

Evaluation of hyoid bone movements in subjects with open bite: a study with real-time balanced turbo field echo cine-magnetic resonance imaging

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Objective: To assess the position and movements of the hyoid bone during deglutition in patients with open bite. **Methods:** Thirty-six subjects were divided into 2 groups according to the presence of anterior open bite. The open bite group (OBG) and control group each comprised 18 patients with a mean overbite of -4.9 ± 1.9 mm and 1.9 ± 0.7 mm. The position of the hyoid bone during the 4 stages of deglutition was evaluated by measuring vertical and horizontal movement of the bone. **Results:** Interactions of group and stage showed no significant effect on the measurements ($p > 0.05$). However, when group and stage were evaluated individually, they showed significant effects on the measurements ($p < 0.001$). In OBG, the hyoid bone was more inferiorly and posteriorly positioned, and this position continued during the deglutition stages. **Conclusions:** The hyoid bone reaches the maximum anterior position at the oral stage and maximum superior position at the pharyngeal stage during deglutition. Open bite does not change the displacement pattern of the bone during deglutition. The hyoid bone is positioned more inferiorly and posteriorly in patients with open bite because of released tension on the suprahyoid muscles.

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INTRODUCTION

The hyoid bone is unique because it has no bony articulation. However, it is an insertion element for muscles, ligaments, and fasciae attached to the mandible, clavicle, sternum, cranium, and cervical vertebrae. The hyoid bone is an important part of the musculoskeletal apparatus of the craniofacial complex and factors affecting this system might have not only local but systemic effects as well.¹

Mandibular repositioning by advancement or setback surgeries reportedly changes the position of the hyoid bone by causing alterations in the tension of the suprahyoid and infrahyoid muscles, neck extensor muscles, and cervical fasciae.²⁻⁴ Its position also changes in relation to postural changes of the head and tongue, malocclusion, and facial type.^{1,5-9} Several authors reported that the position of the hyoid bone is affected by the biomechanics of the suprahyoid and infrahyoid muscles and the elastic membranes of the larynx and trachea.^{10,11} Andersen,¹² Subtelny and Sakuda,¹³ and Haralabakis et al.⁹ studied the position of the hyoid bone in patients with open bite and observed the stability of its vertical position. However, Haralabakis et al.,⁹ who also evaluated the horizontal position of the hyoid bone according to a vertical line drawn from the Frankfort horizontal (FH) plane at porion, reported that it is positioned more posteriorly in patients with open bite. Yet the horizontal distance of the hyoid bone from the cervical spine, pharynx, and mandibular plane (MP) is not influenced by open bite.

In most previous studies, cephalometric measurements were used to determine hyoid bone positioning. However, as this bone moves forward and upward during swallowing, evaluation of its movements during deglutition is more important than investigating its static position. Mays et al.¹⁴ evaluated the influence of craniofacial morphology on hyoid bone movements by videofluoroscopy and demonstrated that the forward displacement of the hyoid bone during liquid swallowing is significantly related to craniofacial morphology. For instance, as the FH-MP angle (FMA) increases, the forward displacement of the hyoid bone decreases. These authors suggested that the observed effects are related to the biomechanics of the suprahyoid musculature. Sloan et al.¹⁵ also analyzed hyoid bone behavior during deglutition by cinefluorography and detected two distinct movement patterns: a circular pattern and an oblique, elliptical pattern.

Postural changes in the mandible and tongue affect the position of the hyoid bone.⁵⁻⁸ Open bite is usually associated with posterior rotation of the mandible and changes in the tongue posture and deglutitive tongue movements.¹⁶⁻¹⁸ Therefore, open bite may also affect the position and movements of the hyoid bone during deglutition. The aim of this retrospective study was to

assess the position and movements of the hyoid bone during deglutition in patients with open bite by real-time balanced turbo field echo (B-TFE) cine magnetic resonance imaging (cine MRI).

MATERIALS AND METHODS

Subjects

The cine MRI images used in this study were selected from records obtained to evaluate deglutitive tongue movements in patients with open bite and Class II malocclusions.^{18,19} This study was initiated after obtaining institutional approval from Gulhane Military Medical Academy's Ethics Committee (1491-373-07). Images of 36 patients with normal overjet (1 - 3 mm) were selected. G*Power software (v3.1.3; Franz Faul, Universitat Kiel, Germany) was used to determine the power of the sample size.²⁰ A sample size of 36 patients was considered sufficient to provide more than 60% power for detecting significant differences with an effect size of 0.30 between groups at a 0.05 significance level.

