized with stratified method. All patients included in this study were adults who had completed their growth. They were 41 male and 79 female patients with the average age of 23.4 years and the range of 18-31 years old at the onset of the treatment. All of the patients studied had undergone fixed orthodontic treatment with edgewise appliances both before surgery and after surgical procedure for correction of their jaw deformities. The subjects were selected from the files of patients at the orthodontic departments of Shiraz University of Medical Sciences and Shahid Beheshti University of Medical Sciences and one private clinic in Shiraz. The records of all 120 patients were retrospectively selected on the basis of the following criteria:

1- Availability of lateral cephalograms both within a month prior to operation (T1) and 1 month to 9 months post - surgery (T2) taken in the natural head position (NHP) between 1383-1388 (2004-2009) with all cephalograms included the second and fourth cervical vertebrae. A minimum 1-month interval between surgery and the acquisition of post surgical cephalograms was required to minimize any effects from postoperative swelling and edema which may adversely affect the airway dimensions. In order to obtain natural head position (NHP) the subjects were instructed to stand at rest in a relaxed manner in cephalostat. Then they were asked to look into the image of their own eyes in a small mirror located at the same level as the pupil of their eyes. Then only one ear post was carefully inserted into their ear canals without changing the head position and the nasal stabilizing device was set in its place. All of the subjects were asked to cont-act their lips lightly while their teeth were in occlusion and the lateral cephalometric radiograph was taken.

2- In order to correct class III deformity the patients received maxillary, mandibular or maxillomandibular surgery. All the patients with mandibular set-back surgery had undergone bilateral sagittal split ramus osteotomy (BSSRO) which was credited by Trauner and Obwegeser [19] and had undergone modifications by Dalpont [20], Hunsuck [21], Gallo [22] and Epker [23]. The subjects with maxillary advancement surgery received LeFort I advancement osteotomy without impaction. The bimaxillary surgical patients had undergone combined LeFort I maxillary advancement osteotomy without impaction and BSSRO mandibular setback surgery. All the patients had rigid internal fixation (RIF) with fixation screws and /or plates following either maxillary or mandibular osteotomies. All of the mandibular setback surgeries and bimaxillary surgeries were accomplished by one surgeon.

3- The patients having one or more of these criteria were excluded from the study: History of trauma to the face and the jaws, absence of completely normal dentition with no missing teeth except those that were extracted for orthodontic purposes and the third molars, apparent facial asymmetry, presence of any syndrome related to orofacial region, cleft lip and/or palate, obstructive sleep apnea (OSA) or even habitual snoring, chronic upper respiratory tract infections and diseases, previous history of orthognathic or facial cosmetic procedures including mandibular inferior border osteotomy (genioplasty) and previous history of adenoidectomy / tonsillectomy and rhinoplasty. The data for excluding these criteria were gathered from patient's medical and dental history, cephalograms (including lateral and posteroanterior views) and facial and intraoral photographs available in the files. Patients were divided according to the type of surgery undertaken in three groups:

Group 1: Those who received combined maxillaary advancement and mandibular setback surgery.

Group 2: Subjects who received mandibular set-back osteotomy.

Group 3: Patients who received maxillary advancement surgery.

Furthermore the patients divided into 3 distinct categories based on their facial height index (FHI) that is the percentage ratio between posterior facial height (measuring from point articulare to the point gonion) and anterior facial height (measuring from point ANS to the point menton) on the lateral cephalograms as described by Horn [24]. Normal group were selected with FHI between 62 and 67 percent, the long face group when the facial height index (FHI) was less than 62 percent and the short face group if the FHI was more than 67 percent in the preoperative cephalometic evaluation were considered.

Radiography

A Proline 2002 CC/XC (Planmeca OY, 00880 Helsinki, Finland) x-ray source was used to take all the cephalograms. The film distance to the x-ray tube was fixed to 150 cm and the film distance to the midsagittal plane of the patients head at 15cm as suggested by the manufacturer. The resulting magnification was 9% as estimated by placing a radiopaque ruler on the unit's nasal positioner and calculating the percent increase in the ruler's image length. The films were exposed at 62-70 KV, 10-11 mA and exposure time of 0.5-0.7 seconds with total filtration of 2.5 mm aluminum equivalent.

