A proportional analysis of the soft tissue facial profile in young adults with normal occlusion

Anders Lundström, DDS, PhD, DSc, DDSc; Carl-Magnus Forsberg, DDS, PhD; Sheldon Peck, DDS, MScD; and John McWilliam, DDS, PhD

Cephalometric analyses have been focused mainly on skeletal relationships, described by an imposing number of variables. Facial disharmony has been assessed by comparing the cephalometric data of a patient with means and standard deviations derived from individuals showing good occlusion. Such analyses help to quantify individual deviations from the normal and facilitate treatment planning, intercolleague communication, and the teaching of treatment procedures.

It has been shown previously that the soft tissues vary in thickness over different parts of the facial skeleton. Consequently, the outline of the soft tissue profile does not correspond well with the underlying skeletal framework.[2,3] A complete analysis of the facial profile, therefore, should also include an evaluation of soft tissue morphology.

Cephalometric standards of the soft tissue profile have been established by Burstone,[4] Peck and Peck,[1] and Holdaway.[3] Burstone used the Herron sample of 40 profiles selected for "good or excellent faces" by four artists, whereas the norms established by Peck and Peck were based on a sample of 49 young women and three young men, popularly acclaimed to possess "pleasing facial esthetics". Forsberg and Odenrick[5] obtained soft tissue standards from subjects selected on the basis of good occlusion. Their study was limited to the description of the relationship between the lips and the E-line[6] at various stages of development.

In recent years, there has been increasing recognition that facial esthetics should be assessed in relation to natural head position (NHP).[7-15] The NHP is a standardized orientation of the head with the eyes focused on a distant point at eye

Abstract

A proportional soft tissue profile analysis is presented, based on natural head position (NHP) and an extracranial vertical reference line through Porion. Twelve linear soft tissue variables and norms for 11 indices expressing vertical and horizontal soft tissue proportions of the face were obtained from lateral skull radiographs of 40 Swedish adults (20 males, and 20 females) with good occlusion. Sexual dimorphism, with larger dimensions in men than in women, was most pronounced in the vertical plane. With regard to facial soft tissue proportions, significant differences between men and women were found only for those indices which involved measurements of lower jaw prominence and facial height.

The means and standard deviations for six indices in the female group were compared with corresponding data obtained from the Peck and Peck sample,[1] which had been selected on esthetic grounds. The results showed a close match between the groups.

The proportional soft tissue analysis is recommended for the treatment planning of patients scheduled for orthognathic surgery.

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Key Words

Face • Soft tissue analysis • Cephalometrics • Natural head position

Figure 1
Horizontal and vertical distances used for the proportional analysis of the facial profile configuration. The vertical line through Porion (PO) registers natural head position of subjects.

