Long-term changes in hyoid bone position and craniocervical posture in complete denture wearers

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Changes in hyoid position in relation to changes in mandibular inclination and craniocervical posture were studied by roentgen cephalometrics in a sample of 24 long-term complete denture wearers over a 15-year period. The measurements were made on lateral occlusion films obtained with the subjects in the sitting position and with the head oriented according to its natural balance. The changes in mandibular inclination ranged from −5.5° to 8.6°, with a mean of zero. The cervical column became significantly more forward inclined (mean, 5°), and the craniocervical angulation became on an average 5° larger. Correlation analyses indicated that the hyoid position was influenced by two postural systems: the changes in mandibular inclination and the changes in cervical and craniocervical posture. The vertical changes in hyoid position in relation to the upper face largely followed the patterns of increase or decrease in mandibular inclination, whereas the horizontal changes mainly followed the changes in cervical inclination and craniocervical angulation. □ *Cephalometrics; denture wearers; head posture; hyoid position*

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Insertion and use of complete dentures cause changes in position and function of the mandible and the tongue. These functional relationships are also dependent on head and cervical posture. The changes in mandibular and tongue position in denture wearers are related to resorption of the residual alveolar ridges and the resultant positional changes of the dentures on the underlying tissues.

To further elucidate etiological problems connected with these interrelationships, a thorough knowledge of changes in head and tongue position in denture wearers is of importance. Changes in tongue position can to some extent be assessed by analysis of changes in hyoid position, and some studies have been published on this subject.

In dentate individuals studies of hyoid bone changes have shown that the hyoid adapts to anteroposterior alterations in head position (1, 2) and to changes in mandibular inclination (3). Furthermore, investigations of the hyoid position in relation to the facial skeleton and the cervical column have indicated that the hyocervical relationship is more stable than the relationship of the hyoid to the skull and the mandible (1, 4–6).

In denture wearers few studies of changes in hyoid position and head posture have been carried out. In a previous roentgen cephalometric investigation of individuals provided with immediate complete upper and lower dentures (7), changes in the hyoid position and the craniocervical posture were studied after insertion of the dentures and during 1 year of denture wear. The findings indicated an average downward positioning of the hyoid bone at the post-insertion stage, which probably was related to changes in tongue position due to insertion of the upper and lower complete dentures. During the 1-year period of denture wear the resorption of the residual ridges caused a forward–upward rotation of the mandible, which was largely accompanied by a similar movement pattern of the hyoid bone. Similar findings that the hyoid bone moved in the same direction as the mandible but not to the same extent, were reported by Jennings (8) in a study of jaw movements in completely edentulous subjects.

In the above-mentioned study of immediate complete denture wearers (7), the posture of the head and the cervical column showed no significant mean changes during

the 1 year. On the other hand, analysis of individual changes indicated that a pronounced decrease in mandibular inclination due to ridge resorption was associated with a retroclination of the cervical column and a decrease in craniocervical angulation. These changes were regarded as adaptive postural changes resulting from the rapid initial alteration in mandibular position. At the same time, the distance from the hyoid bone to the cervical spine showed a mean increase. The hyocervical changes showed less variability than the hyoid bone changes in relation to the maxilla and the mandible.

Long-term wearing of complete dentures has been shown to be associated with a marked decrease in mandibular inclination due to resorption of the residual ridges and accompanying changes in occlusal relationships of the dentures (9, 10).

The present study aims to investigate in a sample of long-term denture wearers changes in hyoid bone position in relation to changes in mandibular inclination and in craniocervical posture.

Materials and methods

The sample consisted of 24 women provided with conventional complete upper and lower dentures at the Institute of Dentistry, University of Helsinki. Twenty of the subjects had their first examination after 10 years of denture wear and thereafter 15 years later—that is, after a total of 25 years' use of complete dentures (11, 12). For 13 of these subjects new dentures had been constructed during the observation period. The other four subjects were followed up from the pre-extraction stage to 15 years of denture wear. These four subjects were included in the study to represent marked decrease in mandibular inclination due to alveolar ridge resorption, and for these subjects only rebasing of the dentures had been performed. The age range of the subjects at the later observation stage was 35 to 88 years, and the mean age 70 years.

