Case Report

Dynamic MRI Evaluation of Tongue Posture and Deglutitive Movements in a Surgically Corrected Open Bite

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Abstract: Tongue thrust usually develops in the presence of anterior open bite in order to achieve anterior valve function. In the literature, tongue thrust is described both as the result and the cause of open bite. If it is an adaptation to malocclusion, then tongue posture and deglutitive tongue movements should change after treatment. In this case report, an adult who had skeletal open bite and Class II malocclusion caused by mandibular retrusion was treated surgically. The mandible was advanced in a forward and upward direction with a sagittal split osteotomy. The open bite and Class II malocclusion were corrected and an increase in the posterior airway space (PAS) was observed. Pretreatment and posttreatment dynamic magnetic resonance imaging (MRI) revealed that tongue tip was retruded behind the incisors and contact of the tongue with the palate increased. It was also determined that the anterior and middle portions descended, whereas the posterior portion was elevated at all stages. Advancement of the mandible, correction of open bite, and an increase in PAS affected not only the tongue posture and deglutitive movements, but also the breathing pattern of the patient.

KEY WORDS: Open bite; Tongue thrust; Posterior airway space; Dynamic MRI; Deglutition; Sagittal split osteotomy

INTRODUCTION

Overbite is defined as vertical overlap of incisors. In normal occlusion, the lower incisal edges contact the lingual surface of upper incisors or at above the cingulum. An overbite of 1–2 mm is defined as normal. In an open bite malocclusion, there is no vertical overlap. Vertical separation of 0–2 mm is accepted as moderate open bite, whereas 3–4 mm is severe and more than 4 mm is extreme.[1]

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Forces from the lips, cheeks, tongue, fingers, or other objects can influence tooth position both vertically and horizontally if the pressures are maintained for enough time. Prolonged sucking habits until the eruption of permanent teeth, tongue thrust swallowing, and mouth breathing because of chronic respiratory obstruction caused by inflammation of nasal mucosa associated with allergies or chronic infection are some of the essential etiological factors in development of open bite.[2–5]

In the presence of open bite it is difficult to seal off the front of the mouth during swallowing. Some authors accept tongue thrusting as an adaptation to open bite rather than the cause of it.[6] According to Proffit,[6] the tongue thrusts forward to achieve anterior valve function in order to prevent food or liquids from escaping. We hypothesized that, if this is so, then the tongue should adapt to a new occlusion by changing its posture and deglutitive movements after correction of an open bite.

Abnormal tongue function and posture in patients with open bite has been investigated in some previous studies, but none have presented the effects of open bite treatment on the movement and posture of the tongue. The aim of this report was to compare pretreatment and posttreatment tongue movements of an open bite patient during deglutition by using real-time

Table 1. Cephalometric Analysis of the Patient

	Pretreatment (T0)	Posttreatment (T1)
SNA (°)	80	82
SNB (°)	74	78
ANB (°)	6	4
NV-A (mm)	−2	0
NV-Pog (mm)	−20	−15
S-N (mm)	76	76
S (°)	122	121
Ar (°)	158	156
Go (°)	118	114
Ar-Go (mm)	62	64
Go-Gn (mm)	85	88
Y Axis (°)	68	64
SN/ANS-PNS (°)	12	12
SN/Occ. (°)	20	18
SN/Go-Gn (°)	39	31
ANS-PNS/Go-Gn (°)	27	19
Co-A (mm)	92	95
Co-Pog	132	143
N-Me (mm)	155	152
N-ANS (mm)	67	68
ANS-Me (mm)	91	86
S-Go (mm)	101	102
S-Go/N-Me (%)	65	67
N-ANS/ANS-Me	43/59	45/57
1/SN (°)	111	106
1/Go-Gn (°)	108	100
1/1 (°)	102	110
1/NA (°)	29	17
1-NA (mm)	8	5
1/NB (°)	33	25
1-NB (mm)	17	8
E-Line	1/6	−1/3

balanced turbo field echo (B-TFE) Cine-MR imaging. This case report is a preliminary presentation of a study planned to determine the alterations of deglutitive tongue movements following correction of open bite.

CASE PRESENTATION

Diagnosis

A 20-year-old male who had Class II division I malocclusion and open bite was referred to the Department of Orthodontics. His main concerns were his unaesthetic profile and anterior open bite, because the open bite created difficulties during chewing and in the pronunciation of some words.