Two groups were formed according to the presence of anterior open bite (at least -2 mm). The open bite group (OBG) included 18 patients (14 girls and 4 boys) with a mean age of 14.5 ± 2.7 years and mean overbite of -4.9 ± 1.9 mm. The control group (CG) comprised 18 patients (11 girls and 7 boys) with a mean age of 16.4 ± 0.9 years and mean overbite of 1.9 ± 0.7 mm. Cephalometric analyses

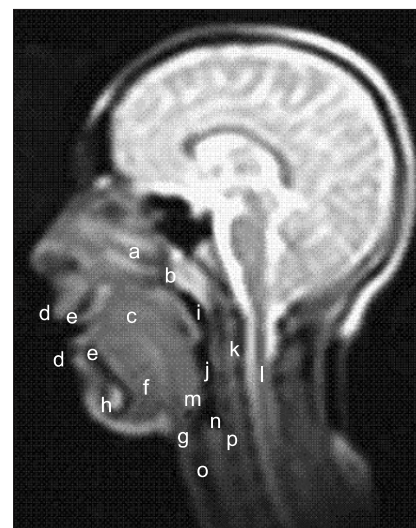


Figure 1. Anatomical structures visible on cine magnetic resonance imaging (a) nasal cavity, (b) nasopharynx, (c) tongue, (d) lips, (e) incisors, (f) floor of the mouth, (g) hyoid bone, (h) symphysis, (i) pharynx, (j) larynx, (k) spinal column, (l) spinal cord, (m) epiglottis, (n) cricoid cartilage and cricotracheal membrane, (o) trachea, and (p) upper portion of the esophagus.

revealed that 4 patients in the OBG and 2 patients in the CG had mild skeletal Class II malocclusions with an ANB angle of 5°, although their overjet was in the normal range. Other patients had skeletal Class I malocclusions and ANB angles ranging from 1° to 4°. In the OBG, the MP angle (SN–GoGn) was $35.56 \pm 1.69^\circ$, FMA was $28.17 \pm 1.62^\circ$, and the palatal plane (PP) angle (SN–PP) was $5.72 \pm 1.28^\circ$, revealing posterior rotation of the mandible and anterior rotation of the PP. In the CG, these measurements were $32.61 \pm 1.33^\circ$, $23.83 \pm 1.29^\circ$, and $7.28 \pm 1.32^\circ$, respectively. None of the patients had complaints related to masticatory difficulty, dysphasia, or swallowing disorders.

Cine MRI and stages of deglutition

A detailed description of the dynamic images obtained by B-TFE cine MRI (New Intera Nova; Philips Medical Systems, Best, The Netherlands) has been presented in our previous reports.^{18,19} Figure 1 shows the anatomical structures visible on these images. For each patient, images of the following 4 stages of deglutition during water swallowing were determined by a consensus of 3 specialists and printed on radiographs.

Stage 1 (oral preparatory stage): The tongue tip contacts the maxillary incisors and/or the palatal mucosa (Figure 2A).

Stage 2 (oral stage): The dorsum of the tongue loses contact with the soft palate (Figure 2B).

Stage 3 (pharyngeal stage): The bolus crosses the posterior or inferior margin of the mandibular ramus (Figure 2C).

Stage 4 (esophageal stage): The bolus enters the esophageal opening (Figure 2D).

Measurements

To determine the position and movements of the hyoid bone during deglutition, linear measurements were obtained from the printed radiographs by the same

investigator (SG) to avoid inter-examiner variability. The distance between the hyoid bone and point sella (H-S), the vertical distance between the hyoid bone and PP (H-PP), and the vertical distance between the hyoid bone and a line connecting the most anteroinferior point of the third cervical vertebra and retrognathion (H-C3RGN) were used to evaluate the vertical movement of the

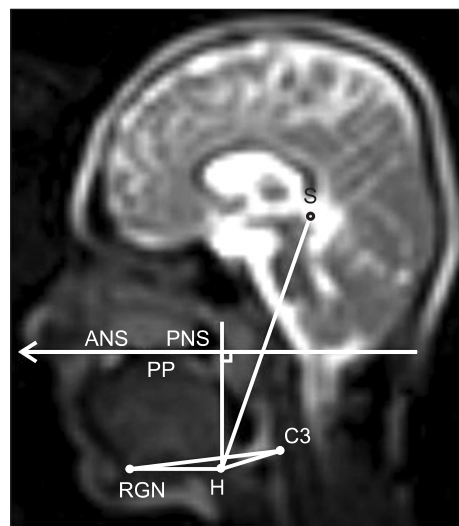


Figure 3. Measurements used for evaluating hyoid bone movements. (1) H-S, distance between hyoidale (H, the most anterosuperior point of the hyoid bone) and point sella (S); (2) H-PP, perpendicular distance of hyoidale to the palatal plane (PP); (3) H-C3RGN, perpendicular distance of hyoidale to the line connecting the most anteroinferior point of the third cervical vertebra (C3) and retrognathion (RNG, the most prominent point of the posterior border of the symphysis); (4) H-C3, distance between hyoidale and the most anteroinferior point of the third cervical vertebra; and (5) H-RGN, distance between hyoidale and retrognathion.

