CHANGES IN HYOID BONE AND TONGUE POSITIONS, AND ORAL CAVITY VOLUME AFTER MANDIBULAR SETBACK BY SAGITTAL SPLIT RAMUS OSTEOTOMY

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Abstract

Purpose: This retrospective study evaluated the changes in hyoid bone and tongue positions as well as oral cavity volume after mandibular setback by BSSRO.

Materials and Methods: 18 Koreans who underwent BSSRO to correct mandibular prognathism were studied. Lateral cephalograms were taken and traced preoperatively (T0), immediately (T1) and approximately 6 months postoperatively (T2). Submentovertex radiograghs were taken and traced before surgery (T0) and about 6 months after surgery (T2). The area and volume of oral cavity, the vertical and horizontal dimensions of the hyoid bone and tongue dorsum were measured.

Results: Mandibular setback surgery resulted in a significant reduction of lower oral cavity volume. The hyoid bone displaced posteroinferiorly immediately after surgery, and it tended to return to its original vertical position at 6 month after mandibular setback by BSSRO. The retropalatal space around tongue was maintained and the retrolingual space around tongue was reduced immediately postoperatively. The re-adaptation of tongue was not evident for that the follow up period was not long enough. No significant statistical correlations between the amounts of mandibular setback and the changes of oral cavity volume were observed.

Conclusion: Mandibular setback surgery resulted in a significant reduction of lower oral cavity volume, which was most likely attributable to the posterior movement of the mandible. More subjects and long-term observations should be performed to assess the changes of oropharyngeal configuration following mandibular setback surgery.

Key words: Oral cavity volume changes, Hyoid bone & tongue positions, Mandibular setback surgery(BSSRO)

Ⅰ. INTRODUCTION

Since sagittal split ramus osteotomy (SSRO) was introduced as a means of correcting dentofacial deformities involving mandible, this important surgical procedure has gained much popularity, especially after several modifications. The correction of Class III skeletal malocclusions has been one of the most difficult problems confronting orthodontics, because acceptable treatment results cannot be obtained by orthodontic treatment alone in patients with marked skeletal mandibular prognathism. Therefore, treatment combining mandibular surgery with orthodontics is often necessary. About 9% of the orthodontic patients have been reported to be severe enough to benefit from mandibular setback surgery[1)]. Surgical orthodontic treatment changes dentofacial skeletal and soft tissue components, though tongue position and function compensate for those changes in the oral environment[2)].

In previous studies, the changes in hyoid bone, tongue and pharyngeal airway space(PAS) following mandibular setback have been described in detail[1-17]. It should be taken attention that there are conflicting views on the degree and duration of the postoperative changes in the tongue, hyoid bone positions and PAS reduction. Several studies suggested that the changes are permanent in the long term[4-9], while some other studies suggested that the changes are temporary as a result of the re-adaptation[2,3,10-13].

It has been suggested that patients treated with mandibular setback surgery might suffer from obstructive sleep apnea (OSA) in the future[15,18,19]. Obstructive sleep apnea is considered as a potential risk factor for systemic and pulmonary hypertension and cardiac arrhythmias and may increase morbidity and mortality. Hoekema et al[20] suggested that pharyngeal airway narrowing might be a reason for OSA. This potential life-threatening complication provoked much interest on the changes of PAS after mandibular setback surgery. Several studies mentioned that the oral cavity volume was reduced after mandibular setback surgery[21-23]. Lew[21] showed that it is likely that mandibular setback surgery, which decreases the size of the oral cavity, may encroach on the tongue space despite the normal size of the tongue.

How about the effect of mandibular setback surgery on oral cavity, hyoid bone and tongue? The purpose of this study was to evaluate the changes in hyoid bone and tongue positions as well as oral cavity volume associated with mandibular setback by bilateral sagittal split ramus osteotomy (BSSRO).

Ⅱ. MATERIALS AND METHODS

1. Subjects

A total of 18 Korean subjects who underwent BSSRO combined with orthodontic treatment to correct mandibular prognathism between March 2007 and February 2009 in Dental Hospital of Kyungpook National University were studied. There were 7 females and 11 males, with a mean preoperative age of 22.7 years (range from 18 to 32 years). Patients who underwent bimaxillary surgery and/or those with a craniofacial anomaly, such as cleft lip, cleft alveolar and cleft palate, were excluded.

All of the osteotomies were performed by one experienced operator with modified BSSRO. After setback of the mandible, all patients underwent semirigid internal fixation with one plate and four 5 mm monocortical screws for each side. The amount of mandibular setback was determined by the need to gain a proper anteroposterior relationship of both jaws, which was measured in millimeters. The average of the amount of mandibular setback was about 8.61±3.21 mm. Intermaxillary fixation was performed immediately after surgery and maintained for 10 days with wires or elastics. Then the patients were educated to perform physical training during 6 or 8 weeks period. All of the subjects received pre and postoperative orthodontic treatment.

2. Lateral cephalometric and submentovertex analysis

Lateral cephalograms were taken preoperatively (T0), immediately (T1) and approximately 6 months postoperatively (T2). Submentovertex (SMV) radiographs were taken before surgery (T0) and about 6 months after surgery (T2). All the radiographs were taken by a standard technique with the jaws in centric relationship. The digital films were exposed during relaxed tidal breathing after swallowing. All radiographs were traced randomly with dates covered by the same examiner to eliminate bias, and the traditional contours and points of dentofacial structure were digitized to enable measurements of the hyoid bone and tongue positions as well as oral cavity volume (Fig.1).

