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Hyoid bone position after surgical mandibular advancement

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SUMMARY A cephalometric evaluation of the changes in the horizontal and vertical placement of the hyoid bone and of those in the position of the head over the cervical spine after surgical mandibular advancement was undertaken. Seven linear and one angular measurement were investigated in 60 patients, 17 males and 43 females, before and one year after surgical mandibular advancement.

The hyoid bone moved forwards horizontally in 78 per cent of the subjects, backwards in 17 per cent, and in 5 per cent of patients it retained its pre-operative position. It moved vertically downwards in 32 per cent of subjects, and in 63 per cent it moved upwards and closer to the body of mandible. The amount of horizontal and vertical change of the hyoid bone was associated with the corresponding change of the mandible after surgery. The vertical change was more distinct in females compared with males. There was variation in the position of the head over the cervical spine; it showed extension in 26.7 per cent of the sample, flexion in 71.7 per cent, and remained the same in only 1.6 per cent after surgery.

The results show that with surgical mandibular advancement the hyoid bone follows mainly the advancement of the mandible and moves closer to the body of the mandible. However, there are variations in the changes of hyoid bone and head position that are difficult to predict.

Introduction

The significance of the hyoid bone has been emphasized in recent years, after it was appreciated that dysfunctional factors affecting the hyoid system produce not only local, but also general effects (Rocavado, 1983; Rocavado and Tapia, 1987). The hyoid bone is an insertion element for muscles, ligaments, and fasciae attaching to the mandible, clavicle, sternum, cranium, and cervical spine. It is also a unique structure because it has no bony articulation. The cervical fasciae are closely related to the hyoid system and these bind the anterior cervical spine to the hyoid bone, as well as the infra- and supra-hyoid muscles, which depend on the hyoid bone and its relationship with the cervical spine for normal function.

There are several reports of the position of the hyoid bone in relation to postural changes of the head, tongue, malocclusion, and facial type (Globeille and Bowman, 1976; Adamidis and Spyropoulos, 1983; Rocavado, 1983; Tallgren and Solow, 1987; Behlfelt *et al*., 1990; Haralabakis *et al*., 1993). In addition, the change in hyoid bone position has been assessed after surgical mandibular advancement procedures (Wenzel *et al*., 1989; Phillips *et al*., 1991; Pim Valk *et al*., 1992; Hayes *et al*., 1994). However, few publications have reported the relationship of the hyoid bone to the cervical spine and how that may affect the spatial position of the head after surgical mandibular advancement (Kylämarkula and Huggare, 1985; Phillips *et al*., 1991; Hayes *et al*., 1994).

It has been reported that surgical mandibular advancement leads to a change in length and tension of the related musculature (Carlson *et al*., 1987), i.e. the supra- and infra-hyoid, the neck extensor muscles, and the cervical fasciae.

On the other hand, alterations in cranium position may produce changes in regulation of neuromuscular activity, altering muscular tone, which may indirectly affect the position and/or function of the cervical spine, hyoid bone, hyolaryngeal system, and tongue. When all the above factors are activated after mandibular surgical advancement and act in concert, this may produce mandibular instability, relapse, and a certain degree of disturbed head balance may result (Schendel and Epker, 1980; Lake *et al*., 1981; Pim Valk *et al*., 1992). Limited mandibular advancement could produce some margin of safety, because the smaller the sagittal surgical repositioning of the mandible, the smaller would be the variation in neuromuscular activity and, consequently, the response at the level of the hyoid system would be minimized, producing more stable results.

The aim of this study was to evaluate cephalometrically how mandibular advancement surgery changes the horizontal and vertical hyoid bone position, and the position of the head over the cervical spine, and to determine whether these changes can be predicted based on the amount of mandibular advancement.

Subjects and methods

Subjects

The sample consisted of 60 patients treated in a private orthodontic practice, 17 males and 43 females of Caucasoid ethnic background, and over 18 years of age. Completed treatment involving orthodontics and orthognathic surgery to advance the mandible, and the availability of pre-surgical and one-year post-treatment lateral cephalograms were the criteria for the sample selection.

During surgery the mandible was moved forward on average 5.1 mm, and was in a forward position after treatment in 96.7 per cent of subjects and in its original sagittal position in 3.3 per cent of patients. Vertically, pogonion moved downwards on average 2.0 mm, and was upward in 85 per cent of subjects, downward in 11.7 per cent, and in the remaining 3.3 per cent there was no vertical change. The lateral cephalograms were taken with teeth in centric relation, the lips in repose, and with the patient in a natural head position. The material was the same as that used in an earlier investigation (Sinclair *et al*., 1995).

