

ORIGINAL ARTICLE

Soft tissue cephalometric analysis: Diagnosis and treatment planning of dentofacial deformity

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This article will present a new soft tissue cephalometric analysis tool. This analysis may be used by the orthodontist and surgeon as an aid in diagnosis and treatment planning. The analysis is a radiographic instrument that was developed directly from the philosophy expressed in Arnett and Bergman "Facial keys to orthodontic diagnosis and treatment planning, Parts I and II" (Am J Orthop Dentofacial Orthod 1993; 103:299-312 and 395-411). The novelty of this approach, as with the "Facial Keys" articles, is an emphasis on soft tissue facial measurement. (Am J Orthod Dentofacial Orthop 1999;116:239-53)

This article will present a technique for soft tissue cephalometric analysis. The analysis is a radiographic instrument that was developed directly from the philosophy expressed in Arnett and Bergman's^{1,2} *Facial keys to orthodontic diagnosis and treatment planning*, published in the AJO/DO in April and May of 1993. Familiarity with those articles is helpful in understanding this article. As with the "Facial Keys" articles, this article emphasizes soft tissue facial measurement and treatment planning.

Many authors have suggested utilizing soft tissue analysis as a reliable guide for occlusal treatment and attendant soft tissue changes.¹⁻¹² Arnett and Bergman presented the Facial Keys to Orthodontic Diagnosis and Treatment Planning as a three-dimensional clinical blueprint for soft tissue analysis and treatment planning.^{1,2}

MATERIAL AND METHODS

Forty-six adult white models comprise the cephalometric database for this analysis (20 male, 26 female). The model cephalograms were digitized and mean val-

ues, SDs, and *P* values were calculated with Microsoft Excel. All models had natural Class I occlusions and were viewed by one of us (G.W.A.) as reasonably facially balanced. A distinction was made during selection between quality of facial parts (hair, eyes, skin, etc) and position of facial parts. Models were chosen for inclusion only on the basis of balance of facial parts, and quality of parts (ie, beautiful eyes) were disregarded. To initiate the Soft Tissue Cephalometric Analysis (STCA), the models were first assessed clinically,^{1,2} in natural head position, seated condyles, and with passive lips.

Proper clinical examination posturing was imperative to insure the reliability of the soft tissue cephalometric analysis that followed. The STCA was not used without clinical input; it required clinical facial assessment to augment and elucidate cephalometric findings. First, facial examination was used as described by Arnett and Bergman,^{1,2} with particular emphasis on midface structures that do not show on standard cephalometric analysis. In particular, orbital rim, subpupil, and alar base contours were noted to indicate anteroposterior position of the maxilla.

Next, in preparation for the cephalometric radiograph, metallic markers were placed on the right side of the face to mark key midface structures. The metallic beads were placed on the models midface with the following routine. The orbital rim marker was placed directly over the osseous orbital rim and directly under the pupil with the eye in straight-ahead gaze. Cheekbone marking required two perspectives. First, examined from the left in $\frac{3}{4}$ view, the right malar height of contour was marked with ink. Then, with the examiner standing directly in front of the

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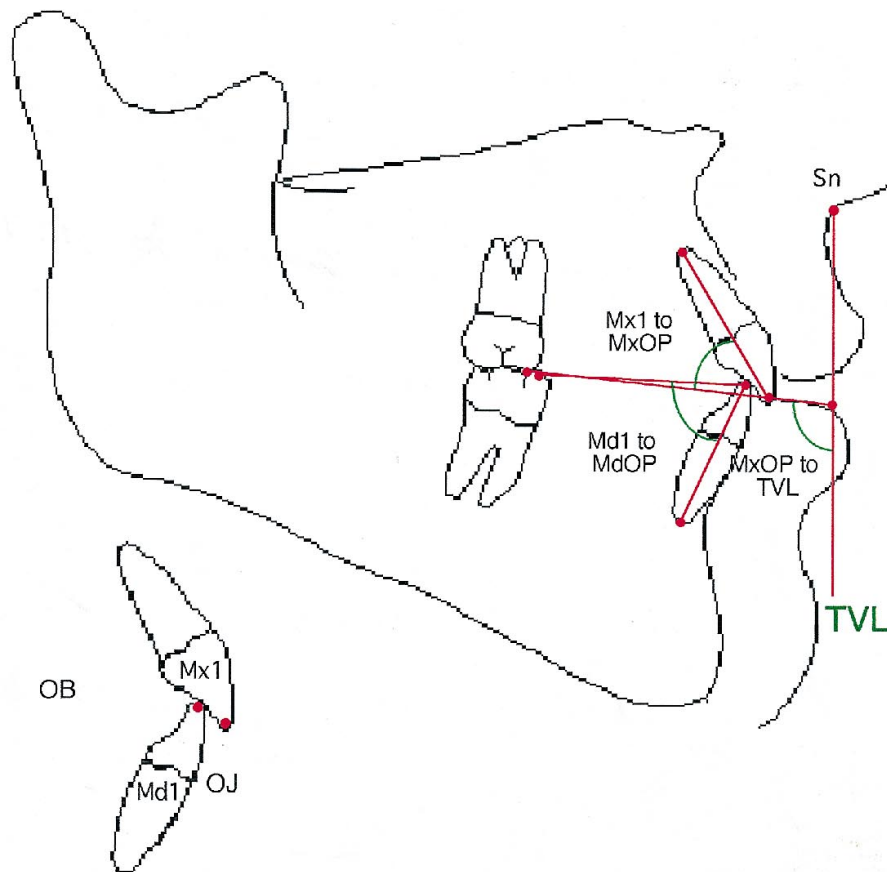