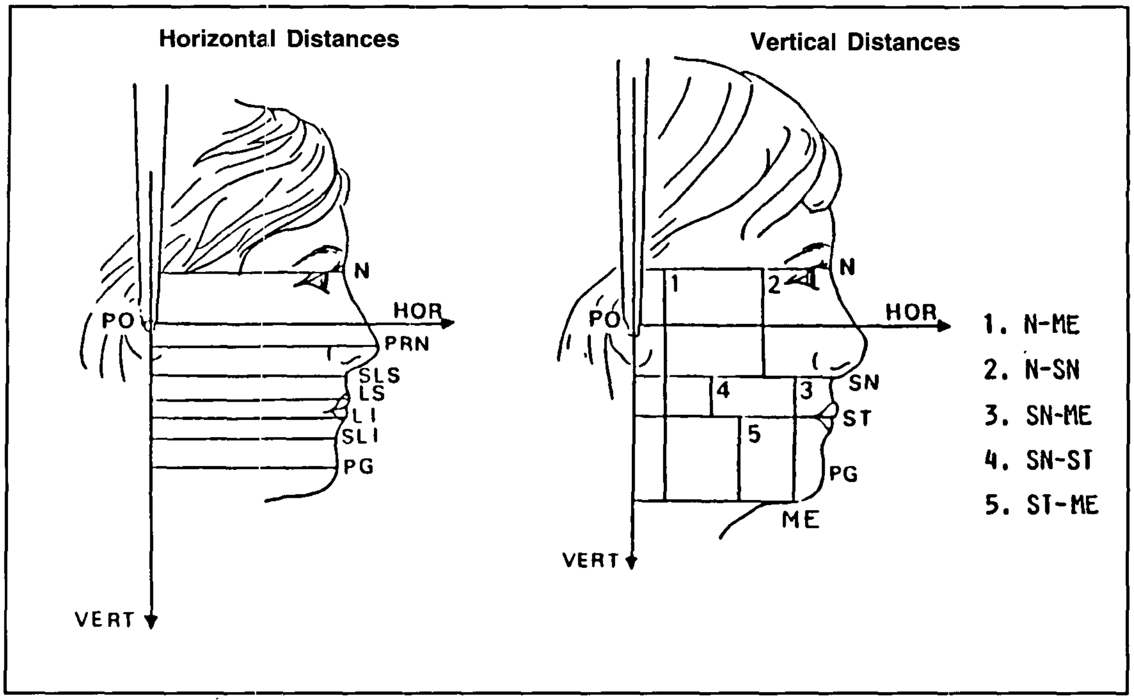

Figure 1

level. Cooke[12] claimed that NHP should be the head position of preference for profile evaluation because it reflects the everyday true life appearance of people. A further advantage of NHP is that it provides the use of an extracranial reference line (true vertical or horizontal) for cephalometric analysis. Admittedly, measurements based on an extracranial reference line may be affected by the variability associated with the reproducibility of NHP. This variation is small (close to 2 degrees) however, in comparison with the considerable biological variation (SD 4 to 6 degrees) in the inclination of conventional intracranial reference lines (e.g. Sella-Nasion, Frankfurt Horizontal).[16]

A proportional soft tissue analysis based on lateral headfilms, exposed in NHP, has been used previously by Lundström and Cook[17] to compare the profiles of British and Chinese children.

Objectives

1. To design a proportional soft tissue analysis based on lateral cephalograms oriented in natural head position (NHP).

2. To determine norms for horizontal and vertical facial proportions in Swedish adult males and females with normal occlusion.

3. To compare soft tissue profile proportions of Swedish females with corresponding data obtained from a sample of North American females, selected on esthetic grounds.

Materials and methods

Sample 1 consisted of 40 Swedish dental students, 20 men and 20 women, approximately 25 years of age, selected according to the following criteria:

- •Complete dentition, third molars excluded;
- •Neutrocclusion of the dental arches with normal overbite and overjet;
- •Minimal spacing or crowding;
- •No history of orthodontic treatment.

The second sample consisted of 49 North American women of European ancestry, with a mean age of 21 years, selected for good facial esthetics (the Peck and Peck sample[1]).

In the first sample, the proportional analysis[17] was based on soft tissue tracings of standardized lateral skull radiographs. These films were taken in centric occlusion, with the lips in light contact and with relaxed perioral musculature. In the second sample, the same analysis was performed on right profile photographs.

At the time the material was collected, the significance of NHP was not fully recognized. Consequently, registrations of natural head position were not available in either sample. Therefore, the tracings and photographs had to be subjectively oriented to a natural head position. This method has been tested previously and proved to be satisfactory when compared with an objectively registered orientation (diff 0.7 degrees $\pm$ 0.9 degrees, not statistically significant[18]).

Sample 1

Individual outlines of the soft tissue profile from the upper part of the forehead to the lower part of the chin were drawn on tracing film. The reference point Porion (ear rod center)* was also marked.