During clinical examination, it was observed that the patient had mouth breathing. He had the classic features of an adenoid face consisting of narrow width dimensions, a convex profile with a receding chin, and a long face with a fairly shallow mentolabial sulcus. The musculature of the lips was hypotonic and the lips were separated at rest. An intraoral examination revealed a Class II division I malocclusion with excessive overjet and anterior open bite. Cephalometric analyses indicated that the patient had a moderate skeletal Class II discrepancy caused by mandibular retrusion and a hyperdivergent skeletal pattern. Cephalometric values are presented in Table 1. The patient didn't give permission for presentation of intraoral or extraoral photographs, so in Figures 1 and 2 only study models are shown.

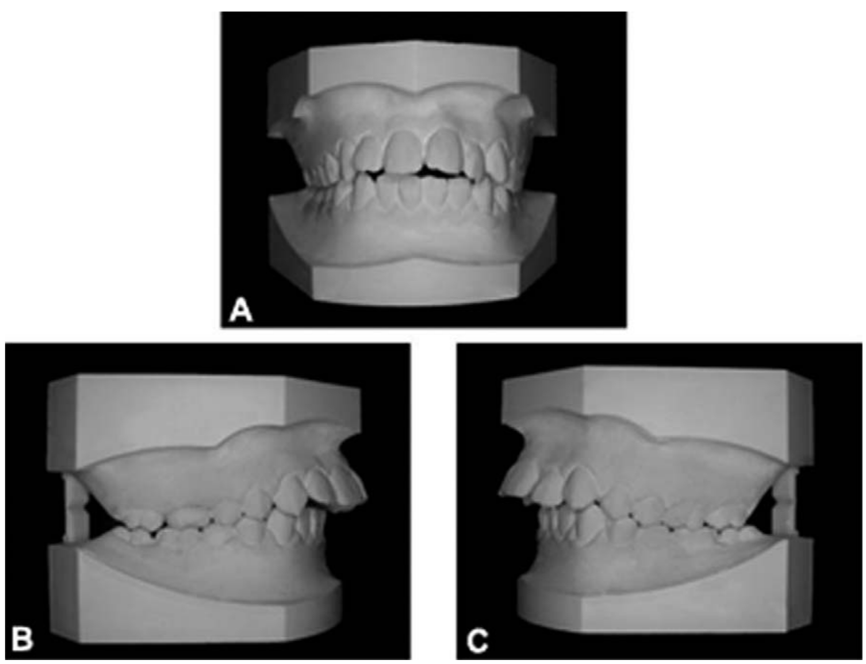

Figure 1. Orthodontic casts (A, B, C) before treatment.

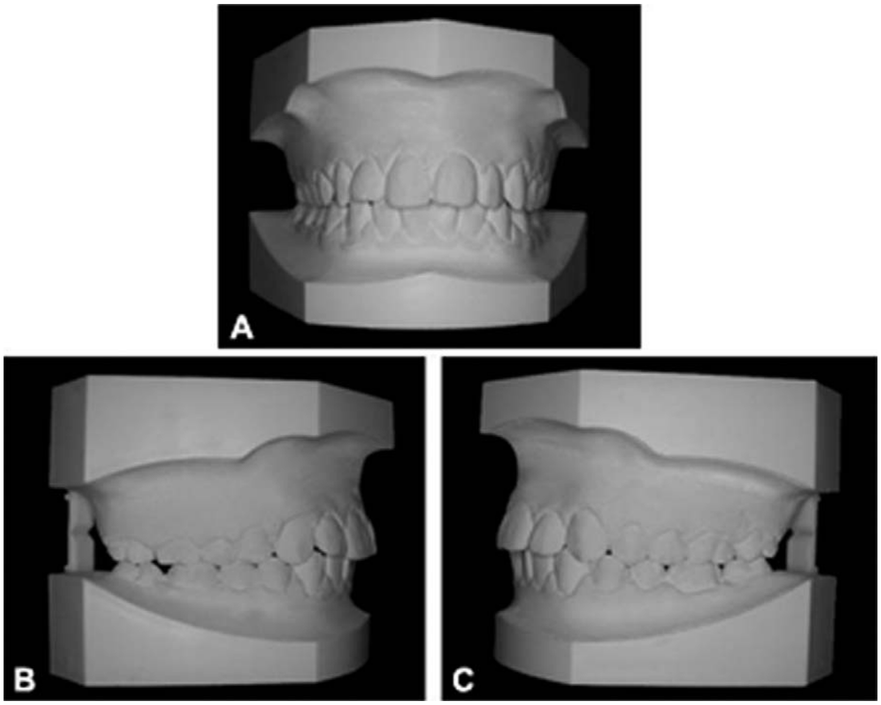

Figure 2. Orthodontic casts (A, B, C) after treatment.

