Soft-Hard Tissue Correlations and Computer Drawings for the Frontal View

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The composite arrangement of the elements of the human face has long attracted the talents of investigators in disparate fields. The artist has delighted in manipulation of elements of the facial complex to attain esthetically pleasing relationships. The interest of the medical scientist lies in consideration of those elements relevant to successful cosmetic and functional correction of facial deformity. Despite years of interest there exists little data and less agreement upon the elements and determinants of facial form.

The orthodontic literature reflects current concern with the relationships of the facial soft tissue to the etiology, diagnosis, and treatment of deformities within the orofacial region.[1-8] Orthodontic study has limited itself largely to consideration of the static relationship of the soft tissue to the underlying skeleton in the sagittal plane. Despite many hypotheses little hard data have been introduced to identify soft tissue types or to implicate soft tissue in the etiology of deformities.

Population study to yield normative values for soft tissue facial profile has been limited largely to two tactics: (1) derivation of angular values relating soft tissue landmarks to one another or to the facial skeleton and (2) recording of the mean and range for linear measurements of various aspects of the soft tissue drape.[1,4,6-9] Few definitive conclusions can be drawn from these studies as angular measurement, without an external referent, does not distinguish between positional variability in the elements of the angular relationship. Linear measurement which is not normalized yields limited applicable information in the clinical situation. It is not surprising, therefore, to find little agreement on whether or not the soft tissues relate in any predictable fashion to the underlying skeleton.

Study of positional change of soft tissue with orthodontic or surgical treatment has shed some light on the complex interaction of what would seem to be multivariant determinants of the soft tissue drape.[10-13] The soft tissues respond to treatment with a certain degree of predictability which is not strictly definable in terms of change at only one bony landmark.

The goal of the following study is one of testing the feasibility of designing a computer program which displays iconically a predicted face based on studies of photographs and cephalograms with statistical correlation of relationships between hard and soft tissue landmarks. The feasibility in design of such a program would test the hypothesis that positional variation in elements of the soft tissue face can be described from the position of a sufficient number of underlying skeletal landmarks which can be identified radiographically. Further development of this computer model could be extended to several areas of clinical applicability. Description of relationships between hard and soft tissue architecture can

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lead to more accurate recognition of the interaction of bone and soft tissue through growth and development and in the etiology of facial deformities. Computer-aided pattern recognition may substantiate the existence and determinants of skeletal and facial types. Lastly, iconic representations of post-treatment facial pattern can be afforded the clinician.

The material chosen for study consists of standardized frontal photographs and posterior-anterior cephalograms. The frontal plane was chosen as it is of import in esthetic evaluation of the face and, to the writers' knowledge, neglected within the literature relating facial soft tissue to the skeleton.

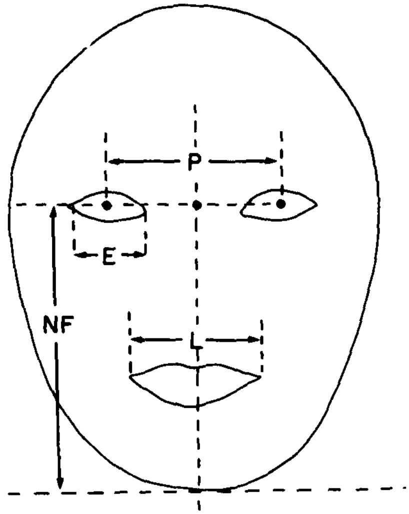

Fig. 1 Reference lines and points used to measure soft tissue facial components: P, interpupillary distance; E, palpebral width; L, lip length; NF, normalization factor.

Methods and Materials

Nine Caucasian females between ages 20 and 30 were selected. All had Angle Class I occlusion and were considered to be in good health.

Frontal photographs were taken of each subject. Camera subject distance was held constant with the lens at the level of the pupil. The subjects assumed the natural head position.[14] The teeth were in occlusion and an attempt was made to achieve a relaxed lip posture.[8]

Standardized posterior-anterior cephalograms were taken for each subject. The orientation of the cranium was that of the natural head position utilizing ear rods to position the subject.

Measurements

On the soft-tissue tracing a horizontal line was drawn through the center of the pupils. All measurements were made either parallel or perpendicular to this interpupillary line and approximated to the nearest .5 millimeter. All measurements were then normalized by dividing by the height of the pupils, obtained by measuring the distance from the pupils along the perpendicular bisector of the interpupillary line to where it meets the most inferior point on the contour of the chin (Fig. 1).

