Original Article

Changes of Hyoid, Tongue and Pharyngeal Airway after Mandibular Setback Surgery by Intraoral Vertical Ramus Osteotomy

Soonshin Hwang[a]; Chooryung Judi Chung[b]; Yoon-Jeong Choi[c]; Jong-Ki Huh[d]; Kyung-Ho Kim[e]

ABSTRACT

Objective: To assess changes in hyoid, tongue, pharyngeal airway, and head posture in patients who had mandibular setback surgery by intraoral vertical ramus osteotomy (IVRO) and to investigate the influence of LeFort I osteotomy.

Materials and Methods: Sixty patients with skeletal Class III malocclusion were evaluated. All patients had mandibular setback surgery via IVRO, and 45 patients had additional maxillary impaction surgery via LeFort I osteotomy. Lateral cephalograms were taken before, immediately after, approximately 1 month after, and at least 1 year after surgery. Parameters indicating the hyoid, tongue, pharyngeal airway, and head posture were evaluated.

Results: The hyoid significantly moved inferoposteriorly immediately after surgery and relapsed superoanteriorly during observation periods. The tongue significantly moved posteriorly during all periods. The final position of the hyoid and tongue was significantly posterior, and the final pharyngeal airway was significantly narrower compared with its presurgical position. Significant cervical hyperflection occurred during observation periods and was strongly correlated with anterior movement of the hyoid. The hyoid and tongue showed similar positions regardless of the presence of different genders or LeFort I osteotomy after the long-term observation period.

Conclusions: The hyoid and tongue moved posteriorly after mandibular setback surgery via IVRO, and there was a tendency to relapse back to its original position. However, the final pharyngeal airway width remained narrower after the long-term observation period. Based on our results, careful monitoring of the airway may be needed after mandibular setback surgery via IVRO. (*Angle Orthod.* 2010;80:302–308.)

KEY WORDS: Hyoid; Tongue; Pharyngeal airway; Mandibular setback; Intraoral vertical ramus osteotomy

INTRODUCTION

Orthognathic surgery is a common treatment for patients with severe mandibular prognathism, but the mandibular osteotomy may influence functional soft tissue components including the tongue and pharyngeal airway. Several studies have shown changes in the tongue, hyoid, pharyngeal airway, and head posture following mandibular setback surgery.[1–4]

The tongue has been reported to move posteriorly after mandibular setback surgery, causing encroachment into the airway.[1–3] As a compensatory reaction to maintain adequate airway, extension of the head has been noted after mandibular setback surgery.[3,4]

[a] MS Student, Department of Orthodontics, Gangnam Severance Dental Hospital, College of Dentistry, Institute of Craniofacial Deformity, Oral Science Research Center, Yonsei University, Seoul, South Korea.

[b] Assistant Professor, Department of Orthodontics, Gangnam Severance Dental Hospital, College of Dentistry, Institute of Craniofacial Deformity, Oral Science Research Center, Yonsei University, Seoul, South Korea.

[c] Lecturer, Department of Orthodontics, Gangnam Severance Dental Hospital, College of Dentistry, Institute of Craniofacial Deformity, Oral Science Research Center, Yonsei University, Seoul, South Korea.

[d] Associate Professor, Department of Oral and Maxillofacial Surgery, Gangnam Severance Dental Hospital, College of Dentistry, Institute of Craniofacial Deformity, Oral Science Research Center, Yonsei University, Seoul, South Korea.

[e] Professor, Department of Orthodontics, Gangnam Severance Dental Hospital, College of Dentistry, Institute of Craniofacial Deformity, Oral Science Research Center, Yonsei University, Seoul, South Korea.

Corresponding author: Dr Kyung-Ho Kim, Department of Orthodontics, Gangnam Severance Dental Hospital, College of Dentistry, Institute of Craniofacial Deformity, Oral Science Research Center, Yonsei University, 146-92 Dogok-Dong, Gangnam-Gu, Seoul, 135-720 South Korea
(e-mail: khkim@yuhs.ac)

Accepted: July 2009. Submitted: April 2009.

Tongue position and its effect on the airway can be analyzed more accurately by evaluating the hyoid position.[2,5,6] The hyoid is unique in that it does not articulate with any other bone and its position is determined by many muscles and ligaments.[7] The hyoid has been reported to move inferoposteriorly immediately after mandibular setback surgery and return close to its initial position during retention periods.[4–6,8,9]