Treatment Objective

The patient had a skeletal Class II malocclusion, open bite, and tongue-thrust swallowing. Because the patient was an adult, surgical procedures were inevitable for the correction of the convex profile and facial disharmony.

In order to determine the alterations in the tongue posture and deglutitive movements resulting from the correction of open bite and Class II malocclusion, dynamic images of tongue movements before orthodontic treatment and after debonding were obtained.

Method Used in the Determination of Deglutitive Tongue Movements

Deglutitive tongue movements were determined with real-time B-TFE Cine-MR imaging. The patient was examined using a 1.5 Tesla superconducting magnetic resonance scanner (The New Intera Nova, Philips Medical Systems, Best, The Netherlands) using a standard quadrature head coil with version 9 software release. The system was equipped with magnetic field gradients capable of a maximum strength of 33 mT/m and maximum slew rate of 160 T/m/s. He was instructed to take 10 mL of water with a syringe just before imaging. Real-time B-TFE images (500/10 ms, TR/TE, one excitation) were obtained in the midsagittal plane by using 50° flip angle, 10-mm slice thickness, 350 × 350 mm field of view, and 256 × 256 matrix size during swallowing of water.

One hundred dynamic scans were obtained in 11 seconds. Acquired cine images were then transferred to a system workstation (Easy Vision R4, Philips Medical Systems), and image analysis and cine display was performed off-line on the workstation. Selected cine images were transferred by an image capture program of the vendor on a one-by-one image basis. Images matching the oral preparatory stage and the oral, pharyngeal, and esophageal stages of deglutition were determined and were printed out on a radiograph. Linear measurements defined by Fujiki et al[7,8] were performed on these radiographs.

Preoperative Orthodontic Treatment

Model setup revealed a transverse deficiency in the maxillary dental arch when the mandible was advanced in the forward and upward direction, so a removable expansion appliance was inserted at the beginning of the orthodontic treatment. After 4 months of expansion, preadjusted appliances (0.018 × 0.022 inch) were placed and rectangular stainless steel arches were inserted following the leveling phase. The model setup revealed that the mandible should be advanced 5 mm forward and 8 mm upward for ideal occlusion and facial aesthetics. An acrylic surgical splint was prepared according to these findings and the patient was referred to the Department of Maxillofacial Surgery for the surgical procedure.

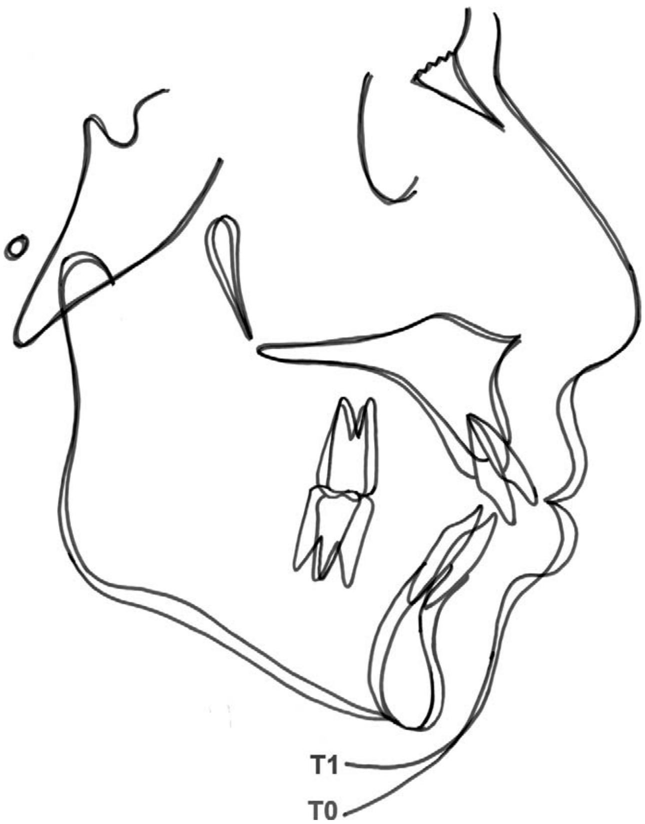

Figure 3. Superimposition of face before and after treatment (T0-T1).

Figure 4. Superimposition on maxilla before and after treatment (T0-T1).

Surgical Technique

A bilateral sagittal split osteotomy (BSSO) was performed under general anesthesia. The mandible was rotated in the upward and forward direction in order to shorten the overall facial height and to correct the Class II malocclusion and anterior open bite.