Radiographic procedure

Lateral head films were obtained with the subjects in the sitting position with the head oriented in accordance with its natural balance, as described by Tallgren (11). The head films were taken with the aid of a Björk's cephalostat, and care was taken that no strain or change in head posture occurred when fixing the head in the cephalostat. Exposures were made in habitual occlusion and in mandibular postural position, but the present analysis comprises only the occlusion films.

Cephalometric analysis

The roentgen cephalometric analysis was carried out at the Institute of Orthodontics, The Royal Dental College, Copenhagen. The craniofacial and cervical reference points and lines are shown in Fig. 1. The reference lines NSLP/n, NLP/sp, and MLP/gn are the perpendiculars to NSL, NL, and ML through points n, sp, and gn, respectively. The hyoid point (hy) was defined as the most anterosuperior point on the hyoid bone. The other reference points and lines were defined in accordance with Solow & Tallgren (13). The variables studied are described in Tables 1 and 2. Because no lead wire was used during exposure to indicate the true vertical on the film, the left border of the cephalogram was used as the vertical reference line.

For each subject the reference points were marked with a sharp soft pencil on the film from the first observation stage. Subsequently, the reference points on the cranial base and the maxilla were transferred from the film from the first stage to the film from the later stage by superimposing the two films, using the basal cranial and maxillary structures as references. Correspondingly, in marking the mandibular, cervical, and hyoid reference points on the film from the later stage, the location of the points was transferred by superimposing the two films, using the respective bone structures as references.

The x- and y-coordinates of the reference points were digitized by a D-Mac Pencilfollower directly from the films, as described by Solow & Tallgren (13, 14). The values of the variables were calculated from the x- and

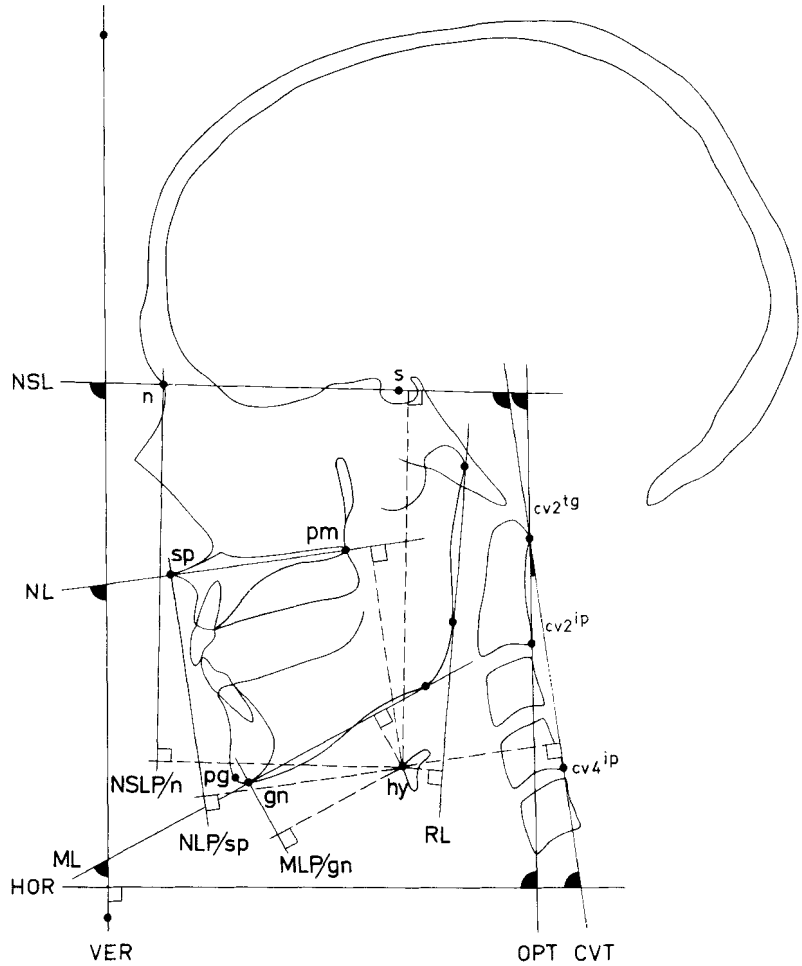

Fig. 1. Reference points and lines on the profile cephalometric films. The perpendicular distances from the hyoid (hy) to the reference lines are indicated.

y-coordinates of the reference points. No corrections were made for the roentgenographic enlargement of 6.6%.