However, many of the previous studies are focused on the skeletal and soft tissue changes after mandibular setback surgery via sagittal split ramus osteotomy (SSRO). Intraoral vertical ramus osteotomy (IVRO) is another frequently used surgical method to correct mandibular prognathism. This procedure has many advantages over SSRO, such as a lower incidence of injury to the inferior alveolar nerve, technical simplicity, reduced surgical time, and ability to obtain biologic equilibration of the condyle.[10–12] However, proximal and distal mandibular segments after IVRO are not rigidly stabilized and are only overlapped to freely move and heal accordingly. This healing concept may have troubled surgeons and orthodontists in terms of stability and could have attributed to its less popular usage compared to SSRO.[13] Nevertheless, recent study indicates that the skeletal stability after IVRO is equal to that of SSRO.[14]

IVRO exhibits a different short- and long-term skeletal relapse pattern compared to SSRO. Due to differences in stabilization, healing, and relapse pattern after surgery, the hyoid and tongue position may exhibit different features after setback surgery by IVRO. Thus, the aim of this study was to assess changes in hyoid, tongue, pharyngeal airway, and head posture in patients who had mandibular setback surgery via IVRO and to investigate the influence of LeFort I osteotomy (1-jaw vs 2-jaw).

MATERIALS AND METHODS

Subjects

The sample consisted of 60 Korean patients (30 male, 30 female) with mandibular prognathism. All subjects were nongrowing adults, and the mean preoperative age was 23.1 years for male patients and 23.3 years for female patients. The subjects met the following inclusion criteria:

- All 60 patients had presurgical orthodontic treatment and mandibular setback surgery via IVRO. Of the total group, 45 patients had additional maxillary impaction surgery via LeFort I osteotomy. The surgical and orthodontic treatments were done at Gangnam Severance Dental Hospital, Yonsei University.
- All subjects were free of any craniofacial anomalies, syndromes, severe asymmetry, or clefting.

Surgical Technique

All patients had undergone bilateral IVRO performed by one oral surgeon. After completion of the mandibular split, the jaws were placed in a planned position by the acrylic surgical stent and stabilized with 0.125-mm intermaxillary stainless steel wire for the first 2 weeks and with elastics for the following 2 weeks. Postoperative orthodontic treatment started 4 weeks after surgery.

Cephalometric Analysis

Lateral cephalograms were taken with the same cephalostat (Orthopos, Siemens, Germany) in natural head position before (T1), immediately after (T2), approximately 1 month after (T3), and an average of 16.62 months after (T4) surgery with exposure values of 60 KVp, 10 mA, and 0.12 seconds. All subjects had standardized lateral cephalograms of adequate quality and resolution exposure in each observation stage. All cephalometric landmarks were pencil traced on acetate paper by the same investigator. All lines and angles were measured to the closest 0.01 mm and 0.1 degrees. Ten radiographs, chosen at random, were traced by the same investigator on two separate occasions at least 2 weeks apart. No significant difference was found when the repeat measurements were evaluated with paired *t*-tests.

A horizontal reference plane (HRP) was drawn by rotating 7 degrees clockwise to the sella-nasion line at sella and a vertical reference plane (VRP) was drawn perpendicular to this line at sella.

The hyoid position was determined by the perpendicular distances from the most superoanterior point of the hyoid (hyoidale) to HRP and VRP. Measurement from the hyoidale to the most posterior point of the mandibular symphysis (C point) was taken to represent the suprahyoid ligaments. The tongue position was determined by measuring a line from PNS to the dorsum of the tongue perpendicular to VRP (D1) and the shortest distance from basion to the most superoposterior point on the dorsum of the tongue (D2). Basion was used as a landmark because it has been used in several studies as a landmark for tongue or pharyngeal airway measurements.[3,15,16] The pharyngeal airway space was determined by measuring the distance between the tongue and the posterior pharyngeal wall at the inferior plane of the second cervical vertebra parallel to HRP. Odontoid process tangent (OPT) and cervical vertebral tangent (CVT) were measured as representative head posture