Table 1
Indices expressing facial proportions

Horizontal

1. Nasal prominence (PO-PRN/PO-N x 100)
2. Upper jaw prominence (PO-SLS/PO-N x 100)
3. Lower jaw prominence (PO-SLI/PO-N x 100)
4. Upper/lower jaw (PO-SLS/PO-SLI x 100)
5. Lip relationship (PO-LS/PO-LI x 100)
6. Chin eminence (PO-PG/PO-SLI x 100)
7. Chin prominence (PO-PG/PO-N x 100)
8. Facial convexity (PO-SLS/(1/2)(PO-N+PO-PG) x 100)

Vertical

9. Upper/lower face height (N-SN/SN-ME x 100)
10. Upper/lower jaw height (SN-ST/ST-ME x 100)

Vertical/horizontal

11. Face height/depth (N-ME/PO-PG x 100)

Table 2
Mean differences ($\bar{x}_d$) between double determinations (n=18), standard error of single index determinations (Si), standard deviations (SD) for the total sample (males and females).

Index (cf Table 1)		$\bar{x}_d$*	S_i**	SD
1.	PO-PRN/PO-N	-0.2	1.4	2.7
2.	PO-SLS/PO-N	0.6	2.4	2.8
3.	PO-SLI/PO-N	1.1	2.5	2.8
4.	PO-SLS/PO-SLI	-0.6	1.1	2.7
5.	PO-LS/PO-LI	-0.6	0.8	1.5
6.	PO-PG/PO-SLI	0.6	1.0	1.6
7.	PO-PG/PO-N	1.2	2.9	3.4
8.	PO-SLS / 1/2(PO-N+PO-PG)	0.0	0.5	2.5
9.	N-SN/SN-ME	0.5	3.0	7.2
10.	SN-ST/ST-ME	1.2	1.2	4.7
11.	N-ME/PO-PG	0.1	2.3	5.9

* *all x_d values show statistically non-significant deviations from 0*

** $Si=\sqrt{\sum d^2 / 2n}$

Each tracing was then placed on the lighted glass surface of a digitizer and rotated back and forth (by author A.L.) within the rectangular measurement field of the digitizer to estimate natural head position. Then the film and tracing were secured and a line representing the true vertical was drawn through Porion parallel to the vertical edges of the measurement field (Figure 1). Ten soft tissue reference landmarks were digitized for subsequent measurement of 7 horizontal and 5 vertical dimensions, also shown in Figure 1. All linear measurements were corrected for radiographic magnification. The dimensions were used to calculate 11 indices that express size-independent facial proportions (Table 1).

Sample 2

Right-profile photographs of the 49 women in the original study by Peck and Peck[1] were reproduced as enlarged overhead transparencies. Each photograph was taped to the measurement table of the digitizer in an estimated natural head position. In almost all instances, this orientation was identical to that found in the original publication.[1] The analysis of this sample was limited to 6 of the 11 indices.

Method errors

In order to assess the magnitude of the method errors, 18 subjects from sample 1 were retraced after an interval of about 2 months. Thereby sys-

* In this study, the reference point Porion was defined as the center of the ear rod because this point is easily located on both the radiographs of sample 1 and the photographs of sample 2. Antero-posteriorly, this point coincides with the conventional Porion located at the mid-point of the upper edge of the ear rod. Since Porion was involved only in antero-posterior measurements, the difference in landmark definition is irrelevant. When bony Porion is used instead of ear rod Porion, the horizontal index values are the same since both numerator and denominator are changed equally (i.e. the antero-posterior difference between the landmarks). The index facial height (N-ME) to facial depth (PO-PG), however, is affected slightly. A positive difference of 3 mm of PO-PG, for instance, reduces the male mean index value from 127.0 to 123.1.

Table 3

Mean values ($\bar{x}$) in mm, standard deviations (SD), and mean differences (diff) between males and females for 12 linear soft tissue variables. Sex differences in percent of the the female means are also given. p= level of significance.

