Dentofacial morphology in professional opera singers

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The interaction between muscle function and bone development has been studied mainly in animals. The aim of the present investigation was to study the dentofacial skeleton in individuals with a high degree of activity of muscles associated with the facial skeleton. It was assumed that a professional singer would constitute such an individual. Lateral cephalograms of singers from the Royal Opera Choir in Stockholm were studied and compared with lateral cephalograms of a control group. Significant differences between the singers and controls were found, such as length of mandible, length of maxilla, and increased facial height. The findings could be interpreted as an association between facial muscle hyperactivity and respiratory hyperfunction and dentofacial morphology. □ *Cephalometrics; facial growth; muscle hyperactivity*

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In orthodontics bone remodeling is generated from the stimuli initiated by the orthodontic appliance. The stimulus has been identified as mainly a biomechanical one but also as a trigger mechanism, changing the sensory motor feedback pattern of the orofacial musculature, thus creating bone remodeling. Experiments in bone remodeling in humans have shown a significant correlation among bite force, electromyographic (EMG) activity, and facial morphology (1–3). Harvold (4) has shown bone apposition in relation to induced muscular tension zones. Animal experimentation in increased bone remodeling has been done in association with orthodontics but also without the use of conventional orthodontic appliances (5, 6).

In animal studies Woodside et al. (5) and McNamara (7) have demonstrated growth increments of the mandible associated with continuous change of the posture of the mandible. Hard chewing of food has also been shown to increase mandibular body length (8, 9). The flexibility of the facial skeleton with regard to changes of the environment has also been demonstrated via changes in mode of breathing (10, 11). Furthermore, the mode of breathing seems to influence the head posture, and an association between head posture and craniofacial morphology has been reported (12, 13).

Bone remodeling of components of the facial skeleton has thus been found in association not only with an orthodontic appliance but also with factors such as degree of functional use of the mandible, change of head posture, and mode of breathing. The results indicate different approaches to direct bone remodeling of the dentofacial complex.

The aim of the present investigation was to study the dentofacial skeleton of professional singers as healthy individuals with a high degree of facial muscle activity.

Materials and method

The sample comprised members of the Royal Opera Choir, 29 women and 19 men. Only those with a history of singing since before puberty were selected. The controls were dental students, 28 women and 26 men. All students above 25 years from three courses were selected.

The distribution of the material and the mean ages at registration are shown in Table 1.

Lateral cephalograms were obtained of

Table 1. Numbers and mean ages of opera singers and controls

		Age, years
Female singers	29	37.5
Male singers	19	38.0
Female controls	28	31.0
Male controls	26	31.0

the singers and the controls. All participants were registered in the same cephalostat in a seated position, with the head fixed by ear rods and a nose pin.

Each film was traced by one investigator and checked by a second one to verify the accuracy of the 31 landmark placements (Fig. 1). The definitions of reference points and lines used are from Linder-Aronson (10), and those of additional landmarks are given in Table 2. The films were digitized, and the x- and y-coordinates of registered points were stored in a computer at the Eastman Institute. Linear, angular, and point-to-line variables were recorded, and possible differences between group means were tested by Student's t test.

Error of method

The error of the method included double determination of the cephalometric landmarks included in the study. The method errors were calculated with the formula:

$$\text{si} = \sqrt{\frac{\Sigma d^2}{2N}}$$

where d is the difference between two measurements, and N is the number of double determinations.