The following landmarks in Fig. 1 were used for analysis:

On lateral cephalograms, the basic horizontal reference was Frankfurt horizontal (FH) plane, which was confirmed as X axis. And the basic vertical reference was porion vertical (PRV) plane, which was confirmed as Y axis. 4 linear, 3 area and 3 volume measurements were analyzed.

The position of hyoid bone was determined in the vertical and sagittal planes. The perpendicular distance from the most anterosuperior point of the hyoid bone (H) to FH plane (H-FH) was measured of the vertical dimension of the hyoid bone, and the perpen-

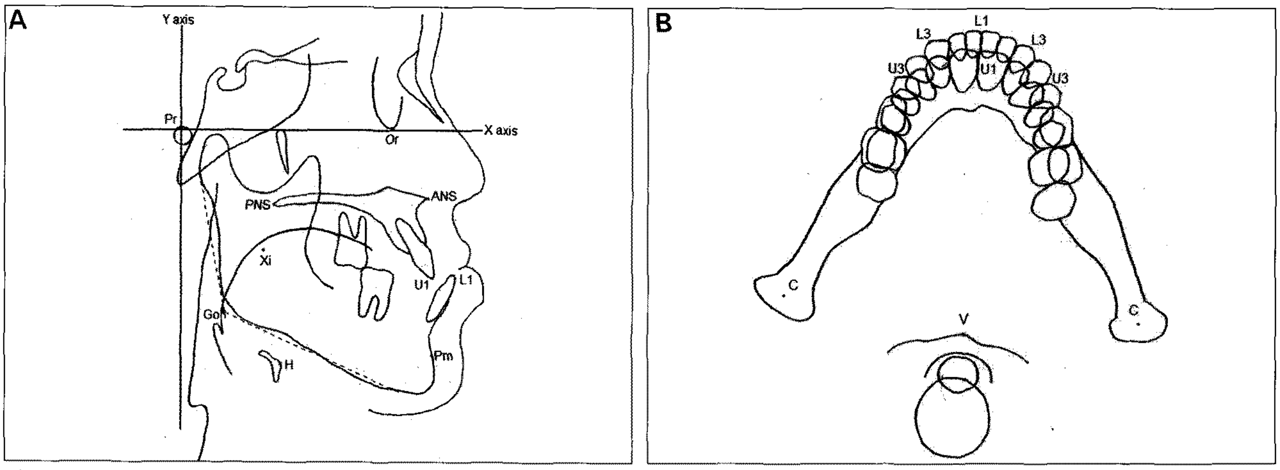

Fig. 1. Landmarks and linear measurements on lateral cephalograms (A) and landmarks on submentovertex views (B).

(A) Landmarks and linear measurements on cephalometric lateral view:
FH (Frankfurt Horizontal plane : X axis) : Anatomic porion(Pr)-orbitale(Or) plane
PRV (Porion Vertical Plane : Y axis) : The vertical plane that runs through porion (Pr) point and perpendicular to FH plane
ANS (anterior nasal spine) : Apex of the anterior spine
PNS (posterior nasal spine) : Apex of the posterior spine
U1: The midpoint of the distance between the left upper incisor tip and right upper incisor tip
L1: The midpoint of the distance between the left lower incisor tip and right lower incisor tip
Pm (protuberance menti) : The top point of the crest of the bony cortex in the outline of the symphysis in the area of the mental protuberance
Go (Gonion) : The point located by bisecting the angle formed by tangents to the posterior border of the ramus and inferior border of the mandible
Xi (centroid of the ramus, Ricketts' analysis) : The halfway point between the lowest point of the sigmoid notch and a point immediately inferior to it on the lower border of the ramus in the Frankfurt horizontal orientation
H : The most superoanterior point of hyoid bone

(B) Landmarks on Submentovertex views:
U1 : The midpoint of the distance between the left and right upper incisor tip
U3 : The midpoint of upper canine tip
L1 : The midpoint of the distance between the left and right lower incisor tip
L3 : The midpoint of lower canine tip
C : The center point of condyle
V : The most anterior point of vertebra

dicular distance from H to PRV (H-PRV) was measured of the horizontal dimension of the hyoid bone. The position of tongue dorsum was also determined in the vertical and horizontal planes. The vertical distance (D1) between the dorsum of the tongue and posterior nasal spine (PNS) on a line perpendicular to the FH plane was measured, and the horizontal distance (D2) between dorsum of the tongue and posterior pharyngeal wall on a line parallel to FH that runs through gonion (Go) was measured.

The oral cavity was divided into 3 parts on cephalograms: S1 (upper oral cavity area), S2 (middle oral cavity area) and S3 (lower oral cavity area). Various points (ANS, Xi and U1) were pointed, forming the shaded area (S1) to be measured the upper oral cavity area on cephalograms (Fig. 2A). Points (Xi, L1 and P) were pointed, forming the area (S2) to be measured the middle oral cavity area. Points (P, L1 and Pm) were pointed, forming the area (S3) to be measured the lower oral cavity area. Various points (Xi, L1 and Pm) were pointed, forming the shaded area (S2 and S3) to be measured the middle and lower oral cavity area on cephalograms (Fig. 3A). Correspondingly, oral cavity space can be divided into 3 parts: V1 (upper oral cavity volume), V2 (middle oral cavity volume) and V3 (lower oral cavity volume).

