Dentoskeletal Determinants of Soft Tissue Morphology

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A statistical evaluation of correlations among hard and soft tissue reference points, finding the strongest relationships between soft tissue values and incisors and convexity measurements.

KEY WORDS: • CEPHALOMETRICS • SOFT TISSUE • PROFILE •

The importance of soft tissue assessment in orthodontic treatment planning is widely recognized. Changes in the soft tissues associated with changes in the hard tissues during treatment are an important aspect of pretreatment evaluation.

Soft tissues are affected by a variety of variables, including skeletal relationships, dental positions, soft tissue thickness, and function. The effects of growth during treatment compound the problems of predicting the effects of treatment.

The two aspects of soft tissue assessment which have received the most attention are the relationships between soft tissue and dentoskeletal variables in normal occlusion, and the changes in soft tissues associated with therapeutic changes in dentoskeletal structures.

One problem which requires particular attention is the relationship of the lips at rest. Are they in contact at rest? If not, the investigator must choose between exposing the cephalometric radiograph with the lips at rest but apart, or closed together under strain. The comparison of pretreatment and posttreatment radiographs can be affected by the presence of different degrees of lip strain. This investigation is based on the Ricketts (1968) approach, with all radiographs exposed with the lips in light contact.

The difficulties of comparing assessments of the morphology of the circumoral soft tissues are compounded by the many differences between previous studies. Age ranges and group compositions varied widely.

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Some studies, such as those of STONER (1955) AND BURSTONE (1958, 1959) laid the foundations for objective methods of assessment, but these were largely descriptive. They did not investigate the relationships between hard and soft tissue structures, although Burstone did note individual variations in the shape and thickness of the soft tissues which tended to mask hard tissue variations.

RIEDEL (1957) was one of the first to directly investigate the relationships between the morphology of the lips and the underlying dentoskeletal structures. His sample included a variety of occlusions, and the average subject age of 19 years is well past the age for significant growth. He considered the soft tissue profile to be related to the underlying dental and skeletal structures, and also stressed the importance of individual variation.

Orthodontic Treatment

Many subsequent studies have looked at the effects of orthodontic treatment on hard tissues and the resultant effects on the soft tissues. The general aim has been to predict soft tissue changes associated with anticipated hard tissue changes.

RUDEE (1964) found a generally close relationship between upper and lower incisor and lip retraction, yet HERSHEY (1972), concluded that the prediction of soft tissue response to incisor movements was not clinically useful. This was later challenged by SCHULHOF ET AL. (1978), who claimed an acceptable accuracy of prediction based on the incisor positions. HUGGINS AND MCBRIDE (1975) stated that retraction of the upper labial segment altered lip posture, although a significant correlation was demonstrated only for females.

Roos (1974) compared pretreatment relationships in a group of Class I and Class II individuals, and further studied the changes in the Class II group due to treatment. The age ranges in the groups were wide, and each group included both males and females. In view of known sex differences, some of these findings should be viewed with some reservation. Roos found varying responses to treatment, with a complex interaction of the determining variables. The position of the lower incisors was found to be one important influence on lower lip position.

Growth Effects

The effects of growth on soft tissue form have been investigated by SUBTELNY (1959), BOWKER AND MEREDITH (1959), POSEN (1967) AND WISTH (1972). These studies highlight the importance of variations within groups due to age differences and overlapping effects of age and treatment. Age changes are usually small, with a greater tendency for thickening in males than in females as the chin becomes more prominent.

Profile Assessment

Various measurements have been suggested for assessment of the individual soft tissue profile. WILLIAMS (1969) stated that the antero-posterior position of the lower incisor is more important than its angulation in influencing upper and lower lip balance. Optimum lip balance occurs when the lower incisor lies on the line from point A to pogonion.

TWEED (1954) recognized the importance of facial esthetics and proposed that the angle between lower incisor and Frankfort plane should be about 65°. These and prior cephalometric systems do not directly address the assessment of the soft tissues.