Figure 5. Superimposition on mandible before and after treatment (T0-T1).

Table 2. Posterior Airway Space Analysis of the Patient

	Pretreatment (T0)	Posttreatment (T1)
P-PNS (mm)	36	36
VAL (mm)	80	81
Ba-N (mm)	112	112
A-PNS (mm)	48	50
TL (mm)	84	85
S-PAS (mm)	26	28
I-PAS (mm)	8	10
N-PAS (mm)	10	12

Cephalometric Superimposition

The interpretation of linear and angular changes was undertaken by superimposing according to Rickett's norms. Evaluation of pretreatment and posttreatment cephalograms revealed that the excessive overjet and negative open bite were corrected and that there was a significant increase in the posterior airway space, created by the forward and upward movement of the mandible (Figures 3 through 5). Postoperative cephalometric alterations are presented in Table 1.

Alterations in the Posterior Airway Space

Cephalometric evaluation of the posterior airway space (PAS)[9,10] revealed increases at H-MP, Val, A-PNS, TL, S-PAS, I-PAS and N-PAS. Increase at A-PNS depends on the forward movement of point A because of the retrusion of the upper incisors. An increase of TL was caused by the anterior rotation of mandible and retrusion of tongue tip. Increases of all other parameters mentioned above were because of the forward displacement of the mandible (Table 2, Figures 6 and 7).

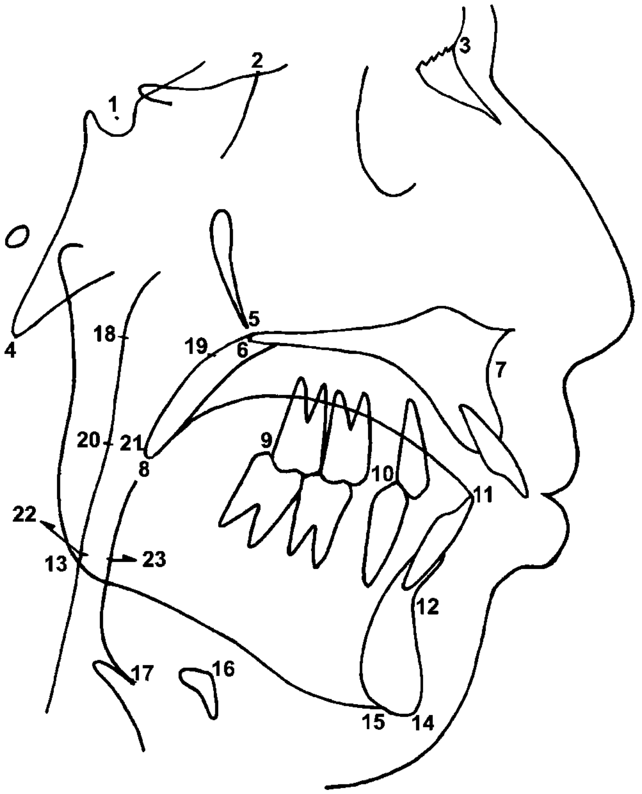

Figure 6. Landmarks used for PAS evaluation. 1 indicates S; 2, Se: sphenoethmoidal junction; 3, N; 4, Ba; 5, Ptm; 6, PNS; 7, A; 8, P: palate, most inferior tip of soft palate; 9, Mo: posterior contact point of molar; 10, PreM: contact point of premolar; 11, Tt: tongue tip; 12, B; 13, Go; 14, Gn; 15, Me; 16, H: hyoidale; 17, Eb: base of epiglottis; 18, PhwS: superior posterior pharyngeal wall; 19, Psp: posterior-superior palate, most posterior-superior point of soft palate; 20, PhwN: posterior pharyngeal wall at narrowest point; 21, STBn: most anterior point in airway on soft palate; 22, PhwI: inferior posterior pharyngeal wall; and 23, STBi: most anterior point in airway on tongue.