On SMV views, the midpoint of the distance between left lower incisor tip and right lower incisor tip was confirmed as point L1 and the most anterior center point of vertebra was confirmed as point V. According to the same distance between L1 and P point ensured in lateral cephalograms, the P point was ensured again in the line through L1 and V on SMV views. The midpoint (L1) of the distance between the left lower incisor and right lower incisor

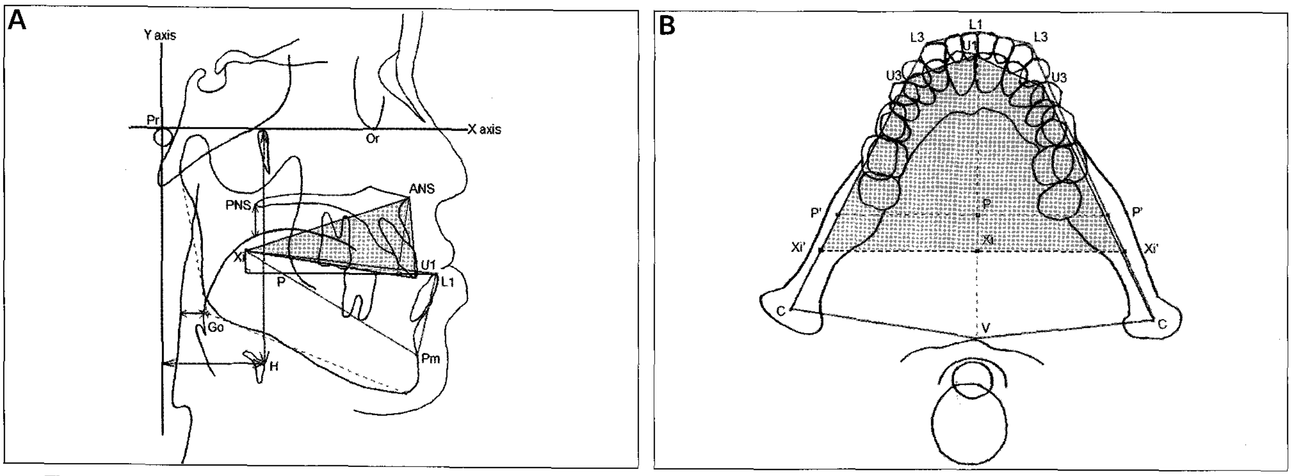

Fig. 2. The reference points and measurements on preoperative lateral cephalograms (A) and submentovertex views (B).

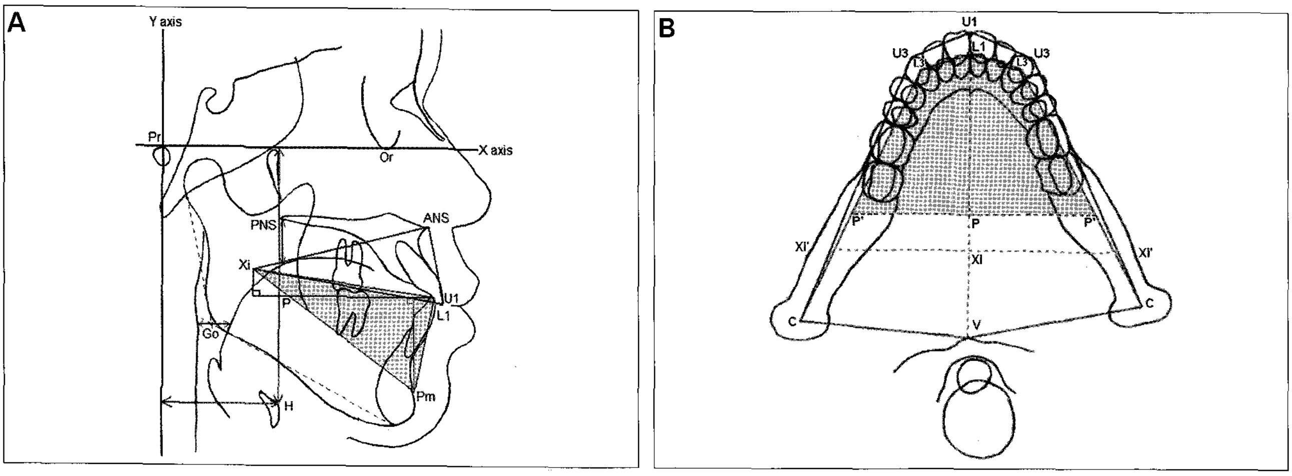

Fig. 3. The reference points and measurements on postoperative lateral cephalograms (A) and submentovertex views (B).

The reference points and measurements on lateral cephalograms (A) and submentovertex views (B) of preoperation (Fig. 2) and postoperation (Fig. 3).

(A) The reference points and measurements on preoperative and postoperative lateral cephalograms :

P point : The intersection of corpus axis (Xi-Pm)and the line that runs through L1 point paralleling to FH, which actually locates inferoanterior to the tongue base.