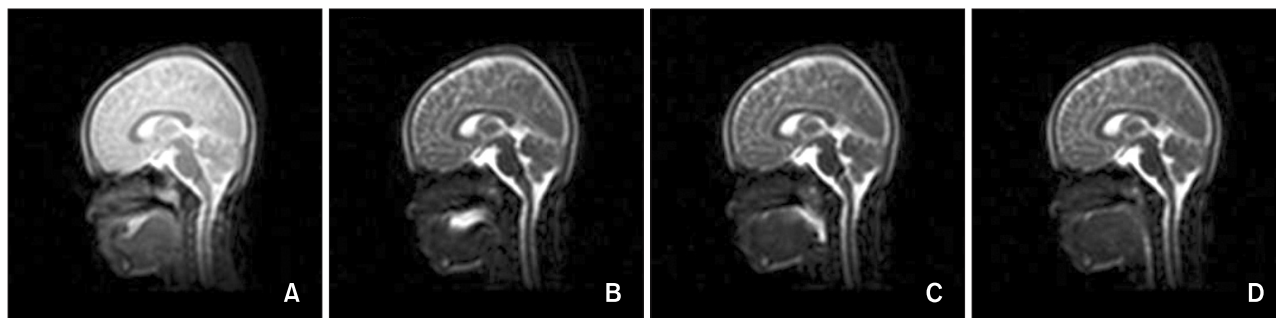


Figure 2. Stages of deglutition. A, stage 1 (oral preparatory stage), the tongue tip contacts the maxillary incisors and/or the palatal mucosa; B, stage 2 (oral stage), the dorsum of the tongue loses contact with the soft palate; C, stage 3 (pharyngeal stage), the bolus crosses the posterior or inferior margin of the mandibular ramus; and D, stage 4 (esophageal stage), the bolus enters the esophageal opening.

hyoid bone. The horizontal movement was evaluated by measuring the distances between the hyoid bone and the most anteroinferior point of the third cervical vertebra (H-C3) as well as the distance between the hyoid bone and retrognathion (H-RGN) (Figure 3).

The measurements of 10 patients were repeated 1 month

later, and reliability was evaluated by using intraclass correlation coefficients (ICCs) and Bland–Altman plots.

Statistical analysis

All statistical analyses were performed with SPSS for Windows (version 15, IBM SPSS Inc., Chicago, IL,