STEINER (1964) suggested a line from the chin to the middle of the S curve formed by the lower border of the nose and the upper lip, with the lips falling on this line in average cases.

HOLDAWAY (1964) proposed a line tangent to the soft tissue chin and upper lip convexity. HOLDAWAY (1966) further stated that facial contour is most pleasing when lower incisor and pogonion lie ahead of the nasion–point B line by the same amount.

MERRIFIELD (1966) constructed a line similar to Holdaway's, tangent to the soft tissue chin and the most prominent lip. This was related to the Frankfort plane.

RICKETTS (1968) proposed the E line, from tip of the soft tissue chin to the tip of the nose. He states that the lips in Caucasians should be within this line and that they become more retrusive with growth.

Objectives of This Study

The above provide a variety of methods for measuring the hard and soft tissues and the changes that occur during treatment. Age and sex differences have made it difficult to establish standards. With these points in mind, the present study was designed to study the soft tissue thickness within a limited age range in females only.

A wide range of dentoskeletal variables was selected for evaluation in relation to the soft tissue profile. An attempt is also made to determine whether any measures of soft tissue morphology are especially useful for clinical assessment.

This study was not concerned with changes due to treatment; however, it should be noted that if pretreatment relationships between hard and soft tissues are not somewhat interdependent, it is unlikely that they can provide a basis for prediction of changes due to treatment.

— Materials and Methods —

This study was limited to females to eliminate the effects of sex differences as demonstrated by BURSTONE (1959), SUBTELNY (1959), AND MAUCHAMP AND SASSOUNI (1973). Subjects were selected on the basis of the A–N–B difference to give a wide spread of cases in the Class I and Class II skeletal categories. Class III cases were specifically excluded because insufficient numbers were available. The range of A–N–B values ranged from 0.7° to 8.7°.

Lateral cephalometric radiographs of sixty Caucasian females were selected under the above criteria. All were exposed with the teeth in centric occlusion and the lips in light contact. Dental development in each case showed complete formation of the mandibular cuspid root and incomplete apical closure on the second mandibular bicuspid. CHERTKOW (1980) demonstrated a significant relationship between cuspid root formation and pubertal maturation.

Ten soft tissue points (Fig. 1) and thirty-six dentoskeletal points were digitized on each radiograph. From these points 21 dentoskeletal and 21 soft tissue variables were calculated (Table 1). The

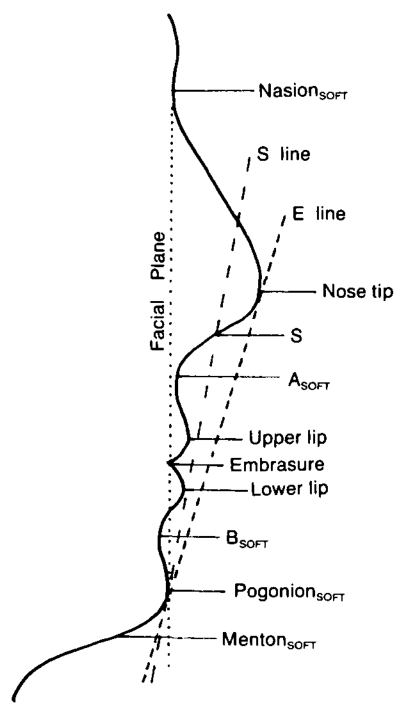

Fig. 1 Soft tissue profile landmarks

dentoskeletal variables were chosen on the basis of widespread clinical use. Two *Wits* appraisals have been included — one using the occlusal plane as defined by JACOBSON (1975) and one based on the functional occlusal plane defined by RICKETTS (1968).

Each radiograph was traced and digitized twice. Coordinates of all points were rotated and transformed on the Frankfort horizontal with porion as the origin. The magnification factor for each radiograph was also computed and used to derive the actual dimensions of variable values (Freer, 1980).