Errors of the method related to marking and recording of the craniofacial reference points have been previously reported (13), and the reproducibility of the head position has also been described (14). To assess the reproducibility of the hyoid bone position, the material used by Solow & Tallgren (14) was reanalyzed. This material comprised two series of recordings of the natural head position (self-balance position) obtained from 21 subjects with an interval of 2 months. No systematic errors were found for any of the hyoid position variables. The errors of the method, s(i), (Table 2) ranged from 1.0 mm to 2.3 mm. The variances of the method errors constituted 5.5% to 12.1% of the total biological variability of the hyoid variables in the present sample and may be considered small.

The statistical description of the variables was made in accordance with Solow (15). The associations between pairs of variables were assessed by means of product–moment correlation coefficients. Individual facial diagrams from the two stages were produced by the Plotcheck program (13). All calculations were performed at the IBM 3033

Table 1. Statistical description of mandibular position and head and cervical posture at stage I. Values are given in degrees and mm. Sample size = 24

Variables	Min.	Max.	$\bar{x}$	SD	$\sqrt{b1}$	b2
Mandibular position						
NSL/ML	10.3	39.9	26.13	6.85	−0.278	2.79
NL/ML	3.8	32.7	18.88	6.09	−0.049	3.54
s-n-pg	76.7	96.3	83.97	4.79	0.885	3.35
n-gn	92.2	122.7	110.49	7.91	−0.456	2.59
sp-gn	44.4	74.4	58.84	7.28	−0.085	2.48
Head and cervical posture						
NSL/VER	88.5	106.4	99.01	4.30	−0.465	2.95
NSL/OPT	76.7	104.9	88.19	7.98	0.567	2.26
NSL/CVT	84.6	106.3	96.06	6.29	−0.119	2.09
OPT/HOR	84.0	113.7	100.82	7.99	−0.300	2.45
CVT/HOR	79.7	105.8	92.95	5.70	−0.125	3.28
OPT/CVT	−1.4	16.8	7.87	3.78	0.110	3.79
ML/CVT	58.2	92.5	69.94	7.48	0.797	4.71
RL/CVT	4.2	28.0	15.66	6.07	−0.096	2.35

installation at NEUCC, the Northern Europe University Computing Centre in Copenhagen.

Results

Descriptive statistics for mandibular position and head and cervical posture at the first stage of observation are shown in Table 1 and for hyoid bone relationships in Table 2.

The means for the inclination of the mandible (NSL/ML, NL/ML) and anterior facial heights (n-gn, sp-gn) were low as compared with adult dentate samples (11, 13). This is because, at the initial observation stage, the

Table 2. Statistical description of the hyoid relationships at stage I. Values are given in mm. Sample size = 24

Variables	Min.	Max.	$\bar{x}$	SD	$\sqrt{b1}$	b2	s(i)*
Hyoid to upper face							
hy to NSL	91.6	113.0	104.41	5.82	−0.458	2.68	2.230
hy to NL	45.3	69.5	58.95	6.28	−0.117	2.62	2.154
hy-sp	56.9	87.2	77.64	6.83	−1.252	4.70	1.609
hy to NSLP/n	42.6	70.5	60.38	6.99	−0.863	3.05	1.990
hy to NLP/sp	34.3	60.1	50.09	7.27	−0.643	2.47	2.020
Hyoid to mandible							
hy to ML	1.7	26.0	14.25	5.03	−0.459	4.27	1.761
hy-pg	37.3	67.4	49.18	6.05	0.685	5.07	1.816
hy to MLP/gn	27.3	58.8	39.69	7.04	0.360	3.80	2.297
hy to RL	6.1	28.1	15.17	5.64	0.549	2.73	1.769
Hyoid to cervical							
hy to CVT	43.4	60.7	50.98	4.27	0.355	2.73	0.999
hy-cv4^{ip}	43.7	61.3	51.41	4.35	0.347	2.76	1.079

* Material from Solow & Tallgren (14); sample size = 21.

majority of the subjects had already been using complete dentures for 10 years without any corrections for lost vertical dimension.