On the cephalometric tracing a line was drawn connecting the lateral corners of the orbits (the superposition of the zygomaticofrontal bone and the petrous ridge) (Fig. 2). All measurements were made either parallel or perpendicular to this line and approximated to the nearest .5 millimeter. Two points were derived on the cephalogram to correspond to the pupils by circumscribing the orbits by rectangles. The "hard-tissue pupils" are taken to be the centers of the circumscribing rectangles. All measurements were normalized by dividing by the distance, along the vertical, from the midpoint of the pupils to the most inferior point on the facial outline.

Correlation coefficients, regression functions, means, and standard deviations were calculated to describe hard and soft tissue relationships.

Computer Program

The computer-graphically-generated

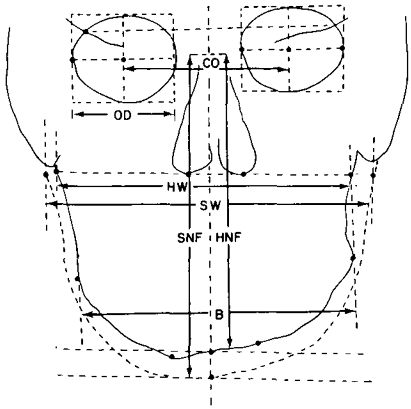

Fig. 2 Reference lines and points used to measure hard tissue facial components: CO, distance between centers of orbits; OD, horizontal orbital diameter; B, bigonial distance; HW, hard tissue width; SW, soft tissue width; SNF and HNF, soft and hard tissue normalization factors.

faces in this study were drawn using a program modified by us which was produced and kindly given to us by Mr. Robert Jacob and Dr. William H. Huggins of the Johns Hopkins University. Their program was based on that designed by Dr. Herman Chernoff (1971) at Stanford University. The program was originally designed for the presentation of multivariate statistical data and was modified by Jacob and Huggins for use in iconic communication. The program[15] is in the Fortran IV language and in our system runs interactively on a DECsystem-10 computer. The output is then plotted as a Calcomp digital drum plotter with an eleven-inch bed.

The data presented describe only those measurements for which significant correlation was found or measurements which help to determine the basic makeup of the face. Other hard and soft tissue relationships were measured; but, because of the small sample size, meaningful statistical information could not be derived.

Table I presents data collected for the separation of pupils. Very strong

TABLE I

Pupil Separation (Normalized)

Subject	*Hard Tissue*	*Soft Tissue*
1	.500	.507
2	.590	.587
3	.615	.605
4	.509	.508
5	.597	.576
6	.520	.543
7	.560	.566
8	.619	.581
9	.600	.566
Mean	.568	.560
S.D.	.047	.034

TABLE II

Palpebral Width (Normalized) VS Orbital Diameter (Normalized)

Subject	*Orbital Diameter*	*Palpebral Width*
1	.301	.246
2	.350	.262
3	.341	.234
4	.325	.237
5	.341	.256
6	.280	.232
7	.347	.262
8	.360	.279
9	.376	.274
Mean	.336	.254
S.D.	.030	.017

correlation, $r = .93$, was found for the hard and soft tissue measurements. Table II presents data collected for the palpebral width (inner canthus to outer canthus) as compared with the horizontal diameter of the orbit (the width of the circumscribing rectangle). Since there were two measurements in each case, the numbers presented are the averages. Here again, strong correlation was obtained, $r = .78$.

Table III presents a comparison between the length of the lips (from commissure to commissure) and the bigonial distance. Here weak, but still significant, correlation was found, $r = .41$. However, it was found that positive correlation, $r = .33$, also exists between the length of the lips and the separation of the hard tissue pupils. Therefore, one would determine the

TABLE III
Lip Length (Normalized)
VS Bigonial Distance (Normalized)

Subject	*Bigonial Distance*	*Lip Length*
1	.885	.471
2	.786	.429
3	.913	.415
4	.816	.381
5	.900	.448
6	.852	.406
7	.931	.443
8	.920	.459
9	.867	.487
Mean	.874	.438
S.D.	.049	.033

TABLE IV
Soft Tissue Width (Normalized)
VS Hard Tissue Width (Normalized)

Subject	*Hard Tissue*	*Soft Tissue*
1	.937	1.081
2	.940	1.139
3	1.087	1.273
4	1.071	1.052
5	1.251	1.262
6	.936	1.083
7	1.028	1.000
8	1.150	1.207
9	.952	1.030
Mean	1.039	1.125
S.D.	.037	.034

length of the lips by means of two hard-tissue measurements: (1) bigonial distance and (2) hard-tissue pupil separation. Taking into account the interpupillary distance in addition to the bigonial distance, the correlation coefficient increased to r = .46. Correlation coefficients for the pupil separation and eye length did not increase significantly by inclusion of other hard-tissue measurements in the linear regression formulas.