— Results —

When Student's t tests were applied to the means of the differences between duplicate variables, none of the soft tissue variables showed significant difference from zero at the five per cent level of probability. Four dentoskeletal variables (S–N–B angle, facial plane angle, lower facial height angle, and the modified Wits skeletal classification) had mean differences significant at the five per cent level of probability.

From the frequency distribution of the differences and from the values of the variance (s^2), it was evident that some variables showed a wider range of variation than others. Two areas of measurement stood out among the dentoskeletal variables — the angles involving incisal and apical location of the incisors, and the mandibular angles incorporating the constructed Xi point.

Interrelationships among the variables were studied primarily by means of correlation coefficients. Correlation coefficients below the absolute value of 0.45 were essentially ignored even though they might be theoretically significant from a purely statistical viewpoint. The R^2 value corresponding to 0.45 is 0.2 and it was felt that this was too low to be clinically useful. The matrix of correlations between dentoskeletal and soft tissue variables is shown in Table 2.

Overbite was most highly correlated with variables measuring the horizontal position of BSOFT and its relation to point ASOFT, but even these correlations were not very high. Overjet was notably correlated only with upper lip convexity, suggesting that the horizontal position of the upper incisor determined the horizontal position of the upper lip to some extent.

The interincisor angle was correlated with a variety of the soft tissue measurements. While no immediate interpretation could be placed on these correlations, the interincisor angle is clearly related to general soft tissue morphology.

Angulation of the upper incisor was also correlated well across several variables. The distance from the upper incisor to the A–Po line correlated highly with upper and lower lip convexity and to some extent with the position of the lip embrasure. All of these correlations suggest a greater importance for the position of the upper incisor than has been previously reported.

Angulation of the lower incisor to both the A–Po line and the mandibular plane is assessed in many cephalometric analyses. The angulation of the lower incisor does not necessarily directly reflect its anteroposterior spatial position. In the present study the angular relationships between lower incisor and both the mandibular plane and A–Po line were not highly correlated with any soft tissue variable; the angulation to mandibular plane showed poor correlation with all soft tissue variables.

While these findings suggest that the angulation of the lower incisor is not an important determinant of soft tissue morphology, the linear distance of the lower incisor from the A–Po line was highly correlated with some of the soft tissue variables, particularly with the horizontal position of point BSOFT and lower lip convexity.

The spatial position of the lower incisor was most directly related to soft tissue variables below the lip embrasure, including lower lip convexity and point BSOFT.

The angles S-N-A and S-N-B were poorly correlated with nearly all soft tissue variables. In addition, facial axis, facial angle and mandibular arc seemed to bear only modest relationships to the overlying soft tissue morphology.

The Frankfort/mandibular plane angle was strongly related to soft tissue variables measured in the vertical plane, but not in the horizontal plane.

On the other hand, lower facial height seemed to be an important determinant of soft tissue morphology in both planes, although it was better correlated with vertical soft tissue variables.

Convexity at point A is clearly a most important determinant of soft tissue profile outline, being well correlated with many of the horizontal soft tissue variables. A-N-B also seems to be important and superior to the *Wits* appraisal. The angle N-A-Po was well correlated with horizontal variables, obviously reflecting point A convexity, while S-N-Po was not as strongly associated.

— Discussion —

The reproducibility of dentoskeletal and soft tissue measurements was acceptable within the objectives of this investigation. The dentoskeletal measurements which exhibited lower levels of reproducibility were the angles involving the incisors, and the mandibular angles incorporating the constructed Xi point. Soft tissue variables with lowest levels of reproducibility were those measured along tangents to the soft tissue outline.

Correlations with the angulation and position of the upper incisors suggest that they are very important determinants of the associated soft tissue morphology. This point may have been overlooked previously, particularly in Class II cases, where studies have dealt mainly with the changes resulting from treatment. This could be especially important in treatment planning for Class II malocclusion, and suggests the importance of great care in the final anteroposterior positioning of the upper incisors.