Cephalometric measurements

For this study, the horizontal reference plane (HRP) was determined on the lateral cephalograms as a line orientated at 7 degrees down to the sella–nasion plane (Bjerin, 1957) and the vertical reference plane (VRP), as a line perpendicular to the horizontal reference plane through sella.

The surgical horizontal advancement of the mandible was assessed by measuring the distance between VRP and pogonion parallel to HRP. The point of intersection of this horizontal line with the VRP was defined as Pgn^1 (Figure 1). Similarly, vertical changes were assessed by measuring the distance between the horizontal reference plane to pogonion, and the point of

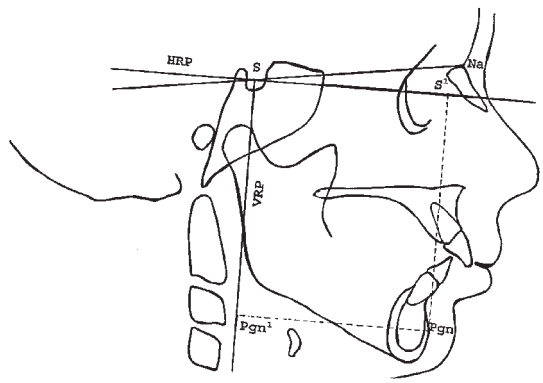

Figure 1 Landmarks and lines used to determine the vertical and horizontal position of the mandible, before and after orthognathic surgery. Landmarks: sella (S), the midpoint of the cavity of sella turcica; nasion (Na), the anterior point of the intersection between the nasal and frontal bones; $sella^1$ (S^1), a point located at the intersection of the vertical line coming from pogonion with the horizontal reference plane (HRP); pogonion (Pgn), the most anterior point of the contour of the chin; $pogonion^1$ (Pgn^1), a point located at the intersection of the horizontal line coming from pogonion, vertical reference line. Planes: HRP, a line orientated at 7 degrees down to the sella–nasion plane; vertical reference plane (VRP), a line perpendicular to the horizontal reference plane through sella.

intersection of the vertical line coming from pogonion in parallel to VRP with the horizontal reference line defined as S^1.

Five vertical and horizontal linear cephalometric measurements were used to evaluate the spatial change of the hyoid bone after orthognathic surgery (Figure 2). In addition, one angular measurement was utilized to detect the possible post-surgical alteration of the position of the head over the cervical spine. For that purpose, the McGregor plane (MGP; Rocavado, 1983; Rocavado and Tapia, 1987) was determined as a line connecting the basi-occiput with the posterior nasal spine and the odontoid plane (OP) as a line crossing from the anterior inferior corner of the odontoid to the superior apex of the odontoid. The cranio-vertebral angle is the posterior angle of the intersection of the McGregor's and the odontoid plane. This angle relates the cranium to the cervical spine and can also reflect the change of head position due to treatment. These changes can be either posterior rotation of the cranium, extension, or anterior rotation of the cranium, flexion. The landmarks and the definitions for these measurements are shown in Figure 2.

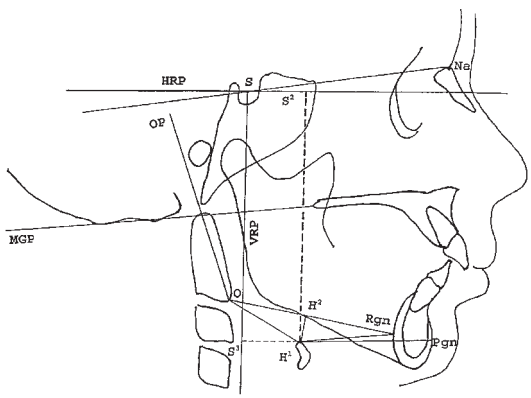

Figure 2 Landmarks, lines and angles used to assess the position of the hyoid bone. Landmarks: odontoid (O), a point located at the anterior inferior angle of the odontoid process; retrognathion (Rgn), the most inferior posterior point of the mandibular symphysis; hyoid bone 1 (H^1), the most superior anterior point of the body of the hyoid bone; hyoid bone 2 (H^2), a point obtained by dropping a perpendicular from the plane O–Rgn to H^1; sella^2 (S^2), a point located at the intersection of the vertical line coming from H^1 with the horizontal reference plane; sella^3 (S^3), a point located at the intersection of the horizontal line coming from H^1 with the vertical reference line. Planes: McGregor plane (MGP), a line that connects the basi-occiput with the posterior nasal spine; odontoid plane (OP), a line that crosses from the anterior inferior angle of the odontoid, to the apex of the odontoid. Angle: cranio-vertebral angle, the posterior angle produced by the intersection of MGP and the odontoid plane (OP).