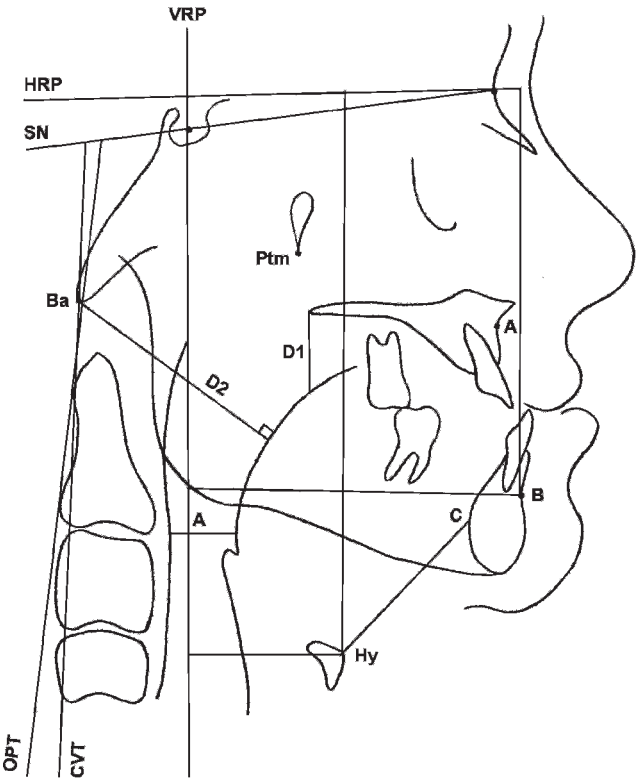

Figure 1. Cephalometric linear and angular measurements. (1) < SNA. (2) < SNB. (3) < ANB. (4) PNS-Ptm: closest distance between posterior nasal spine and pterygomaxillary fissure. (5) HRP-B: perpendicular distance from horizontal reference plane to B point. (6) VRP-B: perpendicular distance from vertical reference plane to B point. (7) HRP-Hy (hyoidale): perpendicular distance from HRP to hyoidale. (The hyoidale is the most superoanterior point of the hyoid.) (8) VRP-Hy: perpendicular distance from VRP to hyoidale. (9) Hy-C point: (most posterior point of mandibular symphysis). (10) D1: line parallel to VRP from PNS to dorsum of tongue. (11) D2: closest distance from basion to dorsum of tongue. (12) < SN-OPT: odontoid process tangent (Cv2ip-Cv2tg). (13) < SN-CVT: cervical vertebral tangent (Cv4ip-Cv2tg).

*Cv2ip indicates the most inferoposterior point of the body of second cervical vertebra; Cv2tg, tangent point at superoposterior extremity of the odontoid process of second cervical vertebra; Cv4ip: the most inferoposterior point on the body of fourth cervical vertebra.

variables[17] (Figure 1). Initial cephalometric parameters of the subjects are shown in Table 1. Parameters indicating the amount of surgical correction and its change during observation periods are shown in Table 2.

Statistics

All statistical analysis was done by the SAS 9.1 program (SAS institute, Cary, NC), and significance was assessed at $P < .05$ and $P < .01$. Time-dependent changes for all cephalometric variables were examined by a paired *t*-test. Independent *t*-tests were used to determine the difference in sex and surgical procedure (1-jaw vs 2-jaw). Pearson *r* correlation analysis was used to determine the strength of the relationship between head posture, hyoid, and tongue position.

Table 1. Presurgical Cephalometric Measurements of 1-Jaw and 2-Jaw Group[a]

Measurement, degrees	1-Jaw (n = 15)	2-Jaw (n = 45)
SNA	80.27 ± 3.20	80.03 ± 4.36
SNB	80.93 ± 2.84	82.40 ± 4.80
ANB	−0.67 ± 1.88	−2.19 ± 2.73
SN-MP	37.90 ± 4.58	38.13 ± 7.93

[a] SNA indicates angle between sella, nasion, and A point; SNB, angle between sella, nasion, and B point; ANB, angle between A point, nasion, and B point; SN, line from sella to nasion; and MP, mandibular plane.

RESULTS

Time-Dependent Change after Mandibular Setback via IVRO

Significant change in skeletal variables reflects the surgical change and relapse pattern after mandibular setback surgery via IVRO. The ANB angle significantly decreased, and the B point moved significantly superoposterior after surgery. The mandible measured from the B point continued to move posteriorly during the observation period (Table 2).

The HRP to hyoidale distance significantly increased after surgery and decreased during short- and long-term observation periods ($P < .01$). The VRP to hyoidale distance significantly decreased immediately after surgery and increased during short- and long-term observation periods ($P < .05$). This indicates that the hyoid showed significant inferoposterior movements immediately after surgery and significant superoanterior movements during short- and long-term observation periods ($P < .05$). The hyoid to C point distance increased significantly immediately after surgery but decreased significantly during short- and long-term observation periods ($P < .05$). The final hyoid bone was significantly posterior by 2.65 ± 14.34 mm, while the final hyoid to C point distance significantly decreased by 3.69 ± 7.46 mm.

The D1 and D2 distance decreased significantly during short- and long-term observation periods ($P < .05$), which indicates a superoposterior positioning of the tongue. The final D2 distance significantly decreased by 3.47 ± 5.62 mm compared with its initial position after the entire observation period (T4-T1) ($P < .05$).

The pharyngeal airway space significantly decreased during short- and long-term observation periods ($P < .01$). The final pharyngeal airway space was significantly narrower by 1.86 ± 2.25 mm compared with its initial width ($P < .01$).