Changes in mandibular position and hyoid bone relationships

The mean changes in mandibular position and hyoid bone relationships to the upper face, the mandible, and the cervical column during the 15-year period are given in Table 3.

The changes in mandibular inclination in relation to the cranial base and maxilla (NSL/ML, NL/ML) ranged from −5.5° to 8.6°. Eleven subjects displayed a decrease in mandibular inclination (NSL/ML) due to alveolar ridge resorption, 1 person showed no change, and 12 subjects showed an increase owing to construction of a new set of complete dentures. The mean change in mandibular position was practically zero.

The vertical distances from the hyoid bone to the maxilla and cranial base (hy to NL, hy to NSL) showed mean increases of 1.8 mm ($p \leq 0.05$) and 1.3 mm, respectively. The changes in the horizontal direction of the hyoid bone, described by the perpendicular distances hy to NSLP/n and hy to NLP/sp, showed mean increases of 4.1 mm and 3.4 mm ($p \leq 0.01$), respectively. In relation to the mandible, the vertical distance from the hyoid bone to the mandibular line (hy to ML) showed a mean increase of 3.3 mm ($p \leq 0.01$). The perpendicular distance from the hyoid to the ramus line (hy to RL) showed a mean decrease of −4 mm ($p \leq 0.01$), the distance hy-pg an increase of 3.6 mm ($p \leq 0.05$), and the perpendicular distance hy to MLP/gn a nonsignificant increase of 2.4 mm. The changes in hyoid bone position in relation to the facial skeleton displayed great individual variations, the standard deviations ranging from 3.3 mm to 6.2 mm.

Correlations between the changes in mandibular inclination and changes in hyoid position in relation to the upper face showed some significant associations (Table 4). The results indicated that the changes in mandibular inclination (NSL/ML, NL/ML) were, on the average, accompanied by a similar movement pattern of the hyoid bone in

Table 3. Changes in mandibular position and hyoid relationships during 15 years of denture wear. Sample size = 24

Variables	Min.	Max.	$\bar{x}$	SD	$\sqrt{b1}$	b2	t
Mandibular position							
NSL/ML	−5.5	7.3	0.29	3.15	0.221	3.01	0.445
NL/ML	−5.0	8.6	0.26	3.01	0.560	4.22	0.426
s-n-pg	−5.7	3.9	−0.29	2.26	−0.601	3.38	0.621
n-gn	−9.9	9.1	−0.18	4.23	−0.138	3.25	0.213
sp-gn	−9.9	9.0	−0.29	4.20	0.016	3.50	0.344
Hyoid to upper face							
hy to NSL	−8.1	10.2	1.25	4.24	0.016	3.10	1.444
hy to NL	−7.2	11.1	1.80	4.01	0.257	3.47	2.198*
hy-sp	−4.7	13.7	3.60	4.00	0.288	3.26	4.411**
hy to NSLP/n	−4.6	12.2	4.06	4.54	−0.225	2.05	4.373**
hy to NLP/sp	−5.7	13.4	3.42	4.70	0.045	2.28	3.563**
Hyoid to mandible							
hy to ML	−1.2	10.3	3.33	3.34	0.842	2.63	4.893**
hy-pg	−6.6	19.6	3.55	5.81	0.631	3.66	2.992*
hy to MLP/gn	−7.3	18.3	2.38	6.16	0.598	3.23	1.890
hy to RL	−18.0	4.3	−3.99	5.22	−0.671	3.37	3.744**
Hyoid to cervical							
hy to CVT	−5.2	10.6	2.47	3.85	0.078	3.05	3.141**
hy-cv4^{ip}	−3.3	13.8	3.03	4.30	0.858	3.87	3.461**

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

Table 4. Correlations between changes in hyoid relationships and changes in mandibular position and head and cervical posture. Sample size = 24