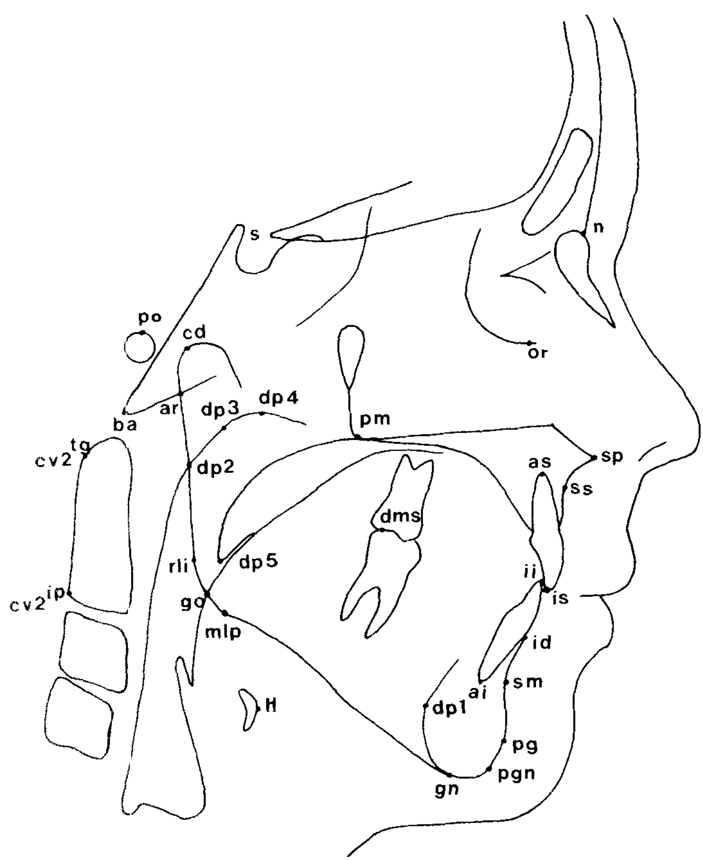

Fig. 1. Reference points on lateral cephalometric films. For definition of landmarks, see Linder-Aronson (10) and Table 2.

Table 2. Definition of additional landmarks

$cv2^{ip}$	The most posterior inferior point on the corpus on the second cervical vertebra
$cv2^{tg}$	The tangent point of OPT on the odontoid process of the second cervical vertebra
dp1	Point of the posterior line of the mandibular symphysis drawn from pg to and parallel to the ML line
dp2	The intersection between the OL line and the pharynx wall
dp3	The intersection between the NL line and the wall of the nasopharynx
dp4	The highest point of epipharynx
dp5	The lowest most inferior tip of the soft palate
H	Hyoid; the most anterior superior point on the body of the hyoid bone (14)
mpl	The posterior tangent point of ML
rli	The lowest tangent point of RL
OPT	Odontoid process tangent; the posterior tangent to the odontoid process through cv2

With one exception (SN/FH) the error of variance (si^2) was less than 3% of the total biologic variance (s^2).

Results

The results of the comparison between female and male singers and controls are shown in Fig. 2, and the significant differences in Table 3. The analyzed variables are grouped with regard to anatomic background.

Discussion

It was the purpose of the present study to assess the possibility of increased bone remodeling in humans without orthodontic appliances, using healthy individuals with an assumed high degree of facial muscle activity. Thus professional opera singers with a history of singing since before puberty provided a unique opportunity to study this subject in humans. The controls were dental students, who could be regarded as a somewhat selected group of normal variation.

Several significant findings were obtained when the opera singers were compared with the controls. Although the cephalograms were recorded with the subjects in a seated position using ear rods and nose pin, the singers demonstrated a significantly more extended head position (NSL/OPT). Since a professional singer sings with his/her head elevated to free the airway space maximally, it is possible that this position also might have influenced the habitual head position.

It is also possible that respiratory hyper-

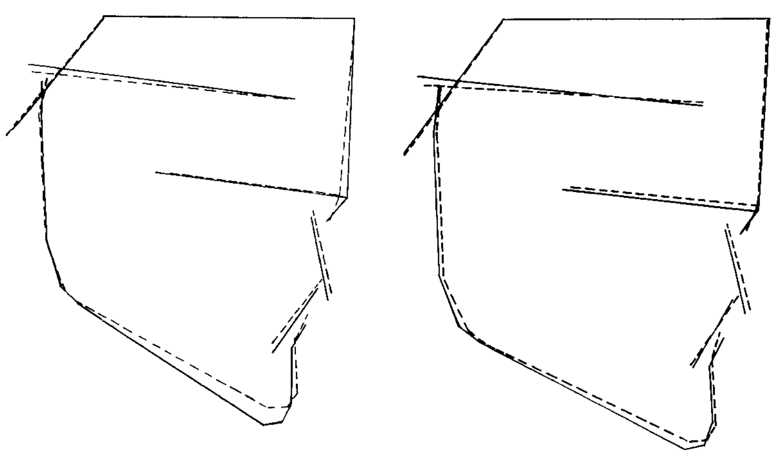

Fig. 2. Mean facial diagrams for female (left) and male (right) opera singers (—) and controls (----). Diagrams were superimposed on the horizontal nasion-sella line and registered on the sella point.