Lateral cephalograms

The cephalograms were hand traced on 0.003 inches thick, 8×10 inches matte acetate tracing paper (Truvision, Ortho Technology Inc., Tampu, Florida, USA; di-stributed by Emergo Europe, Molenstraat, Netherlands) with 3H drawing pencil. Measurement points of the lateral cephalometric tracings include the following (Figure 1).

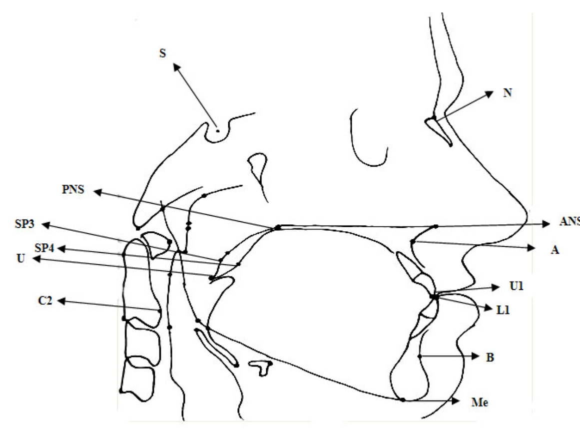

Figure 1 Skeletal and Soft tissue Landmarks

Skeletal Landmarks

- Sella (S): The geometric center of the pituitary fossa [25].
- Nasion (N): The most anterior point on the frontonasal suture in the midsagittal plane [25].

- Point A: The most inferior point on the alveolar bone overlying the maxillary incisors (the most posterior midline point in the concavity between the ANS and the prosthion) [25].
- Point B: The most posterior point in the concavity between the chin and mandibular alveolar process [25].
- PNS (Posterior Nasal Spine): The posterior spine of the palatine bone which constitutes the hard palate [25].

Soft Tissue Landmarks

- U: Tip of the soft palate (Uvula) [26]
- SP3: A point on the nasal surface of the soft palate at its maximum thickness [27].
- SP4: A point on the oral surface of the soft palate at its maximum thickness [27].

Reference Lines

Vertical Reference Line (VRL): The line which is drawn through the most anterior point of the second cervical vertebra (axis or C2) parallel to the edge of the cephalometric film [28]. Horizontal Reference Line (HRL): The line which is drawn through point sella at right angle to the edge of the cephalometric film [28].

Dento-Skeletal Measurements

To assess the hard tissue relationships and comparing pre surgical to post treatment data the following linear and angular measurements were measured:

SNA (degrees): The angle formed by the planes sella-nasion and nasion-point A.

SNB (degrees): The angle formed by the planes sella-nasion and nasion-point B.

ANB (degrees): The angle formed by the planes nasion-point A and nasion-point B.

Overbite (mm): The vertical distance from upper incisor tip to the lower incisor tip.

Overjet (mm): The horizontal distance from upper incisor tip to the lower incisor tip.

Maxillary advancement (mm): the distance from point A to vertical reference line.

Mandibular setback (mm): the distance from point B to vertical reference line.

Soft Tissue Measurements

To evaluate the soft tissue of the airway the following linear quantifications were used:

Soft palate length: Millimetric distance between points PNS and U (1).

Soft palate Thickness: Millimetric distance between points SP3 and SP4 (2).

Soft palate depth: Millimetric distance of the points PNS and U Mirrored on the horizontal reference line (3) (Figure 2).