	Hyoid to upper face					Hyoid to mandible				Hyoid to cervical	
	hy to NSL	hy to NL	hy-sp	hy to NSLP/n	hy to NLP/sp	hy to ML	hy-pg	hy to MLP/gn	hy to RL	hy to CVT	hy-cv4^{ip}
Mandibular position											
NSL/ML	0.60**	0.62**	0.42*	0.07	−0.09	−0.13	−0.64**	−0.69**	0.59**	−0.12	−0.16
NL/ML	0.70**	0.68**	0.52**	0.05	−0.03	0.01	−0.60**	−0.69**	0.57**	−0.19	−0.25
s-n-pg	−0.54**	−0.57**	−0.45*	−0.18	−0.01	0.06	0.61**	0.64**	−0.54**	0.20	0.23
n-gn	0.53**	0.54**	0.28	−0.05	−0.19	−0.33	−0.70**	−0.69**	0.70**	−0.23	−0.26
sp-gn	0.60**	0.62**	0.37	−0.06	−0.15	−0.25	−0.68**	−0.70**	0.69**	−0.24	−0.28
Head and cervical posture											
NSL/VER	−0.35	−0.32	−0.09	0.22	0.18	−0.12	0.27	0.29	−0.21	0.10	0.22
NSL/OPT	−0.39	−0.23	0.39	0.83**	0.75**	0.22	0.66**	0.64**	−0.71**	0.79**	0.82**
NSL/CVT	−0.30	−0.14	0.49*	0.86**	0.78**	0.36	0.71**	0.63**	−0.73**	0.83**	0.85**
OPT/HOR	0.17	0.04	−0.43*	−0.67**	−0.61**	−0.28	−0.48*	−0.44*	0.56**	−0.70**	−0.66**
CVT/HOR	0.08	−0.05	−0.53**	−0.70**	−0.65**	−0.42*	−0.52**	−0.44*	0.59**	−0.74**	−0.69**
OPT/CVT	0.35	0.36	0.37	0.09	0.11	0.53**	0.13	−0.03	−0.08	0.11	0.08

* $p \leq 0.05$.
** $p \leq 0.01$.

relation to the cranial base and maxilla (hy to NSL, hy to NL, hy-sp). Thus a decrease in mandibular inclination—that is, an upward rotation of the mandible due to ridge resorption—was usually accompanied by an upward movement of the hyoid bone, and an increase in mandibular inclination due to construction of new dentures was associated with a downward movement of the hyoid. These associations are illustrated by the individual head plots (Figs. 2 and 3). The horizontal components of the hyoid bone changes in relation to the cranial base and maxilla (hy to NSLP/n, hy to NLP/sp) did not show any correlations with the changes in mandibular inclination. This finding indicates that the hyoid bone movements accompanying the mandibular rotation were mainly vertical.

With regard to hyoid bone changes in relation to the mandible the correlations

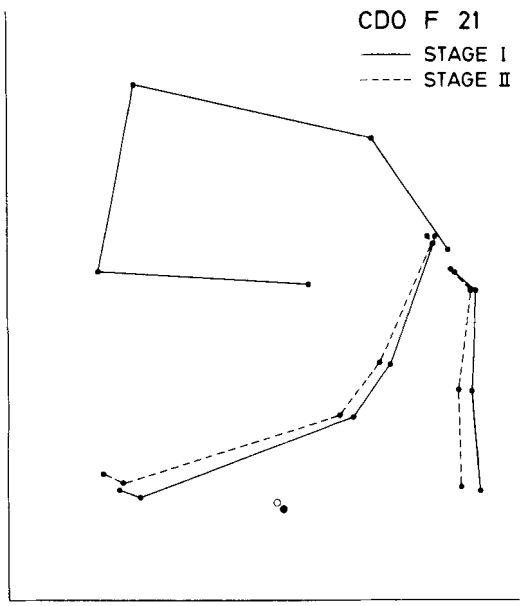

Fig. 2. Individual computer head plots superimposed on the upper facial contours (subject F 21), illustrating a decrease in mandibular inclination (NSL/ML) due to ridge resorption and an accompanying upward change in hyoid position (hy to NSL). The inclination of the cervical column (CVT/HOR) showed a slight increase and the hyocervical distance (hy to CVT) a slight decrease.