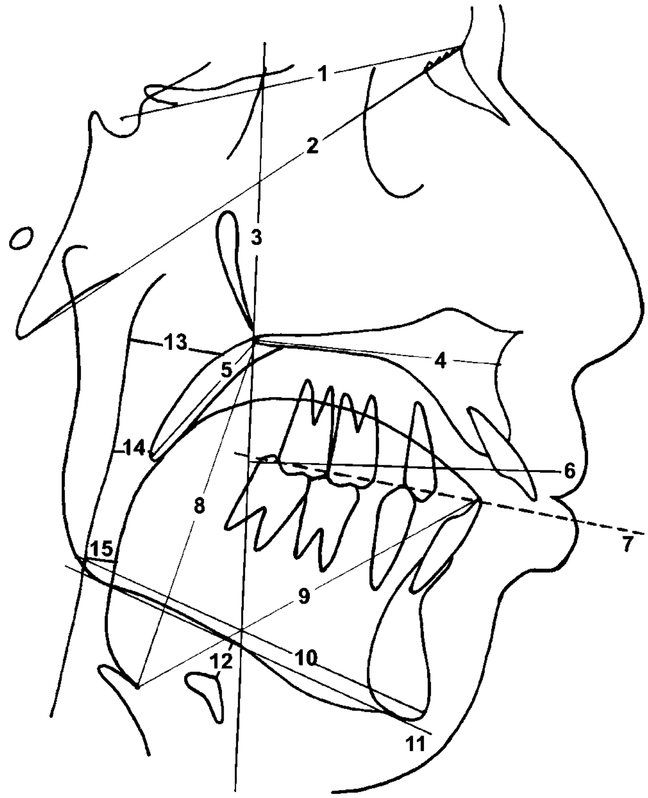

Figure 7. Soft- and hard-tissue linear measurements and reference planes used for PAS evaluation: 1 indicates S-N; 2, Ba-N; 3, Se-Ptm; 4, A-PNS; 5, PNS-P; 6, NOA: neutral occlusal axis, perpendicular from Mo to Se-Ptm; 7, FOP: functional occlusal plane, from PreM to Mo; 8, VAL: PNS to Eb; 9, TL: Eb to Tt; 11, MIB: inferior border of mandible; 13, S-PAS: PhwS to Psp; 14, N-PAS: PhwN to STBn; and 15, I-PAS: PhwI to STBi.

Preoperative and Postoperative Deglutitive Tongue Movements

Measurements of preoperative (T0) and postoperative (T1) tongue movements for each stage are shown in Table 3 and points are presented in Figure 8.

In the comparison of preoperative and postoperative deglutitive tongue movements, retrusion of the tongue tip and an increase at the contact of tongue and palate were observed. When alterations in the movement of dorsum were evaluated, it was determined that, after surgery, the front and middle portions of the tongue descended, whereas the rear parts of the dorsal tongue elevated at all stages of deglutition (Figures 9 through 14).

DISCUSSION

The presence of overjet and an anterior open bite forces the subject to place the tongue between the

Table 3. Deglutitive Analysis of the Patient

	Pretreatment (T0)			Posttreatment (T0)		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
AM-E/AM-PM	0.31	0.19	0.22	0.31	0.37	0.44
MM-MT/MM-MS	0.23	0.23	0.18	0.59	0.46	0.23
PM-PT/PM-PS	0.15	0.22	0.11	0.59	0.68	0.27
C1-D/C1-Me	0.78	0.85	0.78	0.29	0.36	0.26
P’-Ti/PS-I	0.86	0.92	0.94	0.69	0.82	0.67

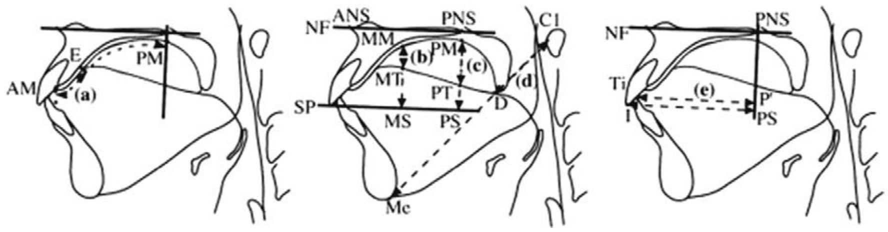

Figure 8. Linear measurements by MRI. (a) Anterior portion of the tongue's dorsum, MP-MT/MP-MS. (b) Midportion of the tongue's dorsum, PP-PT/PP-PS. (c) Posterior portion of the tongue's dorsum, C1-D/C1-Me. (d) Tongue's tip, P9-Ti/PS-I. MPMT, MP-MS, PP-PT, PP-PS, C1-D, C1-Me, and PS-I are straight distances. P9-Ti is the shortest distance from line crossing at a right angle to palatal plane through PNS to Ti (from Fujiki et al[8]).