Statistical methods

To determine the consistency of the method, one experienced orthodontist (AG) traced and measured 20 randomly selected lateral cephalograms three times at two-week intervals, and the intra-examiner consistency (ICC) with 95 per cent confidence intervals (CI) was calculated for these measurements. The values of the ICC were high for all measurements, from 0.856 for S–H^1 (CI 0.728, 0.935) to 0.997 for H^1–H^2 (CI 0.993, 0.999).

A Student's *t*-test was used for comparing differences in pre-surgical skeletal measurements between females and males. Pre- and post-surgical changes in hyoid bone and head position due to mandibular advancement surgery were assessed by multivariate analysis of variance (MANOVA), taking the effect of gender into account. Multiple regression analyses were used to estimate the associations between the changes in the mandible (Pgn–Pgn^1, Pgn–S^1 in mm) and hyoid bone positions (O–H^1, H^1–Pgn, H^1–H^2, S^2–H^1, S^3–H^1 in mm), controlling the effect of gender (female = 0, male = 1). *P*-values $\leq$ 0.05 were considered statistically significant.

Results

Absolute means of variables describing hyoid bone position and cranium angulation before treatment are shown in Table 1 separately for males and females. Males had statistically significantly larger O–H^1, S–H^1, S^1–Pgn, and Pgn–Pgn^1 values before treatment than females. Therefore, gender was included in further analyses.

The hyoid bone moved horizontally (S^3–H^1) on average 2.4 mm in a forward position in 78.3 per cent of the cases, backwards in 16.7 per cent, and in 5 per cent the hyoid bone remained in its

Table 1 Pre-surgical cephalometric measurements in females and males of 60 patients with surgical mandibular advancement procedure.

	Females (n = 43)	Males (n = 17)	P*
	Mean (SD)	Mean (SD)	
Position of the mandible (mm)			
Pgn–Pgn^1	62.2 (7.75)	71.5 (9.60)	0.000
S^1–Pgn	101.7 (6.72)	108.9 (8.84)	0.001
Position of the hyoid bone (mm)			
O–H^1	34.9 (4.68)	44.2 (7.02)	0.000
H^1–Pgn	53.5 (7.28)	57.3 (6.88)	0.076
H^1–H^2	14.4 (6.16)	17.7 (5.20)	0.076
S^2–H^1 (vertical)	105.9 (7.12)	117.0 (7.77)	0.000
S^3–H^1 (horizontal)	9.4 (6.08)	15.9 (10.3)	0.004
Position of the head			
CV angle	86.4 (7.30)	84.2 (9.60)	0.320

*Assessed with Student's t-test; P-values ≤ 0.05 were considered statistically significant.

original position after treatment. Vertically, the average change in hyoid bone position (S^2–H^1) was 1.0 mm in an upward direction, but this was not statistically significant. The hyoid bone moved upwards in 63.3 per cent, downwards in 31.7 per cent of cases, and in 5 per cent it remained in its original position after treatment. In addition, the distance from the hyoid bone to the mandible (H^1–H^2) decreased on average 2.3 mm and to pogonion (H^1–Pgn) increased on average 1.7 mm. The position of the head (CV angle) showed extension in 26.7 per cent of the sample, in 71.7 per cent flexion and in the remaining 1.6 per cent it was in its original position post-operatively. Tables 2 and 3 show the amounts and the frequencies of the changes in the position of the hyoid bone and cranium after surgery.

Multiple regression analyses demonstrated that the amount of the horizontal and vertical

Table 2 Changes (pre-surgical minus one-year post-surgical means/medians) in mandible, hyoid bone, and head positions of 60 adults with surgical mandibular advancement procedure.

	Mean	Median	SD	P*	Min	Max
Position of the mandible (mm)						
Pgn–Pgn^1	–5.0	–5.1	3.1	0.000	–13.9	3.9
S^1–Pgn	–2.0	–2.0	2.1	0.000	–6.1	3.7
Position of the hyoid bone (mm)						
O–H^1	–0.8	–0.9	3.1	0.095	–10.9	7.2
H^1–Pgn	–1.7	–1.6	4.6	0.029	–10.2	11.3
H^1–H^2	2.3	2.3	3.5	0.000	–7.2	11.7
S^2–H^1 (vertical)	1.0	1.0	3.7	0.365	–10.9	12.3
S^3–H^1 (horizontal)	–2.4	–2.5	4.6	0.001	–12.7	18.4
Position of the head						
CV angle	2.1	2.5	5.5	0.014	–10.0	15.5

*Multivariate analysis of variance (MANOVA), gender as cofactor.
P-values ≤ 0.05 were considered statistically significant.

Table 3 Distributions (%) of the subjects according to different types of changes in the mandible, hyoid bone, and head position after mandibular advancement. A comparison of pre- and one-year post-surgery measurements of 60 patients with mandibular advancement procedure.