Fig 1. Dentoskeletal factors: upper incisor to maxillary occlusal plane, lower incisor to mandibular occlusal plane, maxillary occlusal plane, overbite, and overjet are represented. The dentoskeletal factors, to a large extent, control esthetic outcome.

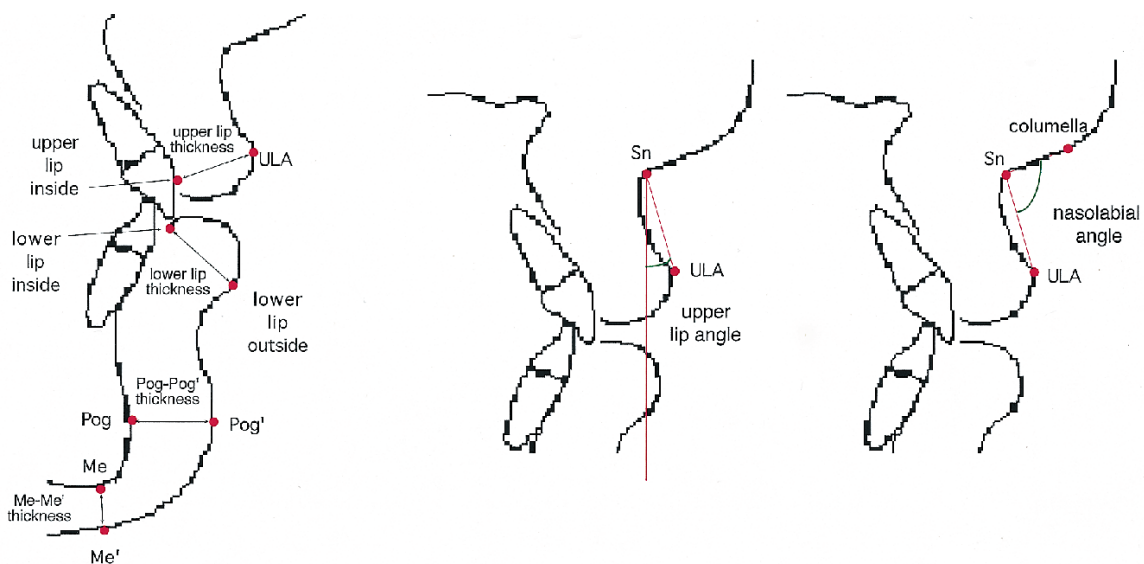


Fig 2. Soft tissue structures: tissue thickness at upper lip, lower lip, Pogonion', and Menton' are depicted. Soft tissue thickness and dentoskeletal factors determine the profile. Upper lip angle and nasolabial angle are depicted. These soft tissue structures are altered by movement of the incisor teeth. These angles should be studied before orthodontic overjet correction to assess the potential for changes out of normal range.