Table 2. Postoperative (T2-T1), Short-term (T3-T2), Long-term (T4-T2), and Accumulative (T4-T1) Skeletal Change Due to Surgical Correction in Total Group[a]

	T2-T1			T3-T2			T4-T2			T4-T1		
Total Group	Mean	SD	Sig	Mean	SD	Sig	Mean	SD	Sig	Mean	SD	Sig
SNA, degrees	1.96	2.12	**	−0.21	1.29		−0.03	1.73		1.93	2.37	**
SNB, degrees	−3.40	2.59	**	−0.79	1.18	**	−0.43	1.46	*	−3.84	2.30	**
ANB, degrees	5.23	2.32	**	0.58	1.02	**	0.43	1.35	*	5.66	2.35	**
PNS-Ptm, mm	−3.55	3.34	**	−0.23	1.16		0.40	1.33	**	−3.15	3.39	**
HRP-B, mm	−3.20	2.71	**	0.18	1.34		−0.16	2.21		−3.36	13.15	
VRP-B, mm	−5.43	5.22	**	−2.14	2.85	**	−1.23	3.72	*	−6.65	4.68	**

[a] SD indicates standard deviation; Sig, significance; SNA, angle between sella, nasion, and A point; SNB, angle between sella, nasion, and B point; ANB, angle between A point, nasion, and B point; PNS, posterior nasal spine; Ptm, pterygomaxillary fissure; HRP, horizontal reference plane; and VRP, vertical reference plane.

* $P < .05$; ** $P < .01$.

The odontoid process tangent and cervical vertebral tangent significantly decreased immediately after surgery but significantly increased during short- and long-term observation periods ($P < .05$) (Table 3).

Horizontal movements of the hyoid represented by hyoidale to VRP distance showed a moderate correlation with both head posture angles (SN-OPT and SN-CVT), indicating that the hyoid moved more anterior as the head extended during short- and long-term observation periods (Table 4). There was no significant difference in gender for all variables (Table 5).

Comparison of 1-Jaw and 2-Jaw Surgery

Since LeFort I osteotomy in addition to mandibular setback surgery could affect the hyoid and tongue position, significant change of skeletal variables was evaluated separately in the 1-jaw and 2-jaw group for all periods. Changes in the SNA angle and PNS to Ptm distance were the only variables that showed significant skeletal difference between the 1-jaw and 2-jaw group (Table 6). Although additional posterior impaction of the maxilla was performed for the 2-jaw surgery group, the overall position of the B point relative to the VRP and HRP was similar and did not show statistical difference for the two groups.

Some variables showed significant differences between the 1-jaw and 2-jaw group. Nevertheless, there was no significant difference in accumulative change (T4-T1) for all variables of the hyoid, tongue, pharyngeal airway, and head posture between the 1-jaw and 2-jaw group (Table 7).

DISCUSSION

The hyoid moved inferoposteriorly immediately after mandibular setback via IVRO. This is in accordance with previous studies in that adequate postoperative airway was maintained by inferior movement of the hyoid.[2,6,9] The hyoid continued to relapse superoanteriorly returning close to its preoperative position and encroachment of tongue upon the airway was observed during observation periods. Similar results of the hyoid and tongue position were reported after mandibular setback surgery via SSRO.[2,3,8] Cervical hyperflection of the head posture has been noted as a compensatory reaction after mandibular setback surgery to maintain patent airway dimensions after

Table 3. Postoperative (T2-T1), Short-term (T3-T2), Long-term (T4-T2), and Accumulative Change (T4-T1) of the Hyoid Bone, Tongue, Pharyngeal Airway, and Head Posture in Total Group[a]

	T2-T1			T3-T2			T4-T2			T4-T1		
Total Group	Mean	SD	Sig	Mean	SD	Sig	Mean	SD	Sig	Mean	SD	Sig
HRP-Hy, mm	9.62	7.75	**	−7.44	5.27	**	−7.85	4.82	**	1.76	12.53	
VRP-Hy, mm	−4.85	7.14	**	2.19	6.21	**	2.20	6.41	*	−2.65	14.34	*
Hy-C, mm	1.85	6.61	*	−6.37	6.20	**	−5.53	5.77	**	−3.69	7.46	**
D1, mm	0.80	5.09		−1.31	4.63	*	−2.80	4.19	**	−2.00	5.03	
D2, mm	−1.96	4.19	**	−1.62	3.61	**	−1.51	3.56	**	−3.47	5.62	**
Airway, mm	−0.67	3.40		−1.63	3.25	**	−1.19	3.42	**	−1.86	2.25	**
SN-OPT, degrees	−3.35	7.03	**	2.33	6.41	**	1.98	6.59	*	−1.37	10.45	
SN-CVT, degrees	−3.99	7.51	**	2.58	6.30	**	2.57	6.94	**	−1.42	11.05	

[a] SD indicates standard deviation; Sig, significance; HRP, horizontal reference plane; VRP, vertical reference plane; Hy, hyoidale; C, most posterior point of mandibular symphysis; D1, line parallel to VRP from PNS to dorsum of tongue; D2, closest distance from basion to dorsum of tongue; OPT, odontoid process tangent; and CVT, cervical vertebral tangent.