D1 : The vertical distance between the dorsum of the tongue and posterior nasal spine (PNS) on a perpendicular line of the FH plane.

D2 : The horizontal distance between dorsum of the tongue and posterior pharyngeal wall on a line parallel to FH that runs through gonion (Go).

H-FH : The vertical distances from the most anterosuperior point of the hyoid bone (H) to FH plane .

H-PRV : The horizontal distances from the most anterosuperior point of the hyoid bone (H) to PRV plane .

S1 (upper oral cavity area) : The area of the triangle formed by points of ANS, Xi and U1 (shaded area on Fig.2(A)).

S2 (middle oral cavity area) : The area of the triangle formed by points of Xi, P and L1.

S3 (lower oral cavity area) : The area of the triangle formed by points of P, L1 and Pm.

(B) The reference points and measurements on preoperative and postoperative submentovertex views:

P point : The intersection ensured in lateral cephalograms according to the same distance from L1 to P point in the line through L1 and V.

P' point: The intersection between the L3-C line and the line perpendicular to the L1-V line through P point.

Xi point : The intersection ensured in lateral cephalograms according to the same distance from L1 to P point in the line through L1 and V.

Xi' point : The intersection between the U3-C line and the line perpendicular to the U1-V line through Xi point.

S4 (upper oral cavity area on SMV): The area of the pentagon formed by points of U1, U3 on left side, U3 on right side, Xi' on left side and Xi' on right side (shaded area on Fig.2(B)).

S5 (lower oral cavity area on SMV): The area of the pentagon formed by points of L1, L3 on left side, L3 on right side, P' on left side and P' on right side (shaded area on Fig.3(B)).

point, the lower canine tip (L3) on left and right side and the P' point on left and right side formed a pentagon, which was taken as the base of the lower oral cavity. Similar with lower oral cavity, upper oral cavity base can be ensured on SMV views. The midpoint (U1) of the distance between the left upper incisor and right upper incisor, the upper canine tip (U3) on left and right side and the Xi' point on left and right side formed a pentagon, which was taken as the base of the upper oral cavity.

Various points (U1, U3 on left and right side and Xi' on left and right side) were pointed, forming the shaded area (S4) to be measured the upper oral cavity area on SMV views (Fig. 2B). Various points (L1, L3 on left and right side and P' on left and right side) were pointed, forming the shaded area (S5) to be measured the lower oral cavity area on SMV views (Fig. 3B).

Corresponding with the division of oral cavity area on lateral cephalograms, oral cavity space can be divided into 3 parts: V1 (upper oral cavity volume), V2 (middle oral cavity volume) and V3 (lower oral cavity volume). The following sketch map was formed to analyze the oral cavity volume (Fig. 4).

Various points (ANS, U1, Lt & Rt U3 and Xi' point on both sides) were pointed to measure the upper oral cavity volume (V1) in Fig. 4. Various points (L1, Lt & Rt L3, P' on both sides and Xi' on both sides) were pointed to measure the middle oral cavity volume (V2). Various points (Pm, L1, Lt & Rt L3, and P' on both sides) were pointed to measure the lower oral cavity volume (V3).

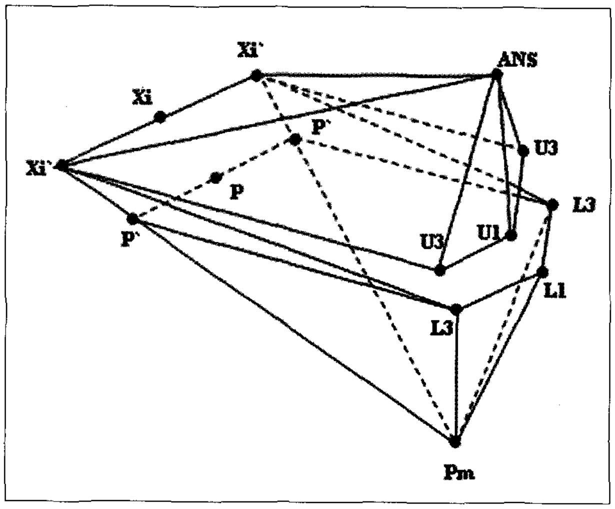

Fig. 4. The sketch map of oral cavity volume (The plane formed by the points of L1, Lt & Rt L3 and P' on both side was parallel to the FH plane).

3. Error at measuring and calculation

To evaluate measurement error, the records of the 18 patients were re-evaluated 1 month later. The mean differences were found less than 1.0 mm and 1.0°, respectively. The standard error of a single measurement was calculated for each variable and the systematic error was determined using paired t-tests. No significant systemic errors and an acceptable reliability were noted. The areas and volumes of upper oral cavity and lower oral cavity were calculated respectively by using mathematic method. With the support of mathematicians, a calculate method was developed specifically for this purpose according to some basic formulas ($V=1/3Sh$, Heron formula: $S=\sqrt{p(p-a)(p-b)(p-c)}$, $p=(a+b+c)/2$). Several points forming the oral cavity space were measured to determine the area in millimeter square (mm^2). Various points forming the oral cavity space were measured to determine the volume in millimeter cube (mm^3).