	Males		Females				
Variable	$\bar{x}$	SD	$\bar{x}$	SD	diff	p	percent
Horizontal							
PO-N	99.8	3.5	92.5	2.9	7.3	***	7.9
PO-PRN	129.4	4.3	113.5	4.0	9.9	***	8.7
PO-SLS	103.6	3.8	97.0	3.4	6.6	***	6.8
PO-LS	106.6	4.1	100.3	3.2	6.2	***	6.2
PO-LI	103.3	4.1	97.2	3.4	6.1	***	6.3
PO-SLI	94.7	3.0	90.2	3.6	4.5	***	5.0
PO-PG	97.1	3.1	92.8	4.1	4.3	***	4.6
Vertical							
N-ME	123.2	5.6	112.8	4.2	10.4	***	9.2
N-SN	51.3	2.5	47.7	3.7	3.6	***	7.5
SN-ME	71.9	5.0	65.0	3.4	6.9	***	10.6
SN-ST	23.0	2.3	21.3	2.1	1.7	*	8.0
ST-ME	48.9	3.5	43.8	2.3	5.1	***	11.6

***p<0.001; *p<0.05

tematic differences and random errors could be determined. The results are presented in Table 2.

By superimposition of the duplicate profile tracings, random errors in estimating NHP could be determined as the angle between the two verticals. The standard deviation for a single observation (the standard deviation of differences divided by the square root of 2) was found to be 1.5 degrees. The mean difference between the first and second observation was statistically non-significant (0.5 degrees $\pm$ 0.5 degrees), indicating negligible systematic errors over time.

Nonetheless, the standard deviation of double determinations are not negligible and this error is reflected in the standard deviations.

Results

Facial dimensions and proportions in sample 1

Mean values for the 12 distances and 11 indices studied are presented in Tables 3 and 4. As expected, all mean facial dimensions recorded were significantly larger in males than in females. These sex differences have also been expressed as a percentage of the female means (Table 3). Sexual dimorphism was most obvious in height measurements: N-ME 9.2%; SN-ME 10.6%; ST-ME 11.6%. Among antero-posterior dimensions, the most marked differences occurred in variables PO-N and PO-PRN (7.9% and 8.7% respectively), whereas the distances PO-SLI and PO-PG exhibited smaller sex differences (5.0% and 4.6% respectively).

Four indices exhibited statistically significant differences between males and females (Table 4). Soft tissue B point (SLI) and chin (PG) proved to be more prominent in relation to Nasion (N) in females than in males. Soft tissue A (SLS) to B (SLI) landmarks showed a higher index value in males than in females. The index for facial height (N-ME) to facial depth (PO-PG) was found to be higher in males than in females.

Comparison of Swedish and North American samples

The comparison was limited to 6 of the 11 indices studied (Table 5). No statistically significant differences between the means of the samples were found, but the North American females exhibited slightly larger variability (p<0.05) for nasal prominence than the Swedish females.

Discussion

In a previous study it was established that well-trained observers may perform reliable estimations of NHP from profile tracings of conventional radiographs.[18] The indices presented in Table 4 should not, therefore, have been influenced adversely by the fact that they were based on estimates rather than objective registrations of natural head position. One observer (AL) performed all estimates in this study. In general, the estimated NHP corresponded well with that of other observers.[18] It should be noted, however, that the estimations in the present study were based on tracings of "normal" profiles. Estimations of NHP in patients with "abnormal" or disharmonious profile outlines may be more difficult to perform with sufficient precision. In a patient with pronounced profile imbalance, therefore, a soft tissue evaluation according to the present analysis, should preferably be based on an objective registration of NHP. A previously described photographic method has proved useful for this purpose.[14]

In this study, the error of a single determination of NHP was found to be 1.5 degrees. The standard deviations of the variables in Table 3 and Table 4 are probably somewhat enlarged due to this error. The group means, however, should not be affected. In individual cases, on the other hand, the error related to the determination of NHP deserves special attention, since rotating the head around an axis through the left and right ear rods will clearly affect some of the horizontal distances used in the analysis. For example, a flexion of the head by 3 degrees (95% confidence interval) results in a reduction of the projected Porion-Pogonion distance along the horizontal line by 5 mm in an average-size male. At the same time, the distance Porion to Nasion will increase by 1 mm. The combined effect of such changes decreases index No. 7 by six units. A deviation of this magnitude could obviously have some influence on the determination of treatment goals in a clinical situation. Great care should be exercised, therefore, during the registration of NHP. The largest effect of rotational errors in the registration of NHP will apply to indices including the Porion-Pogonion distance (PO-PG/PO-N and N-ME/PO-PG). Other indices are less sensitive to this type of error.