anterior teeth to seal off the front of the mouth during swallowing to prevent food or liquids from escaping. In other words, a tongue-thrust swallow is a useful physiologic adaptation to anterior open bite. However, the reverse is not always true. A tongue-thrust swallow is often present in children with appropriate overbite. Thus, a tongue-thrust swallow should be considered as the result of an open bite, not the cause.[3,4,6] Therefore, correcting the malocclusion should cause a change in the swallow pattern. On the other hand, tongue tip protrusion during deglutition is sometimes associated with a forward tongue posture. In this situation, the resting pressure increases because the tongue also applies force during rest. Even if the force is very light, it could affect tooth position vertically or horizontally as the duration of the pressure increased.[6]

Respiratory needs also affect the position of the jaw and tongue posture. Mouth breathing caused by obstruction or restriction of any part of the upper airway may cause respiratory obstruction syndrome.[11] Adenoid facies, long face syndrome and vertical maxillary excess are other terms commonly used for this syndrome. In order to breathe through the mouth, the patient lowers the mandible and tongue, positions the tongue in the forward position, and extends the head. This condition changes the equilibrium of pressures on the jaws and teeth, and affects both cranial morphology and tooth position. Because the lowered mandible

Figure 9. Stage 1 of deglutitive tongue movements before treatment.

Figure 10. Stage 2 before treatment.

Figure 11. Stage 3 before treatment.

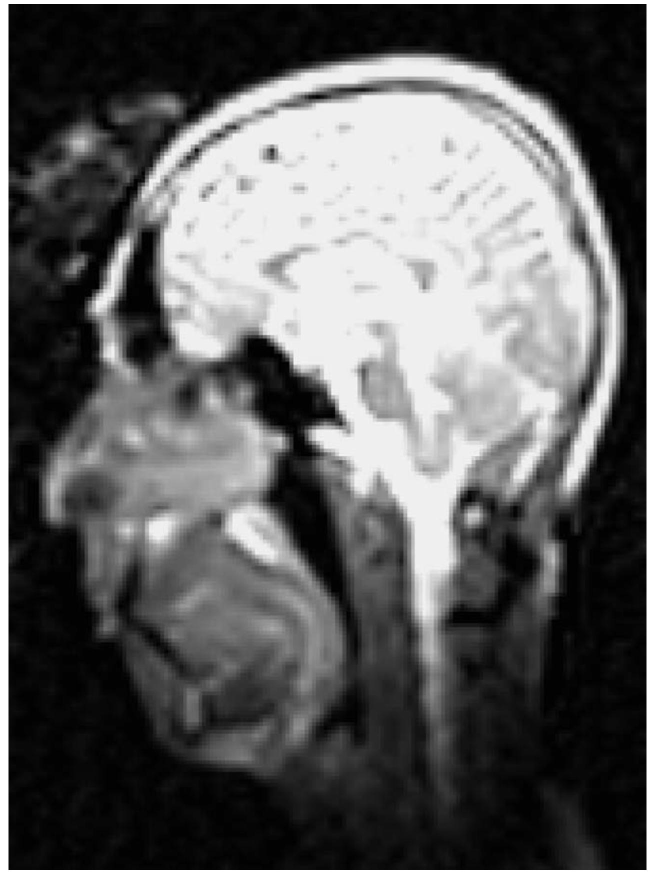

Figure 12. Stage 1 after treatment.

causes the super eruption of posterior teeth, the mandible rotates downward and backward, opening the bite anteriorly and increasing the overjet and anterior face height. Also, increased pressure from the stretched cheeks might cause a narrower maxillary dental arch.[3,4,6,11]

Although cephalometric superimpositions revealed that upper and lower incisors were retruded during treatment because of the Class II elastics and labial root torque applied to the lower arch wire, evaluation of the Cine-MRI showed that the tongue tip was retruded after surgery. The open bite was corrected, so the patient did not need a tongue thrust to achieve an anterior seal during swallowing. Anterior valve function of the tongue tip was eliminated and it was positioned behind the incisors. This retrusion increased the contact of the tongue tip with the palatal mucosa in all stages, and the deglutitive tongue movements returned to their regular pattern.

During swallowing, the anterior and middle portions of the tongue descended, but the posterior portion was elevated. The position of the posterior portion was determined by the proportion of the distances from the front point of the atlas (C1) to the dorsum of the tongue (D) and from the front point of the atlas to the menton (Me). Forward movement of the mandible by a BSSO increases the corpus length and C1-Me distance. This increase caused a severe decrease in the proportion of C1-D/C1-Me. Other reasons for the elevation of the posterior portion were the change in the posture of the tongue caused by correction of the open bite and the increase at PAS caused by forward movement of the mandible.