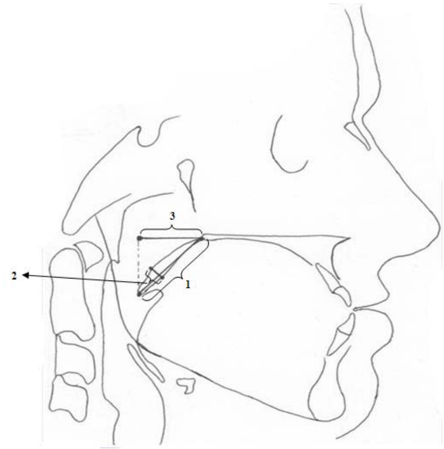

Figure 2 Soft Palate measurements

Method Error

Each cephalogram was traced and measured manually by a single operator. Half of the cephalograms in each group were randomly selected after 2 weeks. All the measurements in each case were repeated. Differences between the original and the retraced cephalograms were statistically analyzed using matched paired t-test. The results of the analysis indicated that there were no statistically significant differences between the original and repeated measurements at the 0.05 level. Therefore the original measurements that were used for the analysis of the dentoskeletal and soft tissue changes were reliable.

Statistical Analysis

Data was gathered and analysed by using the following tests: Comparisons of the group (according to type of surgery) characteristics were done with one way ANOVA test (for variable of age) and chi-square test (for variable of sex). For comparing of the dependent variables (CVT to SN, VRL to EP ...) before and after of surgery, paired t- test and for comparing of mean differences of the dependent variables between groups ANOVA test were used. We evaluated the effect of group on mean differences of the dependent variables after adjustment of other

Table 1 Demographic data of class III patients treated with surgery

Parameter		Group 1	Group 2	Group 3	P.value
Sex (percent)	Male	12 (30)	13 (32.5)	16 (40)	0.618 [1]
	Female	28 (70)	27 (67.5)	24 (60)	
Face height Number (percent)	Normal	14 (35)	17 (42.5)	14 (35)	0.129 [1]
	Long	18 (45)	12 (30)	9 (22.5)	
	Short	8 (20)	11 (27.5)	17 (42.5)	
Age (mean ± SD)		22.99 ± 4.53	22.73 ± 3.29	24.48 ± 2.53	0.064 [2]
Advancement (mean ± SD)		4.04 ± 1.78	-----------	4.33 ± 1.5	0.371[3]
Setback (mean ± SD)		3.3 ± 1.49	4.35 ± 1.29	------------	0.001[4]*

*: statistically significant (1) Chi square test (2) ANOVA (3) Mann-Whitney U test (4) two sample test

independent variables (age, sex, advancement, setback, face height) with multiple linear regression models. Because 2 independent variables, advancement and setback, were not defined for all groups (advancement defined for group 1 and 3; setback defined for group 1 and 2), for the evaluation of group effect on mean differences of the dependent variables after adjustment of advancement, subjects of groups 1 and 3 and for controlling of setback, groups of 1 and 2 selected and entered to multiple linear models. In multiple linear models, variable of group entered to the models with enter method and other variables with stepwise method. Assumption of norm-al distribution was assessed with one Kolmogorov Smirnov test and the results showed that data were normally distributed ($p > 0.05$). Box plots were used to visualize the results. Statistical tests, using a two - sided P value (The level of statistical significance was set at $p < 0.05$) were conducted with the SPSS programme (version 16).

Results

The demographic data of class III patients in groups I to III are shown in table1.

The group I (bimaxillary group) consisted of 40 patients with the mean age of 22.99± 4.53 years. Sex distribution of patients in this group was 12 males (30%) and 28 females (70%). According to face height index, group I consisted of 14 (35%) normal, 18(45%) Long and 8(20%) short face subjects. The mean surgical movements of the jaws were 3.3±1.49mm maxillary advancement and 4.04±1.78 mm mandibular setback in group I. The group II (mandibular setback) consisted of 40 patients with the mean age of 22.73±3.29 years. Gender distribution of patients in this group was 13 males (32.5%) and 27 females (67.5%). Considering face height index, group II included 17 (42.5%) normal, 12 (30%) long 11(27.5%) short face subjects. The mean surgical mandibular setback movement in this group was 4.35± 1.29mm. There was statistically significant difference between setback movement in group II and group I.