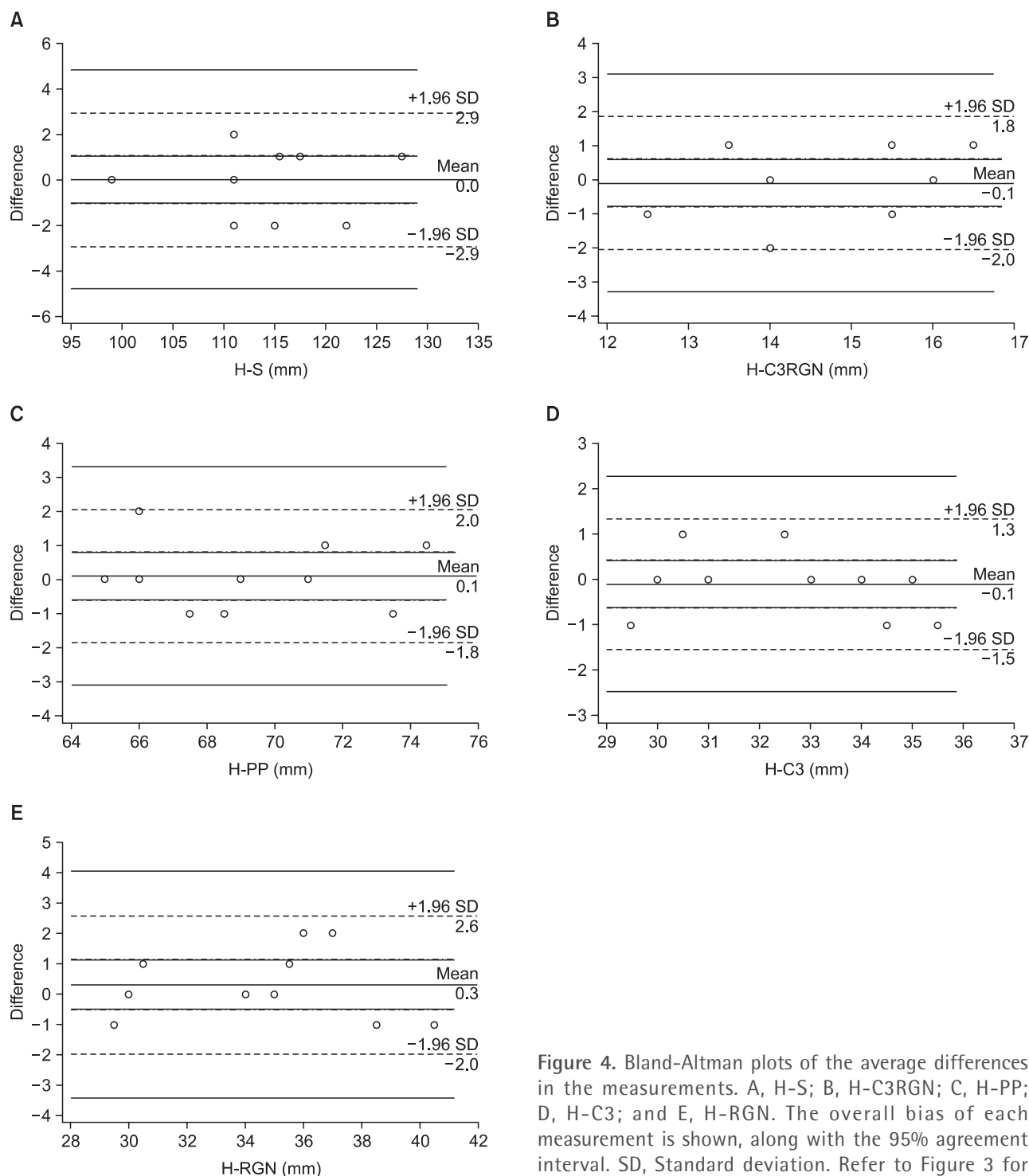


Figure 4. Bland–Altman plots of the average differences in the measurements. A, H-S; B, H-C3RGN; C, H-PP; D, H-C3; and E, H-RGN. The overall bias of each measurement is shown, along with the 95% agreement interval. SD, Standard deviation. Refer to Figure 3 for measurements and abbreviations.

USA). The Shapiro-Wilks and Levene tests were applied to the data and mean ages, which were both found to be normally distributed and showed homogeneity of variance between groups. Therefore, parametric tests were performed for further analysis. Within-group differences in the stages of deglutition were analyzed with the paired-samples t-test. Repeated-measures analysis of variance (ANOVA) was used to evaluate the differences between groups and the significance of the interaction between stages and groups. $p \leq 0.05$ was considered significant.

RESULTS

The ICCs for H-S, H-C3RGN, H-PP, H-C3, and H-RGN measurements were 0.99 (95% confidence interval [CI] = 0.96 to 0.99), 0.86 (95% CI = 0.40 to 0.96), 0.98 (95% CI = 0.92 to 0.99), 0.96 (95% CI = 0.83 to 0.99), and 0.97 (95% CI = 0.90 to 0.99), respectively. Bland-Altman plots showed a high degree of agreement (Figure 4).

Descriptive statistics of the measurements are presented in Table 1. In this table, mean values and standard deviations of the measurements according to the stages are shown for both OBG and CG.

With regard to the vertical movement of the hyoid bone (Tables 2 and 3), the OBG and CG showed significant decreases in the H-S measurement ($p < 0.001$ and $p < 0.01$, respectively) between stages 1 and 2 and between stages 1 and 3. However, the groups showed significant increases ($p < 0.001$ and $p < 0.01$, respectively) at stage 4, as determined by the comparisons between stages 2 and 4 and stages 3 and 4. However, only the OBG showed a significant difference between stages 1 and 4 ($p < 0.05$). Similarly, the H-C3RGN measurement significantly decreased between stages 1 and 2 and between stages 1 and 3, but significantly increased between stages 2 and 4

and stages 3 and 4 in the OBG ($p < 0.01$). On the other hand, in the CG, this measurement showed significant changes only between stages 1 and 2 ($p < 0.01$) and stages 1 and 3 ($p < 0.05$). Moreover, both groups showed significant decreases in the H-PP measurement at stages 2 and 3 when compared with stage 1 ($p < 0.001$ for the OBG; $p < 0.01$ and $p < 0.001$, respectively, for the CG). Significant increases in this measurement were also found between stages 2 and 4 and between stages 3 and 4 in the OBG ($p < 0.001$) and CG ($p < 0.05$ and $p < 0.01$, respectively).