As expected, all linear measurements used in the analysis were significantly greater in men than in women. With regard to facial proportions, on the other hand, significant differences between the sexes were found in only 4 of the 11 indices. Two of these (No. 3 and No. 7) describe the prominence of the lower jaw and chin in relation to Nasion. The values of these indices were significantly greater ($p<0.01$) in women than in men. This result was mainly due to the sex difference in the antero-posterior location of Nasion (7.3 mm) that was comparatively greater than the corresponding difference in the position of SLI (4.5 mm) and PG (4.3 mm). A similar explanation applies to index No. 4 (PO-SLS/PO-SLI), which was also somewhat greater ($p<0.05$) in women than in men.

Index No. 11 (N-ME/PO-PG) was the proportional variable that differed most between the sexes. This finding was not surprising, considering the fact that facial height (N-ME) was substantially greater ($p<0.01$) in men than in women. The horizontal dimension (PO-PG) included in index No. 11 exhibited a sex difference to a lesser degree.

The similarities in soft tissue facial proportions between Swedish women with normal occlusion and North American women, selected for their pleasing looks, was interesting. In spite of the fact that the samples had been selected on the basis of entirely different criteria, the indices in the two groups were nearly identical. This finding may be seen as an illustration of the strong inter-relationship between good facial esthetics and normal occlusion. Further support for the existence of this association arises from the dental examination of the North American sample, revealing that all had relatively normal posterior occlusions, and 25% of the subjects had undergone orthodontic treatment.

Table 4

Mean values ($\bar{x}$) in mm, standard deviations (SD), and mean differences (diff) between males and females for 11 proportional indices. p= level of significance.

No.	Index	Males $\bar{x}$	Males SD	Females $\bar{x}$	Females SD	diff	p
Horizontal							
1.	PO-PRN/PO-N	123.6	3.0	122.7	2.4	0.9	NS
2.	PO-SLS/PO-N	103.8	3.3	104.9	2.2	-1.1	NS
3.	PO-SLI/PO-N	94.9	3.2	97.5	2.5	-2.6	**
4.	PO-SLS/PO-SLI	109.5	2.5	107.6	2.8	1.9	*
5.	PO-LS/PO-LI	103.1	1.2	103.3	1.8	-0.2	NS
6.	PO-PG/PO-SLI	102.6	1.6	102.8	1.5	-0.2	NS
7.	PO-PG/PO-N	97.3	3.6	100.3	3.2	-3.0	**
8.	PO-SLS / 1/2(PO-N+PO-PG)	105.2	2.6	104.7	2.4	0.5	NS
Vertical							
9.	N-SN/SN-ME	71.7	6.4	73.9	8.0	-2.2	NS
10.	SN-ST/ST-ME	47.1	4.4	48.6	5.0	-1.5	NS
Vertical/Horizontal							
11.	N-ME/PO-PG	127.0	5.3	121.7	6.5	5.3	**

**$p<0.01$; *$p<0.05$

The data presented in this study should be particularly useful for soft tissue profile evaluation in patients with dentofacial deformities that may require surgical treatment. The analysis provides a means of objective determination of deviations in vertical and horizontal facial proportions and should be helpful to define the precise area of profile imbalance. Owing to individual differences in awareness of profile anomalies, the analysis should be of interest to patients expressing concern about their facial configuration. The method can be used to present the problem to the patient and in instances of moderate deviation, can help in the decision to treat without surgery. It is also possible to determine how a dimensional change, resulting from surgical correction of a jaw deformity, may affect facial proportions.