The angulation of the upper incisors was better correlated with soft tissue variables than was the angulation of lower incisors. In fact, the angulation of the lower incisors seemed to bear little relation to the overlying soft tissue morphology. This may have been influenced by the lip posture assumed for the radiographs, which were taken with the lips in light contact. However, the anteroposterior position of the lower incisors was found to be an important influence on the horizontal position of point BSOFT and lower lip convexity.

Deeper skeletal structures did not display any particular relationship to horizontal soft tissue variable values, with the possible exception of lower facial height. The Frankfort/mandibular plane angle, facial axis and mandibular arc were not directly related to soft tissue outline.

Also of importance is the finding that the A-N-B angle and point A convexity are very significant factors in soft tissue outline, especially when the *Wits* appraisal is so poorly correlated with most soft tissue variables. The importance of point A convexity in determining soft tissue outline has not been noted in previous reports.

The complicating effects of lip strain in the context of the present study are difficult to estimate. A combination of dental and skeletal factors clearly account for a large proportion of the variability in soft tissue morphology. However, some variability is also related to the inherent thickness of the soft tissues, and this is modified by lip strain.

Until these issues can be directly investigated, care should be exercised in making interpretations based only on dentoskeletal variables. It should also be remembered that the results of this study were derived from malocclusions at the Class II end of the spectrum, and that the relationship in cases with prognathic or Class III malocclusions will almost certainly be different.

One other point deserves mention. On the basis of the intercorrelations found in this study, there would appear to be very little difference in choosing between the Ricketts E line, the Steiner S line and the soft tissue facial plane.

— Summary —

- The position of the lips and the soft tissues overlying points A and B seem to be substantially related to the horizontal positions of the upper and lower incisors and to the angulation of the upper incisor.
- The angulation of the lower incisor is much less important than its spatial position.
- The A–N–B angle is strongly related to the overlying soft tissue outline.
- Point A convexity is a very important factor in soft tissue form.
- The Ricketts E line, the Steiner S line and the soft tissue facial plane all seem to be equally acceptable bases for assessment of the soft tissues of the profile.

Table I

Variables used in Correlation Analyses

No.	Dentoskeletal	No.	Soft Tissue
1	Overbite (mm)	22	E Line–Point Asoft (mm)
2	Overjet (mm)	23	E Line–U Lip Conv. (mm)
3	Interincisal Angle (deg)	24	E Line–Embrasure (mm)
4	U1/Frankfort (deg)	25	E Line–L Lip Conv (mm)
5	U1–APo (mm)	26	E Line– Point Bsoft (mm)
6	L1/Mandibular Pl. (deg)	27	S Line–Point Asoft (mm)
7	L1/APo (deg)	28	S Line–U Lip Conv. (mm)
8	L1–APo (mm)	29	S Line–Embrasure (mm)
9	S-N-A (deg)	30	S Line–L Lip Conv. (mm)
10	S-N-B (deg)	31	S Lin–Point Bsoft (mm)
11	Facial Axis (deg)	32	S point–Point Bsoft (mm)
12	Facial Depth (deg)	33	S Point–Pogonion soft (mm)
13	Mandibular Arc (deg)	34	S Point–Menton soft (mm)
14	Frankfort/Mandibular Pl. (deg)	35	Point Asoft–Point Bsoft (mm)
15	Lower Facial Height (deg)	36	Point Asoft–Pogonion soft (mm)
16	Convexity at Point A (mm)	37	Point Asoft–Menton soft (mm)
17	A-N-B (deg)	38	Facial Pl.soft–Point Asoft (mm)
18	S-N-Po (deg)	39	Facial Pl.soft–U Lip Conv. (mm)
19	N-A-Po (deg)	40	Facial Pl.soft–L Lip Conv. (mm)
20	Wits Classif. (Original) (mm)	41	Facial Pl.soft–Point Bsoft (mm)
21	Wits Classif. (Modified) (mm)	42	A-N-B (soft) (deg)

Table 2

Correlation Coefficients between Dentoskeletal (1-21) and Soft Tissue (22-42) Variables
(Variables described in Table 1)