Figures 5A-5C show the displacement of the hyoid bone according to the H-S, H-C3RGN, and H-PP measurements in both groups. The hyoid bone was located more inferiorly at all stages in the OBG than in the CG. In terms of the H-S and H-C3RGN measurements, the hyoid bone reached its most superior position at stage 3 in both groups. However, in the case of H-PP, the hyoid bone reached its most superior position at stage 2 in the OBG.

In the evaluation of the horizontal movement (Tables 2 and 3) of the hyoid bone, a significant increase in the H-C3 measurement was observed in between stages 1 and 2 in the OBG ($p < 0.001$) and CG ($p < 0.01$). Although the increases between stages 1 and 3 and stages 1 and 4 were not significant in the OBG ($p > 0.05$), they were significant in the CG ($p < 0.05$). The H-C3 measurement decreased between stages 2 and 3, stages 2 and 4, and stages 3 and 4 in both groups, but a significant change was determined only between stages 2 and 4 in the OBG ($p < 0.05$). When the H-RGN measurement was evaluated, a significant decrease between stages 1 and 2 was found in both the OBG ($p < 0.05$) and the CG ($p < 0.001$). A significant decrease was also found between stages 1 and 3 in the CG ($p < 0.05$). This measurement increased between stages 2 and 3, stages 2 and 4, and stages 3 and 4 in both groups,

Table 1. Descriptive statistics of the measurements (unit : mm)

		Stage 1	Stage 2	Stage 3	Stage 4
H-S	OBG	115.33 (6.544)	102.83 (7.446)	101.17 (7.687)	114.11 (6.258)
	CG	105.05 (7.089)	95.85 (9.281)	95.90 (9.049)	104.55 (7.977)
H-C3RGN	OBG	14.89 (1.875)	13.11 (2.349)	12.89 (1.875)	15.00 (2.196)
	CG	13.20 (2.042)	11.20 (2.587)	11.30 (3.097)	12.65 (3.528)
H-PP	OBG	67.78 (3.474)	61.22 (4.882)	61.61 (4.717)	67.94 (3.811)
	CG	60.75 (3.291)	55.60 (6.336)	54.60 (4.210)	59.60 (5.557)
H-C3	OBG	33.56 (2.595)	36.72 (2.653)	35.06 (3.134)	35.00 (2.029)
	CG	35.70 (3.854)	39.05 (4.058)	38.30 (3.757)	38.05 (3.103)
H-RGN	OBG	36.06 (4.108)	32.33 (3.272)	34.94 (3.489)	35.11 (3.394)
	CG	39.25 (3.059)	35.85 (2.323)	36.90 (3.354)	37.15 (2.777)

Values are presented as mean (standard deviation).

OBG, Open bite group (n = 18); CG, control group (n = 18).

Refer to Figure 3 for measurements and abbreviations.

Table 2. Differences in the measurements between the stages of deglutition in the open bite group (n=18)

	Stage	Paired differences			t	p-value
		Mean	Standard deviation	Standard error mean		
H-S	1 - 2	12.500	7.733	1.823	6.858	0.000*
	1 - 3	14.167	8.726	2.057	6.888	0.000*
	1 - 4	1.222	2.315	0.546	2.240	0.039*
	2 - 3	1.667	5.099	1.202	1.387	0.183
	2 - 4	-11.278	7.274	1.715	-6.577	0.000*
	3 - 4	-12.944	7.840	1.848	-7.005	0.000*
H-C3RGN	1 - 2	1.778	1.833	0.432	4.115	0.001*
	1 - 3	2.000	2.425	0.572	3.499	0.003*
	1 - 4	-0.111	2.166	0.511	-0.218	0.830
	2 - 3	0.222	2.579	0.608	0.366	0.719
	2 - 4	-1.889	2.632	0.620	-3.045	0.007*
	3 - 4	-2.111	2.847	0.671	-3.146	0.006*
H-PP	1 - 2	6.556	5.159	1.216	5.391	0.000*
	1 - 3	6.167	5.854	1.380	4.470	0.000*
	1 - 4	-0.167	4.004	0.944	-0.177	0.862
	2 - 3	-0.389	4.578	1.079	-0.360	0.723
	2 - 4	-6.722	5.859	1.381	-4.868	0.000*
	3 - 4	-6.333	4.887	1.152	-5.498	0.000*
H-C3	1 - 2	-3.167	2.792	0.658	-4.812	0.000*
	1 - 3	-1.500	4.260	1.004	-1.494	0.154
	1 - 4	-1.444	3.258	0.768	-1.881	0.077
	2 - 3	1.667	4.678	1.103	1.512	0.149
	2 - 4	1.722	3.268	0.770	2.236	0.039*
	3 - 4	0.056	3.572	0.842	0.066	0.948
H-RGN	1 - 2	3.722	5.707	1.345	2.767	0.013*
	1 - 3	1.111	6.144	1.448	0.767	0.453
	1 - 4	0.944	4.608	1.086	0.870	0.397
	2 - 3	-2.611	4.118	0.971	-2.690	0.015*
	2 - 4	-2.778	4.622	1.089	-2.550	0.021*
	3 - 4	-0.167	5.448	1.284	-0.130	0.898

*Statistically significant (by 2-tailed test).