It was difficult to appraise the width of the face on the soft-tissue photograph because of the interference of long hair. However, the outline of the soft tissue can be seen on the radiograph. A horizontal line was drawn tangent to the inferior borders of the hard-tissue nose to the points where the line intersects the hard and soft tissue outlines. Table IV presents a comparison between hard and soft tissue widths. These measurements are normalized as described above except that hard-tissue pupils were used in place of soft-tissue pupils. We obtained the correlation coefficient, r = .67. Some strong, positive correlations were found between horizontal hard-tissue measurements: intermolar width (from posterior-anterior cephalogram) vs. bigonial distance, r = .75; hard-tissue interpupillary distance vs. bigonial distance, r = .33; hard-tissue interpupillary distance vs. horizontal orbital diameter, r = .79; intermolar width vs. hard-tissue interpupillary distance, r = .43.

The linear regression formulas used to approximate the soft-tissue measurements are:

pupil separation = .67 × (hard-tissue pupil separation) + .18.

palpebral width = .23 × (horizontal orbital diameter) + .10

lip length = .23 × (bigonial distance) + .16 × (hard-tissue pupil separation) + .15

width = .61 × (hard-tissue width) + .50

Other dimensions in the drawings are based on averages taken from the data.

Figure 3 presents the iconic representations of the nine subjects based on data taken from the soft-tissue photographs while Figure 4 presents the iconic representations based on the cephalogram. No meaningful correlation was obtained for the nose so it was not included in the iconic representation since its presence may hinder comparison of the iconically represented data significant to the present study.

Discussion

The results presented here represent only the beginning of a long-term venture. Many improvements are possible with much more data, and with more refined photographic procedures one could obtain a large system of equations like those given above. The computer could be programmed to draw very accurate faces in both frontal and profile positions. Given the ability to achieve schematic representations of normal soft to hard tissue relationships, one might envisage clinical application of a computer program in diagnosis and treatment planning. Just as importantly, means of representation of the complex relationship of soft and hard tissue may lead to a better understanding of the pathogenesis of facial deformity.

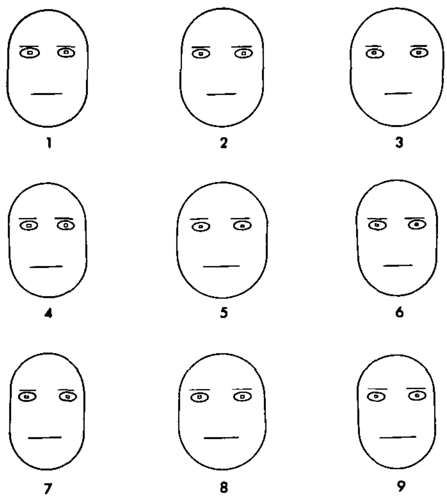

Fig. 3 Iconic representations of nine soft-tissue faces.

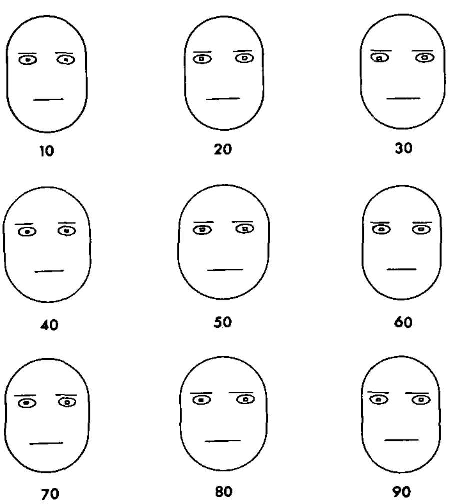

Fig. 4 Iconic representations of nine soft-tissue faces based on hard-tissue regression formulas.

SUMMARY

Hard and soft tissue measurements were obtained for nine Caucasian women. Based on these measurements, regression formulas were derived to approximate the soft tissue covering based on hard tissue data. The results are presented iconically by computer drawings. The preliminary data presented would suggest a definite predictable influence exerted by the facial skeleton on the position of landmarks in the overlying soft tissue.

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