Table 5
Comparison between the Swedish female sample with normal occlusion (n=20) and the American Peck and Peck female sample (n=49) selected on esthetic grounds. p=level of significance

No. Index (cf. Table 1)	Swedish[1]		American[2]		diff		Variances	
	$\bar{x}$	SD	$\bar{x}$	SD	1-2	p	2/1	p
1. PO-PRN/PO-N	122.7	2.4	122.5	3.7	0.2	NS	2.4	*
4. PO-SLS/PO-SLI	107.6	2.8	108.9	3.3	-1.3	NS	1.4	NS
5. PO-LS/PO-LI	103.3	1.8	102.8	1.5	0.5	NS	0.7	NS
6. PO-PG/PO-SLI	102.8	1.5	102.1	1.7	0.7	NS	1.3	NS
10. SN-ST/ST-ME	48.6	5.0	50.3	5.2	-1.7	NS	1.1	NS
11. N-ME/PO-PG	121.7	6.5	122.5	8.2	-0.8	NS	1.6	NS

*p<0.5

Naturally, the cephalometric evaluation must be correlated with clinical observations to arrive at proper conclusions. In patients scheduled for orthognathic surgery, however, the present analysis should offer an additional tool to provide information from preoperative assessment throughout postoperative follow-up observation, including evaluation of the results.

Conclusions

1. Natural head position (NHP) is useful in the hard and soft tissue analysis of the facial profile.
2. Variations in the facial profile of adults with normal occlusion can be evaluated using a proportional analysis based on NHP. The method consists of 11 indices obtained from 12 horizontal and vertical facial soft tissue dimensions. The results should be particularly useful for evaluating patients whose facial proportions are severely affected by dentofacial abnormalities.

Author Address

Professor Em. Anders Lundström
Clinical Research Center, F:68
Huddinge Hospital
S-141 86 HUDDINGE Sweden

A. Lundström is Professor Emeritus of Orthodontics, Karolinska Institutet, Huddinge, Sweden.

C-M. Forsberg is Acting Professor at the Department of Orthodontics, Karolinska Institutet, Huddinge, Sweden.

S. Peck is with the Department of Orthodontics, Harvard School of Dental Medicine, Boston, Massachusetts.

J.S. McWilliam is Associate Professor at the Cleft Palate Clinic, Karolinska Institutet, Huddinge, Sweden.

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Commentary

Analysis of the facial profile

Coenraad F.A. Moorrees

The senior author of this paper has long advocated the use of natural head position in cephalometrics to avoid the potentially misleading information often resulting from conventional analyses.

In conventional analyses, the prominence of the chin and the inclination of the mandibular plane are measured by the angles Sella-Naison-Pogonion and Nasion-Sella and the line tangent to the mandibular plane, respectively. The magnitude of these angles is not only determined by the prominence of the chin and the inclination of the mandibular plane, but also by the cant of the reference line Sella-Nasion, or Frankfort Horizontal.

A downward inclination of the Nasion-Sella intracranial reference line decreases the size of the Sella-Nasion-Pogonion angle, but increases the mandibular plane-Sella-Nasion angle. Thus, the wrong conclusion is derived from cephalometric analysis, simply by variation in the cant of the reference line. That variation is inevitable because the landmarks of intracranial reference lines are subject to biological variation, as are the landmarks in the face and soft tissue profile. Registration of the head in its natural position has the advantage that an extracranial vertical or horizontal, rather than an intracranial reference line, can be used for reference purposes.

Natural head position is not a new concept; it is used universally by plastic and maxillofacial surgeons, and by orthodontists for clinical examination of their patients. It is a standardized, reproducible position of the head in an upright posture and the eyes focused on a point in the distance at eye level.

In cephalometrics, natural head position is achieved by instructing the subject, standing or sitting in the cephalostat, to look at a point on the wall exactly at eye level. Natural head position can also be estimated, and these estimates are reproducible when observers are trained, experienced and possess a measure of common sense judgement. A keen eye can inspect radiographs taken by assistants, and if necessary, correct head posture for quality control.

A final comment on this profile analysis concerns proportionate analysis with a rectilinear coordinate system or mesh diagram, based on natural head position, that reveals simultaneous graphic illustration of both sagittal and vertical components of individual variations in facial development, facial dysmorphology, or disharmonious development of the jaws for treatment planning and research.

An array of indices or a myriad of angular measures and distances cannot readily match the immediate visual impact of the mesh diagram analysis. It offers many advantages for comprehensive, efficient and meaningful study of the facial configuration.