No.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1	−.12	−.32	−.36	−.43	−.49	−.06	−.30	−.34	−.41	−.48	−.34	−.28	−.31	−.50	−.44	−.43	−.07	−.20	−.34	−.38	−.10
2	+.37	+.55	+.42	+.23	+.20	+.39	+.52	+.37	+.18	−.25	−.08	−.13	−.07	+.20	+.15	+.17	+.40	+.41	+.14	+.20	+.67
3	−.23	−.54	−.69	−.67	−.51	−.16	−.50	−.67	−.64	−.49	−.17	−.08	−.18	−.45	−.34	−.38	−.33	−.44	−.50	−.47	−.19
4	+.20	+.56	+.65	+.56	+.27	+.13	+.52	+.62	+.53	+.24	+.01	−.08	+.02	+.39	+.29	+.31	+.21	+.36	+.43	+.20	+.26
5	+.34	+.72	+.76	+.72	+.39	+.31	+.68	+.73	+.68	+.35	+.30	+.18	+.35	+.57	+.46	+.55	+.51	+.62	+.64	+.35	+.45
6	−.05	+.03	+.20	+.17	+.20	−.08	+.02	+.21	+.18	+.22	−.09	−.07	−.09	−.07	−.08	−.09	+.01	+.05	+.18	+.24	−.09
7	−.21	−.02	+.18	+.30	+.39	−.27	−.02	+.21	+.32	+.41	+.14	+.16	+.18	+.13	+.14	+.15	−.18	−.03	+.28	+.35	−.40
8	−.09	+.12	+.32	+.50	+.66	−.15	+.12	+.35	+.52	+.68	+.41	+.35	+.45	+.38	+.31	+.39	+.04	+.17	+.52	+.61	−.34
9	−.04	+.12	+.15	+.02	−.14	−.06	+.11	+.14	±.00	−.15	−.30	−.39	−.29	−.07	−.17	−.12	−.12	−.04	−.08	−.20	+.12
10	−.28	−.15	−.06	−.13	−.18	−.33	−.14	−.04	−.12	−.18	−.33	−.39	−.31	−.18	−.23	−.21	−.48	−.34	−.24	−.29	−.26
11	−.30	−.22	−.13	−.26	−.27	−.34	−.21	−.12	−.25	−.26	−.43	−.47	−.50	−.33	−.37	−.43	−.42	−.32	−.32	−.31	−.18
12	−.35	−.05	−.02	−.01	−.11	−.39	−.02	−.04	−.03	−.10	−.21	−.20	−.16	−.05	−.03	−.06	−.43	−.20	−.07	−.18	−.31
13	−.20	−.09	−.07	−.11	−.28	−.17	−.05	−.04	−.09	−.25	−.40	−.30	−.34	−.29	−.21	−.27	−.28	−.16	−.15	−.25	−.13
14	+.24	+.20	+.13	+.27	+.39	+.25	+.19	+.11	+.27	+.37	+.50	+.45	+.51	+.42	+.38	+.46	+.36	+.30	+.32	+.37	+.10
15	+.16	+.27	+.24	+.41	+.44	+.17	+.26	+.23	+.41	+.43	+.66	+.62	+.70	+.62	+.61	+.68	+.26	+.27	+.39	+.37	+.03
16	+.45	+.54	+.47	+.43	+.38	+.49	+.51	+.44	+.39	+.35	+.27	+.17	+.26	+.36	+.25	+.33	+.75	+.65	+.48	+.44	+.60
17	+.45	+.51	+.40	+.27	+.08	+.50	+.49	+.36	+.23	+.04	+.04	−.03	+.02	+.19	+.11	+.15	+.67	+.57	+.29	+.15	+.73
18	−.31	−.20	−.14	−.23	−.35	−.35	−.19	−.13	−.23	−.35	−.43	−.46	−.41	−.28	−.30	−.31	−.54	−.41	−.36	−.44	−.23
19	+.47	+.52	+.47	+.40	+.36	+.50	+.50	+.43	+.36	+.33	+.22	+.10	+.18	+.32	+.20	+.27	+.75	+.64	+.45	+.42	+.61
20	+.38	+.37	+.23	+.08	−.19	+.42	+.35	+.20	+.04	−.22	−.14	−.17	−.13	±.00	−.04	−.01	+.47	+.38	+.07	−.11	+.68
21	+.28	+.14	+.03	−.05	−.24	+.32	+.12	±.00	−.08	−.27	−.13	−.21	−.15	−.13	−.21	−.12	+.31	+.17	−.06	−.20	+.51