	Increase	Decrease	No change
Position of the mandible (mm)			
Pgn–Pgn^1	96.7	3.3	0
S^1–Pgn	85.0	11.7	3.3
Position of the hyoid bone (mm)			
O–H^1	63.3	31.7	5.0
H^1–Pgn	66.7	30.0	3.3
H^1–H^2	20.0	68.0	2.0
S^2–H^1 (vertical)	31.7	63.3	5.0
S^3–H^1 (horizontal)	78.3	16.7	5.0
Position of the head			
CV angle	26.7	71.7	1.7

change was associated with the corresponding changes in the mandible after surgery (Table 4). The vertical change was also associated with gender, being smaller in males than females.

Discussion

In this study, the pattern of mandibular translatory movement followed by hyoid bone movement showed a forward and upward placement after surgical mandibular advancement. These findings are in agreement with those of Hayes *et al*. (1994), in which the movement was described as superior and slightly anterior. In the present sample, the hyoid bone remained in its original position in 5 per cent of the sample when evaluated one year after surgery. Schendel *et al*. (1978), and LaBanc and Epker (1984) reported a tendency for the hyoid bone to return almost to its original pre-operative position. The present results only partly confirm that finding, perhaps due to the fact that only one year elapsed between measurements, compared with the 10 years in their investigations. Interestingly, almost one-third of the subjects in this study showed a forward, but also a downward placement of the hyoid bone. The nature of the vertical position of the hyoid bone seems to be rather variable.

The hyoid bone moved closer to the body of the mandible after surgery, which may be due to stretching of the hyoid muscles as the active and balancing forces of the supra- and infra-hyoid muscles determine the hyoid bone position. Likewise, the cranio-vertebral joints maintain their normal position, and the temporo-mandibular joints remain equally balanced towards the cranium through tensile forces produced by the normal function of the supra- and infra-hyoid muscles. Therefore, the position of the hyoid bone is a reflection of the tensions in the muscles, ligaments, and fascia attached to it (Rocavado, 1983; Winnberg and Pancherz, 1983; Wenzel *et al*., 1985), and changes in this environment also change the position and function of the hyoid bone.

In this investigation, 28.3 per cent of the subjects showed posterior rotation and 71.7 per cent anterior rotation of the cranium one year post-surgery. Schendel and Epker (1980) and Pim Valk *et al*. (1992) also reported alterations in head posture after mandibular advancement, leading to flexion of the head, and causing a change in length and tension of the related musculature. On the other hand, Phillips *et al*. (1991) described a significant head flexion immediately after surgery, followed by head extension and a reversion toward pre-treatment

Table 4 Associations between changes in hyoid bone and mandibular position after mandibular advancement, controlling the effect of gender. Only statistically significant coefficients are listed. Pre-surgery and one-year post-surgery of 60 patients in surgical mandibular advancement procedure.

Independent variable	Hyoid bone position			
	H^1–Pgn		S^2–H^1 (vertical)	
	Regr. coeff.	*P*	Regr. coeff.	*P*
Pgn–Pgn^1	0.543	0.000		
S^1–Pgn			0.248	0.051
Gender			–0.274	0.031

P-values ≤ 0.05 were considered statistically significant.

posture. One year post-surgery, the mean values were approximately the same as prior to surgery. There seems to be clear adaptive changes in head posture after mandibular advancement, but long-term post-surgical change seems difficult to predict.

A line determined 7 degrees down to the sella-nasion plane was used on the lateral cephalograms as a horizontal reference plane (Bjerin, 1957). This plane is considered to be easier and more reliable to identify than Frankfort Horizontal or the true horizontal plane (Proffit, 1995). However, examination of the patient's orthognathic head position might have been a better option to understand the equilibrium between the head over the cervical spine. This orthognathic head position (Fonder, 1977; Gelb, 1977; Rocavado, 1983) lines up the malar bone, claviculae, and pelvis with the scapular and pelvic belt. Thus, any factor disturbing the balance of one of these could produce a change in head posture, which can further affect the position of the mandible and the tongue. Alteration of the mandibular position due to surgical procedures also modifies the tongue and head position, and affects further, for example, the pelvic equilibrium, and thus the position of the spine, legs, the sitting position, shoulders, head, and finally tongue and mandible.

Conclusions

The results of this study indicate that with surgical mandibular advancement the hyoid bone follows mainly the advancement of the mandible. It moves closer to the body of mandible, which might be due to the tensile forces of the attached musculature. Post-surgery, head posture shows flexion in most cases. However, there is a variation in the changes of the hyoid bone and head position, and their final position is difficult to predict. It may be that a more comprehensive pre-operative examination of the patient's orthognathic head position could be useful in assessing how and why the surgical procedure changes hyoid bone position and head posture.

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