4. Statistical methods

Data were analyzed with paired t-test and Pearson correlation analysis using SPSS (Statistical Package for the Social Science) version 13.0 software program. The paired t-test was performed for comparisons of the differences between preoperative and postoperative variables. Pearson correlation analysis was used to determine the statistical correlation among preoperative measurements of the patients. Pearson correlation analysis was also used to evaluate the correlations among the amount of mandibular setback, the positional changes of hyoid bone and the tongue dorsum, and the changes in oral cavity area and oral cavity volume. Differences were considered to be significant at $p<0.05$.

Ⅲ. RESULTS

The preoperative (T0), immediate (T1) and late (T2) postoperative changes in linear and area measurements on lateral cephalograms were summarized in Table 1. The average of the amount of mandibular setback was 8.61±3.21 mm.

The vertical dimension of hyoid bone (H-FH) was increased from 86.58±9.20 mm to 91.39±9.32 mm in a manner corresponding with the earlier changes from T0 to T1, which suggested the hyoid bone displaced inferiorly significantly immediately after surgery ($p=0.002$). In a manner corresponding with the later changes from T1 to T2, the dimension of H-FH was reduced from 91.39±9.32 mm to 86.36±6.89 mm ($p=0.001$), which indicated the hyoid bone repositioned in its original vertical position at 6 months after surgery. The sagittal dimension of the hyoid bone (H-PRV) depicted by linear distance from the hyoid bone to the porion vertical plane was reduced from 42.67±7.85 mm to 38.22±7.97 mm in a manner corresponding with the earlier changes from T0 to T1 ($p=0.024$), which suggested the posterior movement of hyoid bone with significance. And the later change of H-PRV from T1 to T2 was not evident. The reduction of the sagittal dimension of the hyoid bone was significant ($p=0.011$) in the T0-T2 period.

The vertical distance (D1) between the dorsum of tongue and posterior nasal spine (PNS) on a line perpendicular to the FH plane was reduced from 13.86±4.73 mm to 13.56±3.20 mm ($p=0.743$), which indicated that the dorsum of tongue displaced to upward without significance in the early postoperative period. The distance of D1 was increased from 13.56±3.20 mm to 14.72±4.35 mm ($p=0.199$), which suggested that the dorsum of tongue displaced to downward without significance in the late postoperative period. The reduction of the horizontal distance (D2) between posterior pharyngeal wall and dorsum of the tongue on a line parallel to FH plane that runs through gonion (Go) point was 2.00±3.64 mm ($p=0.032$), which indicated the dorsum of tongue displaced posteriorly significantly and the horizontal dimension of PAS was reduced in the early postoperative period. The increase of D2 was 0.28±3.70 mm ($p=0.749$), which suggested the anterior displacement of tongue dorsum was not significant in the late postoperative period.

Also, the preoperative (T0), immediate (T1) and late postoperative (T2) changes in area measurements on lateral cephalograms were summarized in Table 1. The middle oral cavity area (S2) was significantly reduced from 282.82±91.63 mm^2 to 201.90±58.25 mm^2 in the T0-T1 period ($p=0.001$), and it was significantly increased from 201.90±58.25 mm^2 to 225.80±74.38 mm^2 in the T1-T2 period ($p=0.044$). Significant reduction of middle oral cavity area was found in the T0-T2 period ($p=0.001$). The lower oral cavity area (S3) was reduced significantly from 879.31±135.11 mm^2 to 792.91±90.83 mm^2 ($p=0.001$) in the T0-T2 period. No significant changes of upper oral cavity area (S1) were found in the early or late postoperative period.

The preoperative (T0) and late postoperative (T2) changes in area and volume measurements were summarized in Table 2. The middle oral cavity area (S2) was reduced significantly from 282.82±91.63 mm^2 to 225.80±74.38 mm^2 ($p=0.001$), in a manner corresponding with the changes from preoperative and postoperative 6 months following mandibular setback. The reduction of middle oral cavity area took 20.16% of the preoperative middle oral cavity area. The lower oral cavity area (S3) was reduced significantly from 879.31±135.11mm^2 to 792.91±90.83 mm^2 ($p=0.001$), in a manner corresponding with the changes from preoperative and postoperative 6 months following mandibular setback. The reduction of lower oral cavity area took 16.42% of the preoperative lower oral cavity area. While no significant change of upper oral cavity area (S1) was observed.

The upper oral cavity area on SMV (S4) was reduced significantly from 3978.18±545.52 mm^2 to 3689.01±325.73 mm^2 ($p=0.018$), in a manner corresponding with the changes from preoperative and postoperative 6 months following mandibular setback. The reduction of S4 took 7.27% of the preoperative upper oral cavity area on SMV views. The lower oral cavity area on SMV (S5) was reduced significantly from 2912.89±451.50 mm^2 to 2402.08±303.82 mm^2 ($p=0.001$), in a manner corresponding with the changes from preoperative and postoperative 6 months following mandibular setback. The reduction of S5 took 17.54% of the preoperative lower oral cavity area on SMV views.

The lower oral cavity volume (V3) was decreased significantly from 31589.82±6486.35 mm^3 to 26719.41±3542.59 mm^3 ($p=0.001$), in a manner corresponding with the changes from preoperative and postoperative 6 months following mandibular setback. The reduction of lower oral cavity volume (V3) took 15.42% of the original lower oral cavity volume. The reduction of upper oral cavity volume (V1) took 3.40% of the original upper oral cavity volume ($p=0.130$) and the reduction of middle oral cavity volume (V2) took 2.77% of the original middle oral cavity volume ($p=0.611$), however, there were no significances.