Table 2 Overall changes in soft palate morphology in different groups

Parameter	Group	T1(before)	T2 after	T1 - T2	P.value
Soft palate length	Group 1	36.10±6.83	38.27±6.38	-2.17±4.46	0.004
	Group 2	38.02±6.61	39.25±5.12	-1.22±5.09	0.136
	Group 3	35.52±7.83	38.45±4.74	-2.93±5.91	0.039
Soft palate thickness	Group 1	9.27±2.52	8.87±2.88	0.40±1.75	0.157
	Group 2	9.72±2.52	9.30±1.73 .9.70±	0.45±2.62	0.311
	Group 3	9.25±1.47	9.70±2.08	-0.18±1.67	0.219
Soft palate depth	Group 1	21.78±5.57	23.72±5.04	-1.95±5.17	0.022*
	Group 2	24.63±5.09	26.65±5.14	-2.02±4.21	0.004*
	Group 3	21.33±3.53	22.52±5.80	-1.19±4.35	0.061

*: statistically significant changes

Table 3 Changes in soft palate morphology of females in groups

Parameter	Group	T1(before)	T2 after	T1 - T2	P.value
Soft palate length	Group 1	35.00±6.12	37.18±6.21	-2.18±4.42	0.015*
	Group 2	37.30±5.89	39.11±5.06	-1.81±5.52	0.099
	Group 3	37.42±5.02	36.00±4.52	1.42±5.03	0.181
Soft palate thickness	Group 1	8.57±2.20	8.03±2.44	0.53±1.83	0.134
	Group 2	9.55±2.12	9.44±1.67 .9.70±	0.11±2.26	0.800
	Group 3	9.46±1.35	9.75±2.05	-0.29±2.05	0.493
Soft palate depth	Group 1	20.57±4.86	23.43±4.94	-2.86±5.45	0.010*
	Group 2	25.26±4.65	27.30±5.41	-2.04±4.53	0.027*
	Group 3	21.00±3.48	22.96±4.98	-1.96±4.5	0.065

*: statistically significant changes

The group III (maxillary advancement) consisted of 40 patients with the mean age of 24.48±2.53 years. Sex distribution of subjects in this group was 16 males (40%) and 24 females (60%). Considering face height index, group III consisted of 14 normal (35%), 9 long (22.5%) and 17 (42.5%) short face patients. The mean surgical maxillary advancement in group III was 4.33±1.5mm which was not statistically higher than the mean advancement surgery in bimaxillary group.

The changes in soft palate were evaluated preoperatively and 6±2.5 months after the maxillary, mandibular or maxillomandibular osteotomies. The changes in soft palate dimensions are demonstrated in table 2.

Soft palate length and soft palate depth were increased in group I (bimaxillary group) while soft palate thickness was not changed significantly after maxillomandibular surgery. In subgroups, female patients showed increases in both soft palate length and soft palate depth dimensions but male patients did not showed any significant changes in soft palate dimensions at all (Tables 3 and 4).

Depth size as it increased but no changes observed in soft palate length and soft palate thickness areas. When considering sex differences, female patients showed increases in soft palate depth index and no changes in other soft palate dimensions. In contrast, male subjects showed no alterations in soft palate dimensions at all.

Table 4 Changes in soft palate morphology of males in Groups

Parameter	Group	T1 (before)	T2 after	T1 - T2	P.value
Soft palate length	Group 1	38.67±7.95	40.83±6.31	-2.17±4.74	0.142
	Group 2	39.54±7.94	39.54±5.46	-0.00±3.96	1.000
	Group 3	40.00±3.93	34.81±11.28	-5.19±11.60	0.094
Soft palate thickness	Group 1	10.92±2.54	10.83±2.98	0.08±1.56	0.857
	Group 2	10.08±2.81	9.00±1.87	1.08±3.25	0.256
	Group 3	9.62±1.67	9.62±2.19	-0.00±2.80	1.000
Soft palate depth	Group 1	24.58±6.30	24.42±5.42	0.17±3.86	0.884
	Group 2	23.31±5.88	25.31±4.40	-2.00±3.65	0.072
	Group 3	21.81±3.65	21.87±6.98	-0.06±6.97	0.972

*: statistically significant changes

In group III, soft palate length decreased following surgery. But changes in other dimensions did not observed in soft palate indices. Moreover, there were gender differences between males and females in this group. In subgroups, female patients showed decrease in soft palate length but male patients did not showed any significant changes in soft palate dimensions at all (Table 4).