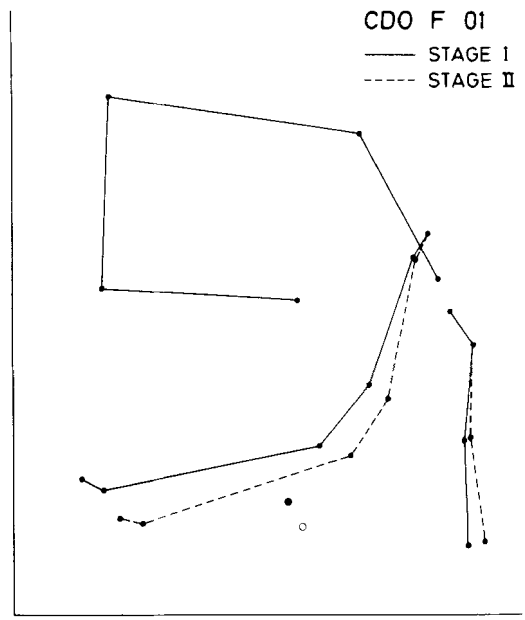

Fig. 3. Individual superimposed computer head plots (subject F 1), illustrating an increase in mandibular inclination (NSL/ML) due to construction of new complete dentures. The hyoid position in relation to the upper face (hy to NSL) showed an accompanying downward change. The inclination of the cervical column (CVT/HOR) showed a slight decrease, and the hyocervical distance (hy to CVT) a slight increase.

(Table 4) indicated that a decrease in mandibular inclination was usually accompanied by an increased distance from hyoid bone to the mandibular symphysis (hy-pg, hy to MLP/gn) and by a reduction of the perpendicular distance from hyoid to the ramus line (hy to RL). The changes in vertical distance from hyoid to the mandibular line (hy to ML) showed no significant correlations with the changes in mandibular inclination. These results indicate that the hyoid bone does not entirely follow the changes in mandibular position.

It should further be noted that changes in distance from the hyoid bone to the cervical spine showed no significance correlations with the changes in mandibular position.

Changes in head and cervical posture

The changes in head and cervical posture during the 15-year period are described stat-

istically in Table 5. The head position in relation to the vertical (NSL/VER) showed no significant mean change during the observation period. However, the cervical column (CVT/HOR) showed a mean decrease in inclination of 5° ($p \leq 0.01$; range −16° to 7°) and a somewhat increased lordosis (OPT/CVT). The craniocervical angulation (NSL/OPT) showed a mean increase of 5° ($p \leq 0.01$). This means that the cervical column, in general, became more forward inclined than at the initial observation stage, and the craniocervical angulation became larger. With regard to the angles between the mandibular base and the cervical column (ML/CVT and RL/CVT), significant mean increases of 6° were observed ($p \leq 0.01$). These changes in cervical posture and craniocervical relations showed great individual variations, the standard deviations ranging from 6.5° to 7.5°.

Correlations between the changes in head and cervical posture and the changes in mandibular position revealed no significant associations (Table 6). As was expected, however, marked correlations ($p \leq 0.05$ and 0.01) were observed between the changes in mandibular position and the changes in angulation between the mandible and the cervical column (ML/CVT, RL/CVT). Thus, a marked decrease in mandibular inclination was associated with an increased angle between the ramus line and the cervical column.

Correlations between changes in head posture and changes in hyoid relationships

Correlations between changes in head and cervical posture and changes in hyoid relationships to the upper face, the mandible, and the cervical column are shown in Table 4.

The changes in hyoid position showed no significant correlations with changes in head position in relation to the vertical (NSL/VER). However, the changes in cervical inclination (CVT/HOR) and in craniocervical angulation (NSL/OPT) displayed marked correlations ($p \leq 0.01$) with changes in the horizontal distances from the hyoid bone to the upper face, mandible, and cervical spine.

Thus a marked forward inclination of the cervical column and an increase in craniocervical angulation were generally accompanied by increased horizontal distances from the hyoid bone to the anterior upper face and mandibular symphysis and by a decreased distance to the ramus line. At the same time the distance from the hyoid to the cervical column showed an increase. This is illustrated by the individual head plot (Fig. 4). The correlation between the changes in craniocervical angulation (NSL/OPT) and the changes in the distance hy to RL is further illustrated by the plot in Fig. 5.