* $P < .05$; ** $P < .01$.

Table 4. Correlation Between Head Posture and Position of the Hyoid Bone and Tongue for 1-Jaw and 2-Jaw Group[a]

	T2-T1 (*r*)				T3-T2 (*r*)				T4-T2 (*r*)			
	1-Jaw		2-Jaw		1-Jaw		2-Jaw		1-Jaw		2-Jaw	
	SN-OPT	SN-CVT	SN-OPT	SN-CVT	SN-OPT	SN-CVT	SN-OPT	SN-CVT	SN-OPT	SN-CVT	SN-OPT	SN-CVT
HRP-Hy, mm	−0.59*	−0.61*	−0.17	−0.12	−0.36	−0.41	−0.13	−0.13	−0.31	−0.32	−0.08	−0.04
VRP-Hy, mm	0.74**	0.84**	0.77**	0.82**	0.82**	0.87**	0.83**	0.84**	0.73**	0.80**	0.61**	0.64**
D1, mm	0.04	−0.06	−0.40**	−0.37*	0.04	−0.04	−0.16	−0.20	−0.44	−0.51	−0.37**	−0.34**
D2, mm	0.34	0.41	0.01	0.03	0.36	0.34	0.15	0.12	−0.32	−0.44	0.04	0.07

[a] HRP indicates horizontal reference plane; VRP, vertical reference plane; Hy, hyoidale; D1, line parallel to VRP from PNS to dorsum of tongue; and D2, closest distance from basion to dorsum of tongue.

* $P < .05$ (significant change per period); ** $P < .01$ (significant change per period); and *r*, Pearson correlation coefficient.

reduced oral volume.[4,8] The results from this study also support this finding in that cervical hyperflection represented by an increase in head posture angles (SN-OPT and SN-CVT) and anterior movement of the hyoid was moderately correlated for observation periods ($r > 0.60$), suggesting cervical hyperflection helped maintain adequate airway. However, in accordance with previous studies, the overall pharyngeal airway space decreased after mandibular setback surgery.[2,5,6] This implies that functional reorientation in soft tissue and adaptation of head posture to maintain adequate airway were similar in cases of mandibular setback surgery via IVRO and SSRO.

Significant constriction of pharyngeal airway space has been reported of patients with obstructive sleep apnea (OSA).[18] Also, posterior airway space of less than 10 mm on cephalometric radiography has been suggested as one of the main indications for surgical treatment of OSA.[19] In our study, the average pharyngeal airway width was 12.34 mm before surgery, and the pharyngeal airway space significantly decreased by an average of 1.86 mm after surgery. This could imply that even though the hyoid and head posture adjusted to maintain adequate airway, the pharyngeal airway space was significantly reduced in some cases to less than 10 mm, which could compromise adequate airway.

Several studies have analyzed the effect of hyoid position and suprahyoid musculature on skeletal relapse pattern after mandibular setback surgery. Gu et al[9] postulated that postoperative hyoid position after mandibular setback surgery may decrease the length and tension of the suprahyoid musculature, resulting in an anteriorly directed skeletal relapse pattern to return the muscles to their original resting tension. The mandible has been reported to relapse inferoposteriorly in cases of mandibular setback via IVRO.[20–22] In this study, the mandible continued to relapse posteriorly even though the hyoid relapsed superoanteriorly and the suprahyoid musculature, measured by the distance between the hyoidale to C point, significantly decreased during retention periods. This suggests that the hyoid position and suprahyoid musculature did not contribute to a change in skeletal relapse pattern in cases of mandibular setback surgery via IVRO.

In the present study, the only significant skeletal differences between the 1-jaw and 2-jaw group were the variables pertaining to the maxilla, which was a result of additional LeFort I osteotomy in the 2-jaw group. The position of the B point relative to the VRP

Table 5. Postoperative (T2-T1), Short-term (T3-T2), Long-term (T4-T2), and Accumulative (T4-T1) Changes of the Hyoid Bone, Tongue, Pharyngeal Airway, and Head Posture in Male and Female Subjects[a]