The correlations test among preoperative measurements were shown in Table 3, which showed that the horizontal dimension of retrolingual space around tongue (D2) correlated with the horizontal distance from hyoid bone to PRV plane (H-PRV); S1 correlated with S4; S5 correlated with S2 and S3; V1 correlated with S1, S4 and S5; V2 correlated with S1 and S2; V3 correlated with S1, S3, S5 and V1.

The correlations were shown in Table 4, and we found a slight statistical correlation between mandibular setback amount and the vertical positional changes of the hyoid bone (H-FH), while no significant correlations were noted between the amount of mandibular setback and the changes in sagittal position of the hyoid bone (H-PRV). No significant correlations were observed between the amount of mandibular setback and the changes in vertical position (D1) of the tongue dorsum or between the amount of the mandibular setback and the changes in sagittal position (D2) of the tongue dorsum.

The correlation analysis among the amount of mandibular setback and the changes of oral cavity area and oral cavity volume was shown in Table 5, and we found that the change of S1 correlated with the change of V1; the change of S2 correlated with

Table 1. Comparison of measurements between pre- and postoperative measurements.

Variables	T0		T1		T2		p value		
	Mean	SD	Mean	SD	Mean	SD	T0-T1	T1-T2	T0-T2
D1	13.86	4.73	13.56	3.20	14.72	4.35	.743	.199	.304
D2	13.31	4.66	11.31	4.18	11.59	2.63	.032*	.749	.087
H-FH	86.58	9.20	91.39	9.32	86.36	6.89	.002**	.001**	.865
H-PRV	42.67	7.85	38.22	7.97	38.18	4.78	.024*	.981	.011*
S1	924.09	130.92	936.21	92.69	930.22	112.18	.517	.672	.626
S2	282.82	91.63	201.90	58.25	225.8	74.38	.001**	.044*	.001**
S3	879.31	135.11	834.94	123.15	792.91	90.83	.345	.305	.001**

D1 : vertical distance between dorsum of the tongue and PNS on a line perpendicular to FH;
D2 : horizontal distance between posterior pharyngeal wall and dorsum of the tongue on a line parallel to FH that through Go;
H-FH : hyoid bone position in the vertical plane;
H-PRV : hyoid bone position in horizontal plane.
* $p<0.05$ ** $p<0.01$

Table 2. Comparison of area and volume measurements between pre- and postoperative 6 months.

Variables	T0		T2		p value
	Mean	SD	Mean	SD	
S1	924.09	130.92	930.22	112.18	.626
S2	282.82	91.63	225.80	74.38	.001**
S3	879.31	135.11	792.91	90.83	.001**
S4	3978.18	545.52	3689.01	325.73	.018*
S5	2912.89	451.50	2402.08	303.82	.001**
V1	29463.69	4526.00	28462.20	3527.93	.130
V2	9146.26	3009.95	8892.90	2732.48	.611
V3	31589.82	6486.35	26719.41	3542.59	.001**

* $p<0.05$ ** $p<0.01$

Table 3. Correlations among the measurements in preoperative patients.

Variables		D1	D2	H-FH	H-PRV	S1	S2	S3	S4	S5	V1	V2	V3
D1		1											
D2	r	.260	1										
	p	.297											
H-FH		.447	.120	1									
		.063	.634										
H-PRV		.035	.657**	.138	1								
		.892	.003	.585									
S1		.280	.274	.353	-.046	1							
		.261	.271	.151	.857								
S2		.115	.371	.074	-.225	.283	1						
		.649	.130	.770	.369	.255							
S3		-.054	-.180	-.067	.093	.466	-.186	1					
		.831	.475	.791	.713	.051	.460						
S4		.197	-.018	.129	.267	.647 **	.139	.427	1				
		.433	.945	.610	.285	.004	.583	.077					
S5		-.009	-.015	.022	-.098	.428	.504*	.735**	.435	1			
		.971	.953	.930	.698	.077	.033	.001	.071				
V1		.154	.202	.269	-.101	.909**	.157	.404	.755**	.484*	1		
		.542	.422	.281	.691	.001	.534	.096	.001	.042			
V2		.138	.367	.242	-.152	.526*	.927**	-.102	.385	-.345	.437	1	
		.585	.134	.333	.548	.025	.001	.688	.115	.161	.070		
V3		.024	-.013	.084	-.107	.652**	-.101	.911**	.464	.769**	.615**	.046	1
		.923	.958	.739	.672	.003	.690	.001	.052	.001	.007	.855	

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4. Correlation coefficients between the amount of mandibular setback and the positional changes of hyoid bone and dorsum of tongue.

Variables (T0-T2)		The Amount of Mandibular Setback
D1	r	.018
	p	.945
D2		.281
		.258
H-FH		.480*
		.044
H-PRV		.013
		.958

*correlation is significant at the 0.05 level (2-tailed).

the changes of S3, S5 and V2; the change of S3 correlated with the changes of S5, V1 and V3; the change of S4 correlated with the change of V1; the change of S5 correlated with the change of V3. However, we didn't find significant correlations between the mandibular setback amount and the changes of oral cavity area or oral cavity volume.