Refer to Figure 3 for measurements and abbreviations.

but significant changes were determined only between stages 2 and 3 and stages 2 and 4 in the OBG ($p < 0.05$).

The hyoid bone was closer to the third cervical vertebra and retrognathion at all stages in the OBG when compared to the CG (Figure 5D and 5E). According to H-C3 and H-RGN measurements, the hyoid bone reached its most anterior position at stage 2 and returned to its normal position gradually during stages 3 and 4 in both

groups.

Interactions between groups and stages had no significant effects on the measurements ($p > 0.05$). However, when these factors were analyzed individually, the effects of group on the measurements were found to be significant ($p < 0.001$ for H-S, H-PP, and H-RGN; $p < 0.01$ for H-C3RGN and H-C3). Similarly, stage also had significant effects ($p < 0.001$ for H-S and H-PP; $p < 0.01$

Table 3. Differences in the measurements between the stages of deglutition in the control group (n=18)

	Stage	Paired differences			t	p-value
		Mean	Standard deviation	Standard error mean		
H-S	1 - 2	9.200	9.666	2.161	4.257	0.000*
	1 - 3	9.150	13.531	3.026	3.024	0.007*
	1 - 4	0.500	3.804	0.851	0.588	0.564
	2 - 3	-0.050	12.800	2.862	-0.017	0.986
	2 - 4	-8.700	10.579	2.365	-3.678	0.002*
	3 - 4	-8.650	13.888	3.105	-2.785	0.012*
H-C3RGN	1 - 2	2.000	2.449	0.548	3.651	0.002*
	1 - 3	1.900	2.972	0.665	2.859	0.010*
	1 - 4	0.550	3.348	0.749	0.735	0.471
	2 - 3	-0.100	3.493	0.781	-0.128	0.899
	2 - 4	-1.450	4.383	0.980	-1.480	0.155
	3 - 4	-1.350	4.271	0.955	-1.414	0.174
H-PP	1 - 2	5.150	7.250	1.621	3.177	0.005*
	1 - 3	6.150	4.452	0.995	6.178	0.000*
	1 - 4	1.150	4.308	0.963	1.194	0.247
	2 - 3	1.000	6.122	1.369	0.731	0.474
	2 - 4	-4.000	7.616	1.703	-2.349	0.030*
	3 - 4	-5.000	6.601	1.476	-3.387	0.003*
H-C3	1 - 2	-3.350	4.404	0.985	-3.402	0.003*
	1 - 3	-2.600	4.535	1.014	-2.564	0.019*
	1 - 4	-2.350	4.848	1.084	-2.168	0.043*
	2 - 3	0.750	3.567	0.798	0.940	0.359
	2 - 4	1.000	5.099	1.140	0.877	0.391
	3 - 4	0.250	3.611	0.807	0.310	0.760
H-RGN	1 - 2	3.400	3.331	0.745	4.565	0.000*
	1 - 3	2.350	4.557	1.019	2.306	0.033*
	1 - 4	2.100	4.564	1.021	2.058	0.054
	2 - 3	-1.050	3.034	0.679	-1.547	0.138
	2 - 4	-1.300	4.181	0.935	-1.390	0.180
	3 - 4	-0.250	4.038	0.903	-0.277	0.785

*Statistically significant (by 2-tailed test).
Refer to Figure 3 for measurements and abbreviations.

for H-RGN, H-C3RGN, and H-C3) (Table 4).

DISCUSSION

The hyoid bone moves upward and downward by the contraction of the suprahyoid musculature and relaxation of the cricopharyngeus.²¹ This synergistic contraction and relaxation also facilitates displacement of the tongue, pulls the larynx forward and upward, and opens the

upper esophageal sphincter, permitting the bolus to enter the esophagus.^{21,22} These phenomena are accompanied by the sealing of the larynx, which is essential for safe swallowing. As the suprahyoid muscles are attached to several craniofacial landmarks, including the mandibular symphysis, inferior border of the mandible, base of the skull, and tongue, a relationship exists between the hyoid, tongue, and mandible during swallowing.