Discussion

The soft palate and its associated muscles in pharynxgeal region are attached directly or indirectly to the maxilla. Therefore, movement of the jaws will result in positional changes of the structures attached to the bone and changes in tension of the attached soft tissue and muscle [11]. This will result in an alteration of the nasal and oral cavities and pharyngeal (posterior) airway (PAS) dimensions depending on the direction and magnitude of the skeletal movements [10-11].

The morphology of the soft palate and its position changed significantly after surgery. In mandibular setback group, the soft palate depth increased significantly after surgery whereas soft palate length and thickness didn't change. Our finding was consistent with the findings of Turnbull & Battagel [29] and Liukkonen et al. [12] concerning changes in soft palate length but in contrast to the studies by Achilleos et al. [15], Saitoh [13], Muto et al. [14], Samman et al. [17] and Marsan et al. [16]. Regarding changes in soft palate thickness our results were in agreement with the findings of Achilleos et al. [15], Saitoh [13], Muto et al. [14] and Marsan et al. [16] but in contrast with the study by Samman et al. [17]. Liukkonen et al. evaluated the soft palate length in patients who had mandibular setback surgery and reported that the length of uvula was unchanged following surgery [12]. Achilleos et al. [15], Saitoh [13], Muto et al. [14] and Marsan et al. [16] found that the soft palate length increased significantly following mandibular setback surgery but the thickness remained unchanged. In contrast Samman et al. showed a decrease in length, sagittal thickness and area of the soft palate following either mandibular setback or bimaxillary surgery [17]. They concluded that this was a compensatory mechanism by the soft palate to protect the airway against obstruction.

We also found that while women showed significant changes in the morphology of the soft palate men didn't show adaptive changes following mandibular setback osteotomy. This may be due to the fact that the overall dimensions of the soft palate are smaller in women so they showed a compensatory mechanism in soft palate region to protect the airway against obstruction following mandibular setback surgery. Until now to our best of knowledge no other study reported sexual dimorphism in the shape of soft palate following mandibular surgery.

In bimaxillary group, our results showed increases in both soft palate length and depth, which were in agreement with Turnbull & Battagel [29], but in contrast to the findings of Samman et al. [17]. This probably represented adaptive postural changes of the soft palate in order to maintain adequate palatal function and an oropharyngeal seal. Once more the female and the male patients showed different changes following bimaxillary surgery. Whilst women showed significant increases in soft palate length and depth, Men showed that their palatal morphology was not affected by 2-jaw surgery. This was in contrast with previous study by Samman et al. [17] which showed no difference in soft palate morphology between women and men. This may reflect the fact that women might need more adaptation in the soft palate and oropharynx to maintain their oropharyngeal seal or velopharyngeal competency following bimaxillary surgery.

In maxillary advancement, the subjects showed increases in the soft palate length. This finding was in agreement with the previous findings by Turnbull & Battagel [29] and Schendel et al. [18]. Schendel et al. quantified the changes in the palatal morphology after LeFort I maxillary advancement surgery and reported a 0.5mm increase in soft palate length per millimeter of maxillary advancement [18]. Our findings also showed that there was sex dimorphism in the changes of palatal morphology following maxillary advancement surgery. Whilst females showed significant changes in palatal morphology (soft palate length); men didn't show any changes in its dimensions at all. This may be caused by the overall size of the soft palate in females that is generally smaller than males in all dimensions; therefore women might need more adaptation in the soft palate and oropharynx to maintain their oropharyngeal seal or velopharyngeal competency following maxillary advancement surgery.

Conclusion

The present cephalometric study evaluated the patients with class III skeletal deformities that underwent orthognathic surgery and the following results were obtained: Soft palate morphology was changed after class III surgeries. Palatal length was increased after maxillary advancement or bimaxillary surgery whereas its depth was increased after mandibular setback or bimaxillary surgery.

Acknowledgment

This manuscript has been derived from postgraduate thesis, No, 1262, Shiraz University of Medical Sciences, Dental Faculty.

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