Ⅳ. DISCUSSION

Many investigations showed that the hyoid bone displaced posteroinferiorly and the dimensions of the retrolingual space around tongue and PAS were reduced after mandibular setback surgery[1-17]. But mentioned long term changes, there are conflicting opinions on the degree and duration of the postoperative displacement of the hyoid bone.

Some studies showed the changes were stable in the long-term period[4-9], however, other studies indicated that the hyoid bone and the tissues tended to return to its original position in the long-term period[2,3,10-13]. The changes are just temporary during the early postoperative period (most studies used 1 month as a settle), and then the tissues re-adapted in the long term period (most studies used 1 year as a settle), resulting in partial or total resolution. Kawakami et al[13] described initial downward displacement of the hyoid bone which went back to normal after 1 year. The present study showed that the

Table 5. Correlations among the amount of mandibular setback and the changes of oral cavity area and volume.

Variables		Setback Amount	S1	S2	S3	S4	S5	V1	V2	V3
Setback	r	1								
Amount	p									
S1		.052	1							
		.837								
S2		.451	-.041	1						
		.060	.871							
S3		.008	.391	-.574*	1					
		.974	.108	.013						
S4		.201	.425	-.001	.446	1				
		.423	.078	.996	.063					
S5		.031	.426	-.494*	.723**	.254	1			
		.903	.078	.037	.001	.309				
V1		.466	.680**	-.319	.501*	.723**	.411	1		
		.051	.002	.198	.034	.001	.090			
V2		.118	.122	.845**	-.406	.194	-.378	-.006	1	
		.641	.630	.001	.094	.440	.122	.980		
V3		.069	.454	-.449	.670**	.153	.869**	.324	-.27	1
		.787	.058	.062	.002	.545	.001	.189	.279	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

hyoid bone moved posteroinferiorly immediate after surgery, which indicated by the significant increase of H-FH and significant reduction of H-PRV from T0 to T1. Then the hyoid bone repositioned upwardly at 6 months after surgery, which indicated by the significant reduction of H-FH from T1 to T2. No significant change of H-PRV was found from T1 to T2. Even though we chose 6 months after surgery to let this settle, the hyoid bone have re-adapted and tended to return to its original vertical position 6 months after surgery. In the early postoperative period, the hyoid bone moved inferiorly for that a reflex alteration took place both in the pharyngeal muscular mechanism and in the suprahyoid and infrahyoid muscles after surgery. Mandibular setback leads to backward displacement of the mandibular body, with its anterior attachment of the suprahyoid muscles, and this condition gives rise to change in the hyoid bone position. Tselnik and Pogrel[15] described that the inferior movement of the hyoid bone was an adaptation preventing an encroachment of the tongue into the pharyngeal airway in the early postoperative period. Saitoh[12] revealed that the upward repositioning of the hyoid bone occurred late postoperatively and was related to the narrowed airway space at the tongue base, which explains the subsequent physiological adaptation of the dentofacial structures following surgery.

Several studies indicated that the retropalatal space around tongue was maintained, the retrolingual space around tongue was reduced and the pharyngeal airway space was narrowed after mandibular setback surgery[2,3,6,13,17]. A similar observation was made in this study: the retropalatal space around the tongue dorsum was maintained in the early postoperative period, which indicated by the no significant increase of D1 from T0 to T1; the retrolingual space around the tongue dorsum was reduced significantly, which indicated by the significant reduction of D2 from T0 to T1. In the late postoperative period, the dimension of D1 was increased but with no significance, which suggested that the dorsum of the tongue may re-adapt to the reduced oral cavity volume and the narrowness of upper airway space. Most studies let 1 year as a long term settle, while the present study use 6 month as a settle. Therefore, long term observation should be performed to assess the changes of oropharyngeal configuration after mandibular setback surgery. It should be taken our attention that Kawakami et al[13] confirmed that the vertical and horizontal spaces around the tongue were maintained postoperatively with the downward movement of the hyoid bone to compensate for the reduced oral volume caused by the mandibular setback. However, maintenance of the retrolingual space differed from the findings of previous studies and may have been a result of the bony fixation method employed. The rigid bicortical fixation with screws used in their study offers superior stabilization of bony segments when compared with wire fixation. Following screw fixation the retrolingual space was maintained.

Some studies indicated a reduction of oral cavity volume after mandibular setback to correct skeletal class III deformity[13,21-23] showed that it is likely that mandibular setback surgery, which decreases the size of the oral cavity, may encroach on the tongue space despite the normal size of the tongue. Park and Kim[22] suspected that the narrowing of the oropharyngeal airway space and posterior movement of the upper tongue posture had an influence on maintaining the total volume of oral cavity against mandibular setback. Kawakami et al[13] described that shortly after mandibular setback the hyoid bone goes downward for physiologic adaption to the soft tissue, including the tongue mass, and the altered tongue posture in the reduced oral cavity volume prevents airway obstruction. Lye[23] described that movement of the jaws will result in positional changes of the structures directly attached to the bone and changes in the tension of the attached soft tissue and muscle, and consequently, an alteration in the volume of the nasal and oral cavity and PAS dimensions depending on the direction and magnitude of the skeletal movements associated with orthognathic surgery.