Table 3. Comparison between singers and controls, women and men, respectively. Mean value ($\bar{x}$), standard deviation (s), and t value

	Women					Men				
	Singers, $n = 26$		Controls, $n = 26$			Singers, $n = 19$		Controls, $n = 28$		
	$\bar{x}$	s	$\bar{x}$	s	t value	$\bar{x}$	s	$\bar{x}$	s	t value
Cranial base										
s-ba (mm)	41.2	2.8	43.1	2.8	−2.447*	46.9	2.8	47.5	2.8	−0.721
NSL/FH (°)	7.0	3.7	5.7	3.1	1.373	6.2	3.3	4.3	2.9	2.032*
Maxilla										
sp-pm (mm)	52.3	3.1	48.2	2.3	5.432***	53.6	2.0	51.5	3.5	2.609*
s-n-ss (°)	82.4	3.1	83.5	3.9	−1.126	81.8	3.2	83.8	3.4	−2.050*
s-n-sp (°)	87.9	3.7	85.4	4.1	2.368*	86.1	3.8	86.5	4.4	−0.332
Mandible										
pgn-cd (mm)	113.9	5.0	111.3	4.3	2.010*	122.9	4.9	120.1	4.3	2.019*
go-gn (mm)	69.4	4.5	66.6	3.7	2.451*	73.8	5.1	72.2	3.5	1.190
id-gn (mm)	30.2	3.2	27.6	2.2	3.414**	32.6	3.5	31.2	3.9	1.285
NSL/ML (°)	32.5	7.0	28.6	5.4	2.249*	27.7	5.8	25.9	6.8	0.973
ML/RL (°)	125.6	6.3	122.2	5.9	2.009*	119.0	6.5	118.2	6.3	0.419
Jaw relations										
ss-n-sm (°)	2.9	2.3	3.6	1.6	−1.552	1.6	2.6	3.1	2.3	−2.032*
NL/ML (°)	25.7	7.4	21.7	4.7	2.327*	21.6	4.5	20.0	5.3	1.112
Nasopharynx										
pm-dp3 (mm)	26.3	2.9	27.8	2.7	−1.930	27.5	2.4	27.4	2.3	0.143
dp4/pm-dp3 (point to line, mm)	15.1	2.6	15.0	1.9	0.158	17.5	3.4	14.7	2.2	3.168**
Dentoalveolar										
ILi/ML (°)	87.7	6.2	81.3	6.6	3.604***	86.9	7.7	82.3	7.2	2.063*
Facial height										
n-gn (mm)	114.1	6.8	109.4	4.8	2.879**	120.7	6.3	117.0	6.2	2.008*
sp-gn (mm)	66.4	6.5	61.0	4.2	3.558***	68.4	5.6	67.0	4.8	0.890
Additional variables										
pm-dp5 (mm)	36.6	4.1	34.0	4.2	2.589*	40.1	5.2	37.0	3.0	2.271*
is-dms (mm)	31.1	3.4	28.4	2.7	3.171**	33.3	4.1	29.5	3.1	3.429***
dms-dp2 (mm)	47.5	5.8	50.2	4.5	−1.875	48.4	6.5	51.9	3.8	−2.115*
NSL/OPT (°)	105.7	5.2	99.0	5.2	4.646***	104.6	7.6	99.8	5.5	2.365*

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

activity in opera singing, in which mouth breathing is necessary, may result in a changed head position. Extended head position has also been found in other types of mouth breathers, such as individuals with obstructed nose passages (10, 11, 13).

The statistically significant differences between the professional singers and the controls with regard to different variables for the mandible, the maxilla, facial height, and epipharynx could be explained by hyperfunction of the muscles associated with the craniofacial complex and by the mode and strength of ventilation. In particular, the significant finding of an increased length of the soft palate among singers could be interpreted as a result of muscular hyperfunction. This could be tested in patients by EMG studies to determine whether hyperfunction truly exists (1).

Differences in singing technique, such as mouth opening, and differences in widening of the pharynx in, for example, soprano and bass, and differences in individually different time periods of active singing might explain why the statistically significant findings for the male and female singers were not in accordance.

The findings cannot be interpreted only as an associated relationship but may also be influenced by constitutional factors. For example, it is possible that an individual who achieves the status of professional singer is originally anatomically different or favored.

A longitudinal study is therefore in progress, registering children since their start of advanced singing training. That study will elucidate the impact of muscle hyperfunction on craniofacial morphology.

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