	T2-T1					T3-T2					T4-T2					T4-T1				
	Male		Female			Male		Female			Male		Female			Male		Female		
	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig
HRP-Hy, mm	10.78**	20.30	8.45**	5.25		−7.57**	4.66	−7.31**	5.90		−7.33**	4.63	−8.38**	5.03		3.46	9.07	0.07	4.03	
VRP-Hy, mm	−4.44**	6.61	−5.26**	7.73		2.20*	5.90	2.18	6.60		1.29	5.73	3.11*	7.02		−3.14**	3.95	−2.15*	4.85	
Hy-C, mm	2.43	7.00	1.26	6.25		−7.10**	6.26	−5.65**	6.16		−5.60**	5.32	−5.45**	6.28		−3.17**	4.56	−4.19**	4.62	
D1, mm	−0.99	4.37	2.58*	5.20		−0.69	4.46	−1.92*	4.78		−2.11*	4.29	−3.48**	4.05		−3.10**	3.62	−0.90	3.44	
D2, mm	−2.53**	4.05	−1.38	4.31		−1.18	3.57	−2.07**	3.66		−1.05*	2.94	−1.92*	4.10		−3.64**	3.52	−3.30**	3.16	
Airway, mm	−0.57	3.21	−0.77	3.62		−1.76*	3.69	−1.50**	2.82		−1.28	3.50	−1.10	3.39		−1.85**	2.45	−1.87**	2.08	
SN-OPT, degrees	−3.1*	6.29	−3.6*	7.80		2.37*	5.71	2.30	7.15		1.80*	4.85	2.17	8.04		−1.30	4.17	−1.43	4.69	
SN-CVT, degrees	−3.5**	6.61	−4.48**	8.41		2.50*	5.66	2.65*	6.98		2.30*	5.31	2.83	8.34		−1.20	4.16	−1.64	5.04	

[a] SD indicates standard deviation; Sig, significance; HRP, horizontal reference plane; VRP, vertical reference plane; Hy, hyoidale; C, most posterior point of mandibular symphysis; D1, line parallel to VRP from PNS to dorsum of tongue; D2, closest distance from basion to dorsum of tongue; OPT, odontoid process tangent; and CVT, cervical vertebral tangent.

* $P < .05$; ** $P < .01$; + $P < .05$ (significant difference between male and female subjects).

Table 6. Postoperative (T2-T1), Short-term (T3-T2), Long-term (T4-T2), and Accumulative (T4-T1) Skeletal Change Due to Surgical Correction in 1-Jaw and 2-Jaw Group[a]

	T2-T1					T3-T2					T4-T2					T4-T1				
	1-Jaw		2-Jaw			1-Jaw		2-Jaw			1-Jaw		2-Jaw			1-Jaw		2-Jaw		
	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig	Mean	S.D.	Mean	SD	Sig
SNA, degrees	0.20	1.01	2.54	2.07**	+	−0.27	1.28	−0.19	1.31		0.13	0.99	−0.09	1.92	+	0.33	1.40	2.46	2.40**	+
SNB, degrees	−2.87	1.51**	−3.58	2.86**		−0.53	1.19	−0.88	1.17**		−0.37	1.17	−0.46	1.56		−3.23	1.61	−4.04	2.47	
ANB, degrees	3.07	1.91**	5.95	1.98**		0.27	0.80	0.69	1.07**		0.50	1.12	0.41	1.43		3.57	1.84	6.36	2.08**	
PNS-Ptm, mm	−1.30	5.52	−4.30	1.72**	+	0.07	0.76	−0.34	1.25	+	0.26	0.63	0.45	1.49	+	−0.04	5.42	−3.85	2.01**	+
HRP-B, mm	−1.94	1.93**	−3.62	2.83**		0.75	1.32*	−0.01	1.30		0.04	1.59	−0.22	2.39		−1.91	2.93	−3.84	2.27	
VRP-B, mm	−3.48	4.99*	−6.08	5.18**		−2.75	2.86**	−1.93	2.85**		−1.73	4.10	−1.06	3.62		−5.2	3.76	−7.14	4.89**	

[a] SD indicates standard deviation; Sig, significance; SNA, angle between sella, nasion, and A point; SNB, angle between sella, nasion, and B point; ANB, angle between A point, nasion, and B point; PNS, posterior nasal spine; Ptm, pterygomaxillary fissure; HRP, horizontal reference plane; and VRP, vertical reference plane.

* $P < .05$; ** $P < .01$; + $P < .05$ (significant difference between 1-jaw and 2-jaw).

and HRP was similar for the 1-jaw and 2-jaw group for all periods. The overall change (T4-T1) of the hyoid, tongue, pharyngeal airway, and head posture were also similar for the two groups, which implies that in cases of comparable mandibular setback, additional LeFort I osteotomy does not affect the overall hyoid and tongue response. Kawakami et al[3] reported that mandibular setback amounts do not correlate with hyoid or tongue movement, which implies that in future studies of cases with different amounts of mandibular setback, additional LeFort I osteotomy should not affect the hyoid and tongue movement.

Cephalometric evaluation of the pharyngeal airway has been reported to provide a high correlation with actual volumes of pharyngeal airway.[23] The efficacy and reliability of lateral cephalometric radiographs in assessing pharyngeal airway have been stated as well.[24,25] Precautions were taken to include radiographs of adequate quality and resolution exposure, and all radiographs were taken in reproducible and unstrained position of the head since difference in head position may interfere with our outcome.