Previous studies using cine MRI revealed that move-

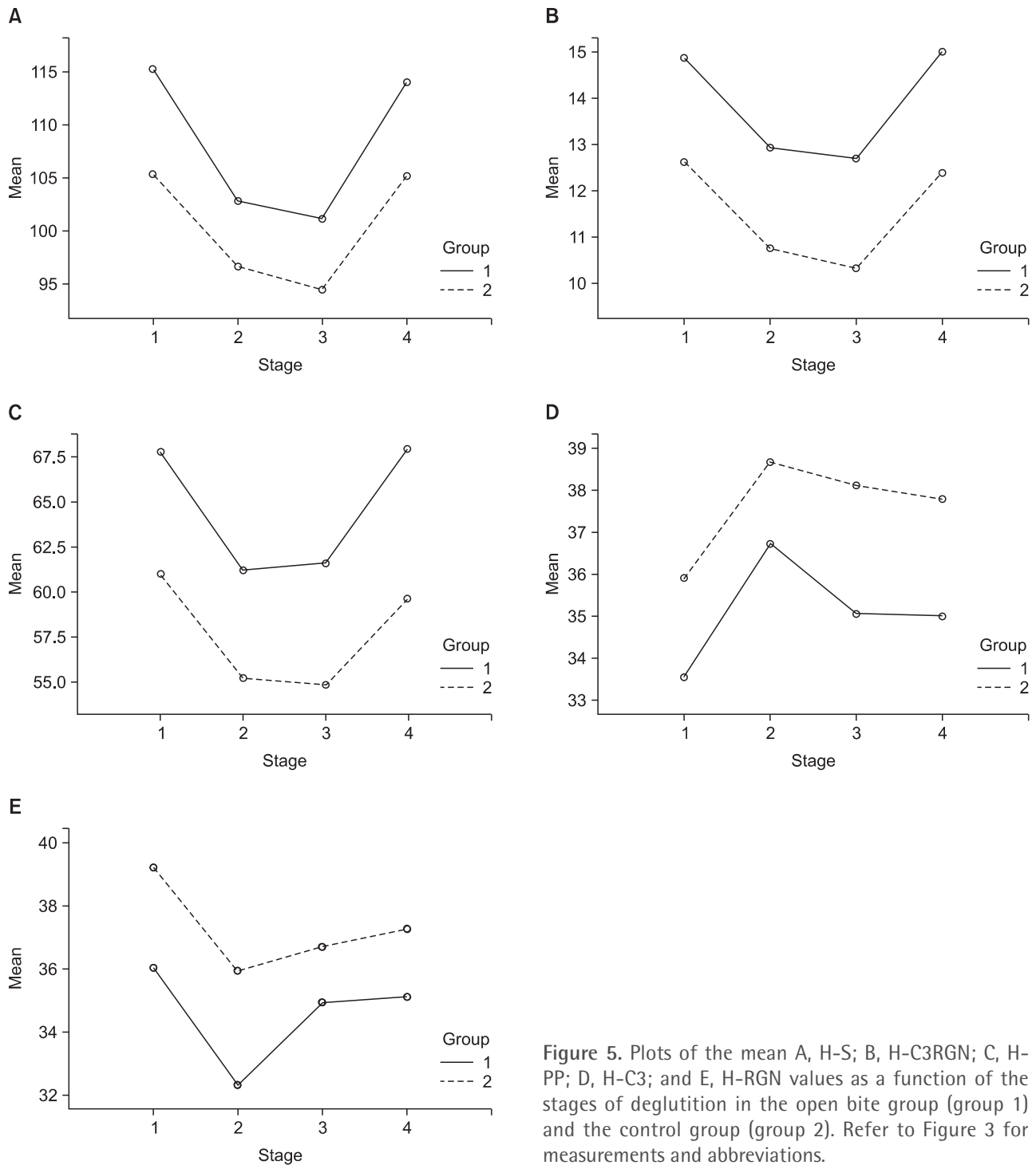


Figure 5. Plots of the mean A, H-S; B, H-C3RGN; C, H-PP; D, H-C3; and E, H-RGN values as a function of the stages of deglutition in the open bite group (group 1) and the control group (group 2). Refer to Figure 3 for measurements and abbreviations.

ments during deglutition are affected by the dentofacial morphology and adaptive changes at the tip, dorsum, and root of the tongue.^{18,23-25} Fujiki et al.¹⁷ and Akin et al.¹⁸ reported compensatory coordination of tongue movement, soft palate movement, and pharyngeal constrictor muscle activity during deglutition in patients with open bite, but the effects on hyoid bone movements during

deglutition were not evaluated. Therefore, we evaluated the effects of anterior open bite on hyoid bone movements during deglutition by cine MRI, a noninvasive and reliable technique. To the best of our knowledge, no such study has ever been performed. The turbo-FLASH sequence was preferred because this sequence provides the best temporal resolution and sufficient spatial resolution