In our opinion, when the patient was protruding his tongue tip to close the anterior open bite, a compensatory descent was occurring, but after retrusion of the tongue tip, the position of this portion returned to normal and was elevated. Increase in the posterior airway space changed the respiratory pattern and the patient was able to breathe through his nose, so he didn't have to lower the posterior portion of the tongue to breathe easily.

Dynamic magnetic resonance imaging (MRI) was preferred in the evaluation of tongue movements. It is a new and noninvasive method that has recently been used to obtain cine images of deglutition. This technique has been reported by various authors[12–17] as a promising tool for the evaluation of anatomical and physiological characteristics of deglutition. In previous studies,[11] various high-speed MRI sequences (EPI, FLASH, and turbo-FLASH) have been compared, and

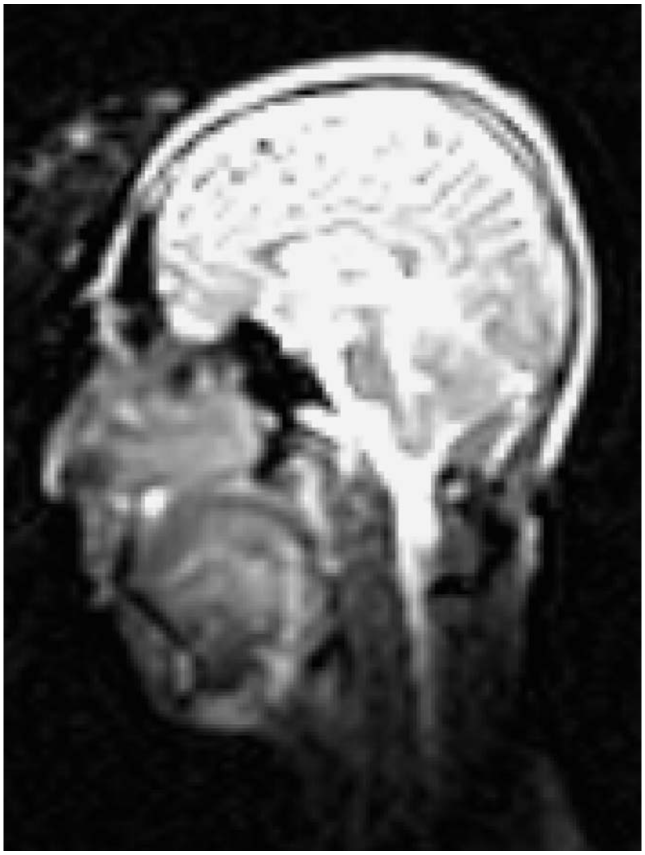

Figure 13. Stage 2 after treatment.

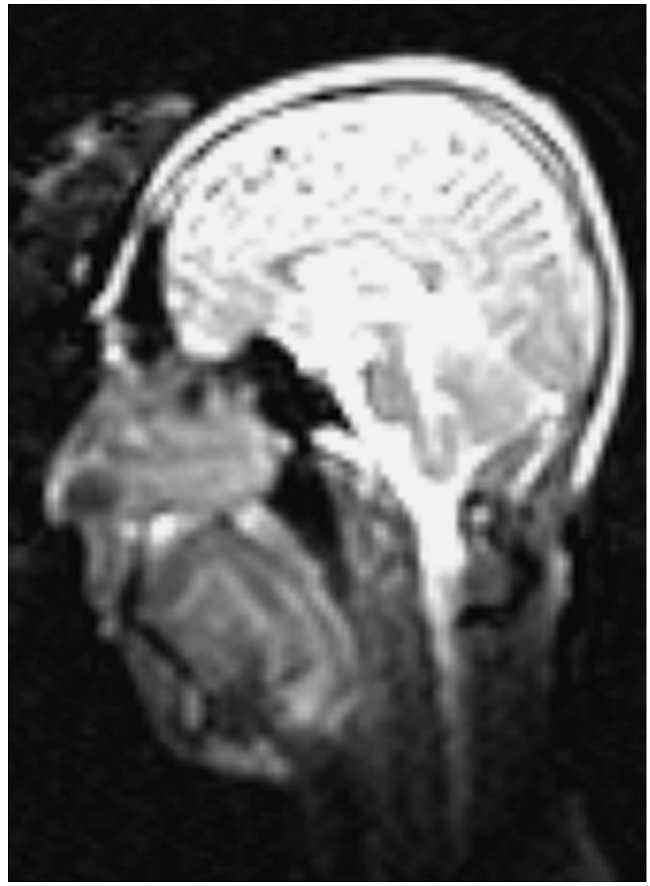

Figure 14. Stage 3 after treatment.

turbo-FLASH sequence was reported as the best temporal resolution and sufficient spatial resolution during motion. In this report we also used the turbo-FLASH sequence.