The changes in the vertical relationship of

Table 5. Changes in head and cervical posture during 15 years of denture wear. Sample size = 24

Variables	Min.	Max.	$\bar{x}$	SD	$\sqrt{b1}$	b2	t
NSL/VER	−6.4	9.0	1.20	4.00	0.312	2.59	1.475
NSL/OPT	−5.9	17.2	5.17	6.56	0.020	2.33	3.866**
NSL/CVT	−4.1	18.0	6.10	6.50	0.099	2.08	4.598**
OPT/HOR	−14.0	7.7	−3.96	6.81	0.265	1.90	2.854**
CVT/HOR	−15.8	6.8	−4.89	6.72	0.207	1.82	3.565**
OPT/CVT	−2.2	4.0	0.93	1.74	0.000	2.26	2.610*
ML/CVT	−7.2	21.7	5.82	7.43	0.227	2.14	3.835**
RL/CVT	−7.5	21.1	5.99	7.45	0.276	2.16	3.939**

* $p \leq 0.05$
** $p \leq 0.01$.

Table 6. Correlations between changes in head and cervical posture and changes in mandibular position. Sample size = 24

	NSL/ML	NL/ML	s-n-pg	n-gn	sp-gn
NSL/VER	−0.14	−0.23	0.09	−0.14	−0.14
NSL/OPT	−0.06	−0.17	0.03	−0.17	−0.19
NSL/CVT	−0.07	−0.14	0.05	−0.20	−0.21
OPT/HOR	−0.02	0.02	0.02	0.08	0.10
CVT/HOR	−0.01	0.00	0.01	0.11	0.11
OPT/CVT	−0.05	0.09	0.06	−0.11	−0.04
ML/CVT	−0.49*	−0.52**	0.43*	−0.58**	−0.58**
RL/CVT	−0.43*	−0.48*	0.41*	−0.54**	−0.54**

* $p \leq 0.05$.
** $p \leq 0.01$.

the hyoid bone to the upper face (hy to NSL, hy to NL) showed no significant correlations with the changes in head and cervical posture.

Discussion

In the present sample of long-term complete denture wearers the changes in mandibular position during the 15-year observation period showed marked variability. About half of the sample had a decrease in mandibular inclination due to resorption of the residual ridges, and the other half displayed an increase, owing to construction of a new set of complete dentures.

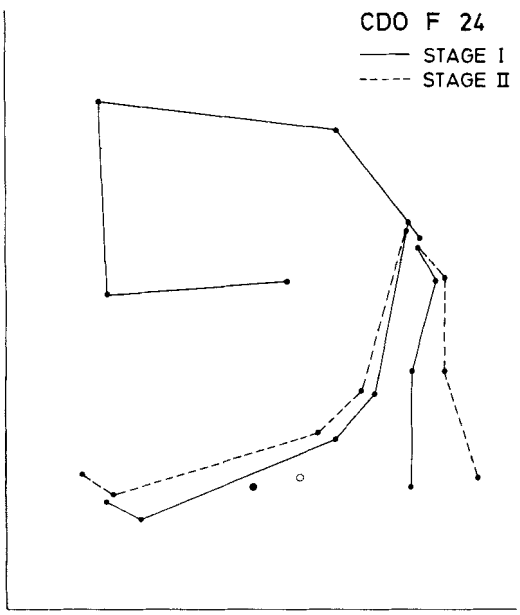

Fig. 4. Individual superimposed computer head plots (subject F 24), illustrating a decrease in mandibular inclination (NSL/ML) and a marked forward inclination of the cervical column. These changes were associated with increased horizontal distances from the hyoid bone to the cervical spine and to the anterior upper face and the mandibular symphysis and a decreased distance to the ramus line.