Table 4. Effects of group and stage on the measurements

	H-S		H-C3RGN		H-PP		H-C3		H-RGN	
	F	p	F	p	F	p	F	p	F	p
Group	58.467	0.000*	16.583	0.001*	112.700	0.000*	16.696	0.001*	28.243	0.000*
Stage	14.267	0.000*	9.610	0.001*	11.455	0.000*	7.279	0.003*	10.518	0.001*
Group × stage	1.404	0.280	0.053	0.983	0.518	0.677	0.264	0.850	0.975	0.431

*Statistically significant (by repeated-measures ANOVA).
Refer to Figure 3 for measurements and abbreviations.

during motion.²⁶ Water-swallowing sets are reportedly more reliable than dry-swallowing sets for distinguishing the stages of deglutition because the borders of soft tissues, especially the tongue, can be easily and correctly determined.²³ In this study, we used 10 mL water as the bolus. Standardization of the bolus volume is also important because it affects the movements of the hyoid bone.²⁷

In the current study, the vertical measurements revealed that patients with open bite had an inferiorly positioned hyoid bone during all stages of deglutition. When the movement of the hyoid bone was evaluated according to sella and the plane connecting the third cervical vertebra and retrognathion, both groups showed superior displacement of the hyoid bone from stage 1 to stages 2 and 3. The hyoid bone reached its most superior position at stage 3 and nearly returned to its initial position at stage 4. However, evaluation according to the PP revealed that the hyoid bone reached its most superior position at stage 2 in patients with open bite. This difference is probably related to anterior rotation of the PP frequently encountered in patients with anterior open bite. Andersen¹² and Subtelny and Sakuda¹³ compared the vertical positions of the hyoid bone between patients with open bite and those with normal occlusion. Contrary to our findings, they found no significant differences between these groups. However, supporting our results, Haralabakis et al.⁹ found that the distance between the hyoid bone and PP is greater in patients with open bite, indicating an inferior position of the hyoid bone.

With regard to the horizontal measurements, the hyoid bone was closer to both the third cervical vertebra and retrognathion in patients with open bite. This result may seem to be conflicting. However, posterior rotation of the mandible is common in patients with anterior open bite²⁸ and may explain our findings. Depending on posterior mandibular rotation, the symphysis is located more inferiorly and posteriorly in these patients. The horizontal measurements revealed that, in both groups, the hyoid bone was displaced anteriorly from stage 1 to stage 2, reached its most anterior position at stage 2, and was gradually displaced in a posterior direction at stages 3 and 4. The inferior and posterior positioning of the hyoid

bone during all stages of deglutition in patients with open bite can be explained by the released tension of the suprahyoid muscles.

Similar to our findings, many previous studies have showed a close association between the inclination of the hyoid bone and mandibular inclination.^{7,9,29} Tallgren and Solow⁷ reported that the vertical positional changes in the hyoid bone follow the patterns of change in mandibular inclination, whereas the horizontal positional changes mainly follow the changes in cervical inclination and craniofacial angulation. In our opinion, the closer position of the hyoid bone to the third cervical vertebra in patients with open bite is related to hyperextension of the head in these patients, causing the cervical spine to be stretched and decreasing the distance between the third cervical vertebra and hyoid bone. In accordance with our view, Opdebeeck et al.³⁰ reported that the cross-section of the lower pharynx is reduced and that the hyoid bone is closer to the cervical spine in subjects with a high FMA. Encroachment of the vital pharyngeal space induces stretching of the cervical spine and hyperextension of the head. Jena and Duggal,²⁹ who evaluated hyoid bone position in subjects with different vertical jaw dysplasias, also reported that subjects with short face and long face syndromes have anteriorly and posteriorly positioned hyoid bones, respectively. Haralabakis et al.⁹ found that the horizontal distance between the hyoid bone and the perpendicular line from the FH plane at porion is greater in patients with open bite, indicating a more posterior position of the hyoid bone. However, Subtelny and Sakuda¹³ found no difference in the horizontal position of the hyoid bone in patients with open bite, contrary to our findings.

CONCLUSION

1. Real-time B-TFE cine MRI is a valuable tool to evaluate the movements of the hyoid bone during deglutition.
2. The hyoid bone reaches its most anterior and superior positions at the oral (stage 2) and pharyngeal (stage 3) stages of deglutition, respectively. Open bite does not affect the displacement pattern of the hyoid bone during deglutition.

3. The hyoid bone is positioned more inferiorly and posteriorly in patients with open bite because of released tension of the suprahyoid muscles.

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