In this study, we calculated the area and volume of the upper oral cavity, middle oral cavity and lower oral cavity respectively. A statistical significant reduction of middle oral cavity area (S2) on lateral cephalograms was observed at 6 months after mandibular setback, while the alteration of middle oral cavity volume (V2) was not significant. The reduction of S2 was most likely attributable to the reduction of the height of the triangle Xi-P-L1 that depicted by the distance from Xi point to the P-L1 line. The reduction of lower oral cavity area (S3) on lateral cephalograms and lower oral cavity volume (V3) was significant at 6 months after mandibular setback, which may due to the posterior movement of the mandible. The changes of upper oral cavity area (S1) on lateral cephalograms and upper oral cavity volume (V1) were not significant, while the reduction of upper oral cavity area on SMV views (S4) was significant following 6 months after mandibular setback surgery. The reduction of S4 may attribute to the improvement in the upper dentition of orthodontic treatment. A significant reduction of lower oral cavity area on SMV (S5) and lower oral cavity volume (V3) was confirmed at 6 months after mandibular setback surgery. The lower oral cavity volume (V3) reduction took 15.42% of original lower oral cavity volume, while the reduction of upper oral cavity volume (V1) took 3.40% of original upper oral cavity volume and the reduction of middle oral cavity volume (V2) took 2.77% of original middle oral cavity volume. The reduction of upper oral cavity volume (V1) and middle oral cavity volume (V2) was not significant. The whole oral cavity reduction took 8.73% of the original whole oral cavity volume. The present study demonstrated that mandibular setback surgery results in a significant reduction of lower oral cavity volume, which was most likely attributable to the posterior movement of the mandible. Mandibular setback surgery for improving of dentofacial outlook displaced the skeleton and altered the associated soft tissues. The hyoid bone, tongue and associated muscles were attached directly or indirectly to the maxilla and the mandible, which indicated that movement of the jaws would result in positional changes of the structures directly attached to the bone and changes in the tension of the attached soft tissue and muscle. This will result in an alteration in the volume of oral cavity depending on the direction and magnitude of the skeletal movements.

This also explained the correlation among the preoperative measurements in Table 3, which showed that the horizontal dimension of retrolingual space around tongue (D2) correlated with the horizontal distance from hyoid bone to PRV plane (H-PRV); S1 correlated with S4; S5 correlated with S2 and S3; V1 correlated with S1, S4 and S5; V2 correlated with S1 and S2; V3 correlated with S1, S3, S5 and V1 in preoperative patients. The posterior displacement of mandible following mandibular setback surgery would result in positional changes of the structures directly attached to the bone and changes in the tension of the attached soft tissue and muscle. Then the oral cavity area and volume would be influenced.

Güven and Saracoglu[9] have reported that no statistically significant correlation was found between the amount of mandibular setback and the changes in sagittal position of hyoid bone or between the amount of mandibular setback and the changes in vertical position of the hyoid bone following mandibular setback. In this study, a statistical correlation between mandibular setback amount and the changes in vertical position of the hyoid bone (H-FH) was found in Table 4, while no significant correlations were noted between the amount of mandibular setback and the changes in sagittal position of the hyoid bone (H-PRV). No significant correlation were observed between the amount of mandibular setback and the changes in vertical position (D1) of the tongue dorsum as well as the amount of the mandibular setback and the changes in sagittal position (D2) of the tongue dorsum.

Lee KH et al[24] showed that a significant correlation between ANS-Xi-PM area and location of dorsum of tongue in pre-operative patients, but they didn' t find any significant differences between preoperative and postoperative ANS-Xi-PM area. In the present study, the correlation test in Table 5 revealed that the change of upper oral cavity volume (V1) correlated with the change of upper oral cavity area (S1) on lateral cephalograms and upper oral cavity (S4) on SMV views; the change of middle oral cavity volume (V2) correlated with the changes of middle oral cavity area (S2) on lateral cephalograms; the change of lower oral cavity volume (V3) correlated with the changes of lower oral cavity area (S3) on lateral cephalograms and lower oral cavity area (S5) on SMV views. However, we didn' t find any significant correlations between the mandibular setback amount and the changes of oral cavity area or oral cavity volume. Though the lower oral cavity volume reduction did not correlate statistically with the setback amount, the reduction was great significant.

Multiple imaging techniques include cephalometry, computed tomography (CT), magnetic resonance imaging (MRI), and fluoroscopy. Theoretically, other techniques would be more useful than cephalometry, but cephalometric radiographs are easy and quick to perform, noninvasive, and of low cost. Therefore, cephalometric radiography was chosen in this study. If the economic conditions were permitted, evaluation of oral cavity size using 3-D CT should be performed deeply.

Ⅴ. CONCLUSION

The hyoid bone displaced posteroinferiorly during immediate postoperative period, and it tended to return to the original vertical position for adaptation to the altered environment after 6 months following mandibular setback surgery by bilateral sagittal split ramus osteotomy (BSSRO). The retropalatal space around tongue was maintained and the retrolingual space around tongue was reduced immediately postoperatively. The re-adaptation of tongue was not evident for that the follow up period was not long enough. Mandibular setback surgery resulted in a significant reduction of lower oral cavity volume, which was most likely attributable to the posterior movement of the mandible.

No significant statistical correlations between the amounts of mandibular setback and the changes of oral cavity volume were observed. More subjects and long-term observations should be performed to assess the changes of oropharyngeal configuration following mandibular setback surgery.

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