The correlation analyses indicated that the changes in mandibular inclination were accompanied by similar changes in hyoid bone position. Thus, an upward rotation of the mandible due to ridge resorption was usually accompanied by an upward movement of the hyoid bone in relation to the maxilla, and a mandibular rotation in posterior direction due to an increased vertical dimension was associated with a downward movement of the hyoid bone. However, in relation to the mandibular base the hyoid bone changes did not correlate entirely with the amount of changes in mandibular position. Thus, a pronounced upward rotation of the mandible was generally accompanied by an increased distance from the hyoid to the mandibular line and to the mandibular symphysis and by a decreased distance to the ramus line. Similar findings that the hyoid bone moves in the same direction as the mandible, but not to the same extent, have also been reported in studies of edentulous subjects (8) and of immediate complete denture wearers (7).

Analysis of changes in head and cervical posture in the present sample of long-term denture wearers revealed no significant mean change in head position in relation to the vertical. However, the cervical column

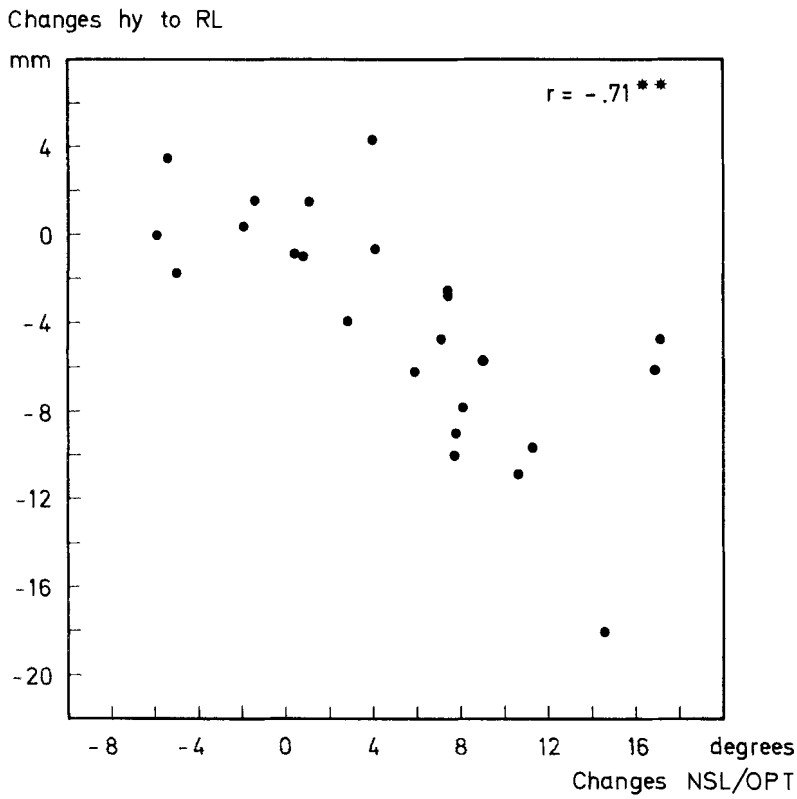

Fig. 5. Plot of the negative correlation ($r = -0.71$, $p \leq 0.01$) between changes in craniocervical angulation (NSL/OPT) and changes in hyoid relationship to the ramus line (hy to RL).

generally became more forward inclined and displayed a somewhat increased lordosis, and the craniocervical angulation became larger. No significant correlations were found between the changes in mandibular position and the changes in craniocervical relationships.

Correlations between individual changes in head and cervical posture and changes in hyoid relationships indicated that a forward inclination of the cervical column and an increase in craniocervical angulation were usually associated with increased horizontal distances from the hyoid bone to the cervical column, to the upper face, and to the mandibular symphysis and by a decreased distance to the ramus line. This is in agreement with the findings on mean changes in these relationships observed during the 15-year period.

The present study of long-term complete denture wearers suggests that the hyoid position is influenced by two postural systems: the changes in mandibular position and the changes in cervical inclination and craniocervical angulation. The changes in mandibular position affect the vertical relationship of the hyoid bone to the cranial base and maxilla and the horizontal relationship of the hyoid bone to the mandible but not the hyocervical relationship; whereas changes in cervical posture affect the horizontal relationship of the hyoid to the cervical column and to the upper face and mandible but not the vertical relationship of the hyoid bone to the upper face.

The above findings emphasize that in studies of hyoid bone position, the hyoid changes should be related not only to changes in mandibular inclination but also to changes in head and cervical posture.

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