However, in a recent study using three-dimensional computed tomography (CT), lateral dimension of the pharyngeal airway has been shown as an important factor for OSA patients suggesting that a two-dimensional image of the pharyngeal airway in a sagittal direction may require careful interpretation.[26] A volumetric evaluation of the airway using three-dimensional CT would be an advancement for future functional studies to focus on.

CONCLUSIONS

- The hyoid bone moved inferoposteriorly following mandibular setback via IVRO but returned close to its initial preoperative position, and the tongue

Table 7. Postoperative (T2-T1), Short-term (T3-T2), Long-term (T4-T2), and Accumulative (T4-T1) Changes of the Hyoid Bone, Tongue, Pharyngeal Airway, and Head Posture in 1-Jaw and 2-Jaw Group[a]

	T2-T1					T3-T2					T4-T2					T4-T1				
	1-Jaw		2-Jaw			1-Jaw		2-Jaw			1-Jaw		2-Jaw			1-Jaw		2-Jaw		
	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig	Mean	SD	Mean	SD	Sig
HRP-Hy, mm	8.02**	3.32	10.15**	16.94		−6.72**	4.90	−7.68**	5.42		−6.74**	3.90	−8.22**	5.08		1.28	2.98	1.93	5.86	
VRP-Hy, mm	−3.95**	4.81	−5.15**	7.79		2.76*	4.80	2.00	6.65		0.96	3.45	2.62*	7.12	+	−3.00	2.87**	−2.53	4.84**	
Hy-C, mm	1.24	6.32	2.05*	6.76	+	−6.14**	5.31	−6.45**	6.53		−3.71**	4.36	−6.13**	6.10		−2.48	3.86*	−4.08	4.77**	
D1, mm	−0.89	4.49	1.36	5.20		−0.80	3.45	−1.48	4.98		−0.97	3.06	−3.41**	4.37	+	−1.86	2.86*	−2.05	3.93**	
D2, mm	−1.32	2.47	−2.17**	4.62	+	−1.25	2.28	−1.75**	3.97	+	−1.04	2.73	−1.67**	3.81		−2.36	2.86**	−3.84	3.40**	
Airway, mm	−0.32	3.23	−0.79	3.48		−1.69*	2.77	−1.61**	3.42		−1.24	3.79	−1.17	3.33		−1.56**	1.56	−1.96**	2.45	
SN-OPT, degrees	−1.73	6.97	−3.89**	7.04		2.00	5.95	2.44*	6.62		0.07	5.05	2.62*	6.96		−1.67	3.40	−1.27	4.72	
SN-CVT, degrees	−2.13	7.31	−4.61**	7.56		1.87	5.96	2.81**	6.46		0.40	5.42	3.29**	7.28		−1.73	3.90	−1.32	4.83	

[a] SD indicates standard deviation; Sig, significance; HRP, horizontal reference plane; VRP, vertical reference plane; Hy, hyoidale; C, most posterior point of mandibular symphysis; D1, line parallel to VRP from PNS to dorsum of tongue; D2, closest distance from basion to dorsum of tongue; OPT, odontoid process tangent; and CVT, cervical vertebral tangent.

* $P < .05$; ** $P < .01$; + $P < .05$ (significant difference between 1-jaw and 2-jaw).

encroached upon the airway during observation periods. Cervical hyperflection of the head seems to have helped maintain adequate airway.

- However, the fact that pharyngeal airway was narrower compared with its presurgical width and that the hyoid and tongue did not fully return and remained in a posterior location compared with its presurgical position should not be overlooked.
- Precautions and careful monitoring are advised to maintain adequate airway after mandibular setback surgery in patients with narrow airways before planning combined orthodontic and IVRO treatment.