The presented patient had a long face and presented all the features of the syndrome, such as an open bite, excessive overjet, posterior rotation of the mandible, protrusion of the incisors, increased anterior face height, narrow face, lip incompetence, and tongue thrust. His main concern was his unaesthetic appearance, and the correction of his profile was possible only with surgical approaches. In addition, the patient had mouth breathing and tongue tip protrusion during deglutition. Advancement of the mandible was effective to provide sufficient space for the rest of the tongue. Additionally, anterior positioning of the mandible increased the posterior airway and made the breathing easier and more comfortable. In the correction of open bite, success of the treatment depends on the adaptation of the tongue to the new occlusion. If the patient had been treated by extracting the upper first premolars, excessive overjet and open bite might have been corrected, but the posterior airway space would not have changed. Therefore, the tongue might not have adapted to the new position of the teeth. In this condition, the tongue thrust might have continued forcing the incisors, resulting in the relapse of the open bite.

REFERENCES

1. Ireland AJ, McDonald F. *Treatment and Biomechanics.* Oxford, Great Britain: Oxford University Press; 2003:52.
2. Martina R, Laino A, Michelottí A. Class I malocclusion with severe open bite skeletal pattern treatment. *Am J Orthod.* 1990;97:363–373.
3. Klein ET. Pressure habits, etiological factors in malocclusion. *Am J Orthod.* 1952;38:569–587.
4. Tulley WJ. Adverse muscle forces—their diagnostic significance. *Am J Orthod.* 1956;42:801–814.
5. Frankel R, Frankel C. A functional approach to treatment of skeletal open bite. *Am J Orthod.* 1983;84:54–68.
6. Proffit WR. *Contemporary Orthodontics*. 3rd ed. St Louis, Mo: Mosby; 2000:134–138.
7. Fujiki T, Takano-Yamamoto T, Noguchi H, Yamashiro T, Guan G, Tanimoto K. A cineradiographic study of deglutitive tongue movement and nasopharyngeal closure in patients with anterior open bite. *Angle Orthod.* 2000;70:284–289.
8. Fujiki T, Inoue M, Miyawaki S, Nagasaki T, Tanimoto K, Takano-Yamamoto T. Relationship between maxillofacial morphology and deglutitive tongue movement in patients with anterior open bite. *Am J Orthod Dentofacial Orthop.* 2004;125:160–167.
9. Enlow DH, Kurada T, Lewis AB. The morphological and morphogenetic basis for craniofacial form and pattern. *Angle Orthod.* 1971;41:161–188.

10. Kulnis R, Nelson S, Strohl K, Hans M. Cephalometric assessment of snoring and nonsnoring children. *Chest.* 2000; 118:596–603.
11. Behfelt K. Enlarged tonsil and the effect of tonsillectomy. Characteristics of the dentition and facial skeleton. Posture of the head, hyoid bone and tongue. Mode of breathing. *Swed Dent J Suppl.* 1990;72:1–35.
12. Foucart JM, Carpentier P, Pajoni D, Rabischong P, Pharaboz C. Kinetic magnetic resonance imaging analysis of swallowing: a new approach to pharyngeal function. *Surg Radiol Anat.* 1998;20:53–55.
13. Anagnostara A, Stoeckli S, Weber OM, Kollias SS. Evaluation of the anatomical and functional properties of deglutition with various kinetic high-speed MRI sequences. *J Magn Reson Imaging.* 2001;14:194–199.
14. Hartl DM, Albiter M, Kolb F, Luboinski B, Sigal R. Morphologic parameters of normal swallowing events using single-shot fast spin echo dynamic MRI. *Dysphagia.* 2003;18:255–262.
15. Akin E, Sayin MO, Karacay S, Bulakbasi N. Real-time balanced turbo field echo cine-magnetic resonance imaging evaluation of tongue movements during deglutition in subjects with anterior open bite. *Am J Orthod Dentofacial Orthop.* 2006;129:24–28.
16. Sayin MO, Akin E, Karacay S, Bulakbasi N. Initial effects of the tongue crib on tongue movements during deglutition: a cine-mri study. *Angle Orthod.* In press.
17. Karacay S, Akin E, Sayin MO, Bulakbasi N. Real time balanced turbo field echo (b-tfe) cine-mri in the analysis of deglutition events and transit times. *J Oral Rehabil.* (In press).