REFERENCES

Bowker, W. C., and Meredith, H. V. 1959. A metric analysis of the facial profile. *Angle Orthod.* 29:149-160.

Burstone, C. J.

1958. The integumental profile. *Am. J. Orthod.* 44:1-25.

1959. Integumental contour and extension patterns. *Angle Orthod.* 29:93-104.

Chertkow, S. 1980. Tooth mineralization as an indicator of the pubertal growth spurt. *Am. J. Orthod.* 77:79-91.

Freer, T. J. 1980. A computer system for research in orthodontics. *Aust. Orthod. J.* 6:102-109.

Hershey, H. G. 1972. Incisor tooth retraction and subsequent profile change in post-adolescent female patients. *Am. J. Orthod.* 61:45-54.

Holdaway, R. Personal communication cited by Hambleton, R. S. 1964. The soft tissue covering of the skeletal face as related to orthodontic problems. *Am.J. Orthod.* 50:405-420.

Holdaway, R. Personal communication cited by Merrifield, L. L. 1966. The profile line as an aid in critically evaluating facial esthetics. *Am. J. Orthod.* 52:804-822.

Huggins, D. G., and McBride, L. J. 1975. The influence of the upper incisor position on soft tissue facial profile. *Brit. J. Orthod.* 2:141-146.

Jacobson, A. 1975. The 'Wits' appraisal of jaw disharmony. *Am. J. Orthod.* 67:125-138.

Mauchamp, O., and Sassouni, V. 1973. Growth and prediction of the skeletal and soft tissue profiles. *Am. J. Orthod.* 64:83-94.

Merrifield, L. L. 1966. The profile line as an aid in critically evaluating facial esthetics. *Am. J. Orthod.* 52:804-822.

Posen, J. M. 1967. A longitudinal study of growth of the nose. *Am. J. Orthod.* 53:746-755.

Ricketts, R. M. 1968. Esthetics, environment and the law of lip relation. *Am. J. Orthod.* 54:272-289.

Riedel, R. A. 1957. An analysis of dento-facial relationships. *Am. J. Orthod.* 43:103-119.

Roos, N. 1974. *The soft tissue profile: An X-ray Cephalometric Study.* Dissertation. Stockholm.

Rudee, D. A. 1964. Proportional profile changes concurrent with orthodontic therapy. *Am. J. Orthod.* 50:421-433.

Schulhof, R. J., Zierenberg, R. H. and Walters, R. D. 1978. The mandibular dental arch: part II. Effects of lower incisor position on the soft tissue profile. *Angle Orthod.* 48:75-79.

Steiner, C. C. Personal communication cited by Hambleton, R. S. 1964. The soft tissue covering of the skeletal face as related to orthodontic problems. *Am. J. Orthod.* 50:405-420.

Stoner, M. M. 1955. A photometric analysis of the facial profile. *Am. J. Orthod.* 41:453-469.

Subtelny, J. D. 1959. A longitudinal study of soft tissue facial structures and their profile characteristics defined in relation to underlying skeletal structures. *Am. J. Orthod.* 45:481-507.

Tweed, C. H. 1954. The FMIA in orthodontic diagnosis, treatment planning and prognosis. *Angle Orthod.* 24:121-169.

Williams, R. 1969. The diagnostic line. *Am. J. Orthod.* 55:458-476.

Wisth, P. J. 1972. Changes of the soft tissue profile during growth. *Trans. Europ. Orthod. Soc.* pp. 123-131.