REFERENCES

1. Wickwire N, White RJ, Proffit W. The effect of mandibular osteotomy on tongue position. *J Oral Surg*. 1972;30: 184–190.
2. Enacar A, Aksoy AU, Sencift Y, Haydar B, Aras K. Changes in hypopharyngeal airway space and in tongue and hyoid bone positions following the surgical correction of mandibular prognathism. *Int J Adult Orthodon Orthognath Surg*. 1994;9:285–290.
3. Kawakami M, Yamamoto K, Fujimoto M, Ohgi K, Inoue M, Kirita T. Changes in tongue and hyoid positions, and posterior airway space following mandibular setback surgery. *J Craniomaxillofac Surg*. 2005;33:107–110.
4. Wenzel A, Williams S, Ritzau M. Relationships of changes in craniofacial morphology, head posture, and nasopharyngeal airway size following mandibular osteotomy. *Am J Orthod Dentofacial Orthop*. 1989;96:138–143.
5. Eggensperger N, Smolka W, Iizuka T. Long-term changes of hyoid bone position and pharyngeal airway size following mandibular setback by sagittal split ramus osteotomy. *J Craniomaxillofac Surg*. 2005;33:111–117.
6. Athanasiou AE, Toutountzakis N, Mavreas D, Ritzau M, Wenzel A. Alterations of hyoid bone position and pharyngeal depth and their relationship after surgical correction of mandibular prognathism. *Am J Orthod Dentofacial Orthop*. 1991;100:259–265.
7. Bibby RE, Preston CB. The hyoid triangle. *Am J Orthod*. 1981;80:92–97.
8. Achilleos S, Krogstad O, Lyberg T. Surgical mandibular setback and changes in uvuloglossopharyngeal morphology and head posture: a short- and long-term cephalometric study in males. *Eur J Orthod*. 2000;22:383–394.
9. Gu G, Gu G, Nagata J, Suto M, Anraku Y, Nakamura K, Kuroe K, Ito G. Hyoid position, pharyngeal airway and head posture in relation to relapse after the mandibular setback in skeletal Class III. *Clin Orthod Res*. 2000;3:67–77.
10. Tornes K, Wisth PJ. Stability after vertical subcondylar ramus osteotomy for correction of mandibular prognathism. *Int J Oral Maxillofac Surg*. 1988;17:242–248.
11. Hashemi HM. Evaluation of intraoral verticosagittal ramus osteotomy for correction of mandibular prognathism: a 10-year study. *J Oral Maxillofac Surg*. 2008;66:509–512.
12. Ghali GE, Sikes JW Jr. Intraoral vertical ramus osteotomy as the preferred treatment for mandibular prognathism. *J Oral Maxillofac Surg*. 2000;58:313–315.
13. Park H-S. A clinical study on prognosis of intraoral vertical ramus osteotomy for mandibular set-back in the mandibular prognathism. *J Korean Assoc Oral Maxillofac Surg*. 1997; 23:561–580.
14. Yoshioka I, Khanal A, Tominaga K, Horie A, Furuta N, Fukuda J. Vertical ramus versus sagittal split osteotomies: comparison of stability after mandibular setback. *J Oral Maxillofac Surg*. 2008;66:1138–1144.
15. Ingman T, Nieminen T, Hurmerinta K. Cephalometric comparison of pharyngeal changes in subjects with upper airway resistance syndrome or obstructive sleep apnoea in upright and supine positions. *Eur J Orthod*. 2004;26:321–326.
16. Marsan G, Cura N, Emekli U. Changes in pharyngeal (airway) morphology in Class III Turkish female patients after mandibular setback surgery. *J Craniomaxillofac Surg*. 2008;36:341–345.
17. Solow B, Tallgren A. Natural head position in standing subjects. *Acta Odontol Scand*. 1971;29:591–607.
18. Chen NH, Li KK, Li SY, Wong CR, Chuang ML, Hwang CC, Wu YK. Airway assessment by volumetric computed tomography in snorers and subjects with obstructive sleep apnea in a Far-East Asian population (Chinese). *Laryngoscope*. 2002;112:721–726.
19. Hochban W, Schurmann R, Brandenburg U, Conradt R. Mandibular setback for surgical correction of mandibular hyperplasia—does it provoke sleep-related breathing disorders? *Int J Oral Maxillofac Surg*. 1996;25:333–338.
20. Phillips C, Zaytoun HS, Thomas PM, Terry BC. Skeletal alterations following TOVRO or BSSO procedures. *Int J Adult Orthodon Orthognath Surg*. 1986;17:203–213.
21. Isaacson RJ, Kopytov OS, Bevis RR, Waite DE. Movement of the proximal and distal segments after mandibular ramus osteotomies. *J Oral Surg*. 1978;36:263–268.
22. Lee JY, Yu HS, Ryu YK. A study on skeletal relapse patterns following orthognathic surgery of Class III patients: comparison between SSRO and IVRO. *Korean J Orthod*. 1998;28: 461–477.
23. Riley RW, Powell NB. Maxillofacial surgery and obstructive sleep apnea syndrome. *Otolaryngol Clin North Am*. 1990;23: 809–826.
24. Henriksson CO, Linder-Aronson S, Westborg B. Roentgenological changes in anteroposterior nasopharyngeal dimensions in 6 to 15 year old. *Dentomaxillofac Radiol*. 1975;4: 19–24.
25. Holmberg H, Linder-Aronson S. Cephalometric radiographs as a means of evaluating the capacity of the nasal and nasopharyngeal airway. *Am J Orthod*. 1979;76:479–490.
26. Kyung SH, Park YC, Pae EK. Obstructive sleep apnea patients with the oral appliance experience pharyngeal size and shape changes in three dimensions. *Angle Orthod*. 2005;75:15–22.