Table I. Soft tissue cephalometric analysis

	Mean \pm SD Females	Mean \pm SD Males	Female to male difference significant when $>.05$
Dentoskeletal factors			
Mx occlusal plane	95.6 \pm 1.8	95.0 \pm 1.4	.1789
Mx1 to Mx occlusal plane	56.8 \pm 2.5	57.8 \pm 3.0	.2585
Md1 to Md occlusal plane	64.3 \pm 3.2	64.0 \pm 4.0	.7764
Overjet	3.2 \pm .4	3.2 \pm .6	.6371
Overbite	3.2 \pm .7	3.2 \pm .7	.7481
Soft tissue structure			
Upper lip thickness	12.6 \pm 1.8	14.8 \pm 1.4	3.388E-05
Lower lip thickness	13.6 \pm 1.4	15.1 \pm 1.2	.0004
Pogonion-Pogonion'	11.8 \pm 1.5	13.5 \pm 2.3	.0086
Menton-Menton'	7.4 \pm 1.6	8.8 \pm 1.3	.0019
Nasolabial angle	103.5 \pm 6.8	106.4 \pm 7.7	.1937
Upper lip angle	12.1 \pm 5.1	8.3 \pm 5.4	.0197
Facial length			
Nasion'-Menton'	124.6 \pm 4.7	137.7 \pm 6.5	8.916E-09
Upper lip length	21.0 \pm 1.9	24.4 \pm 2.5	1.024E-05
Interlabial gap	3.3 \pm 1.3	2.4 \pm 1.1	.0214
Lower lip length	46.9 \pm 2.3	54.3 \pm 2.4	2.158E-13
Lower 1/3 of face	71.1 \pm 3.5	81.1 \pm 4.7	3.170E-09
Overbite	3.2 \pm .7	3.2 \pm .7	.7481
Mx1 exposure	4.7 \pm 1.6	3.9 \pm 1.2	.0417
Maxillary height	25.7 \pm 2.1	28.4 \pm 3.2	.0026
Mandibular height	48.6 \pm 2.4	56.0 \pm 3.0	8.573E-11
Projections to TVL			
Glabella	-8.5 \pm 2.4	-8.0 \pm 2.5	.5246
Orbital rims	-18.7 \pm 2.0	-22.4 \pm 2.7	1.060E-05
Cheek bone	-20.6 \pm 2.4	-25.2 \pm 4.0	7.405E-05
Subpupil	-14.8 \pm 2.1	-18.4 \pm 1.9	2.266E-07
Alar base	-12.9 \pm 1.1	-15.0 \pm 1.7	6.054E-05
Nasal projection	16.0 \pm 1.4	-17.4 \pm 1.7	.0052
Subnasale	0	0	0
A point'	-1.1 \pm 1.0	-3.3 \pm 1.0	.6629
Upper lip anterior	3.7 \pm 1.2	3.3 \pm 1.7	.3836
Mx1	-9.2 \pm 2.2	-12.1 \pm 1.8	1.064E-05
Md1	-12.4 \pm 2.2	-15.4 \pm 1.9	1.312E-05
Lower lip anterior	1.9 \pm 1.4	1.0 \pm 2.2	.1065
B point'	-5.3 \pm 1.5	-7.1 \pm 1.6	.0004
Pogonion'	-2.6 \pm 1.9	-3.5 \pm 1.8	.1294

patient, a metal bead was placed at the intersection of the right malar height of contour ink mark and a vertical line through outer canthus. The alar base marker was then placed in the deepest depression at the alar base of the nose. The subpupil marker was situated directly below the straight ahead gaze of the pupil. Vertically, the subpupil marker was placed one half the vertical distance between the orbital rim and alar base markers. These essential midface structures, although normally lost on traditional headfilms, were metallically marked on the headfilm and became the cornerstone to our cephalometric midface diagnosis and treatment planning. The neck-throat point was then localized, and a metal marker was placed in that position.

With the midface structures marked, a lateral head-

film was obtained with the model positioned in natural head position,^{1,2,13-17} seated condyle, and with passive lips. Lundström and Lundström¹⁸ noted that despite careful natural head position instructions, some patients assume an "unnatural head position." Accordingly, these patients need adjustment to natural "head orientation"¹⁸ by experienced clinicians. As noted by Lundström and Lundström, our models also assumed head positions that were obviously not a natural head position. These headfilms, as per Lundström and Lundström, were leveled to natural head orientations.¹⁸

The True Vertical Line (TVL) was then established. The line was placed through subnasale and was perpendicular to the natural horizontal head position.¹⁵ Soft tissue landmarks, those reported as important in the Facial Keys articles were then marked on the

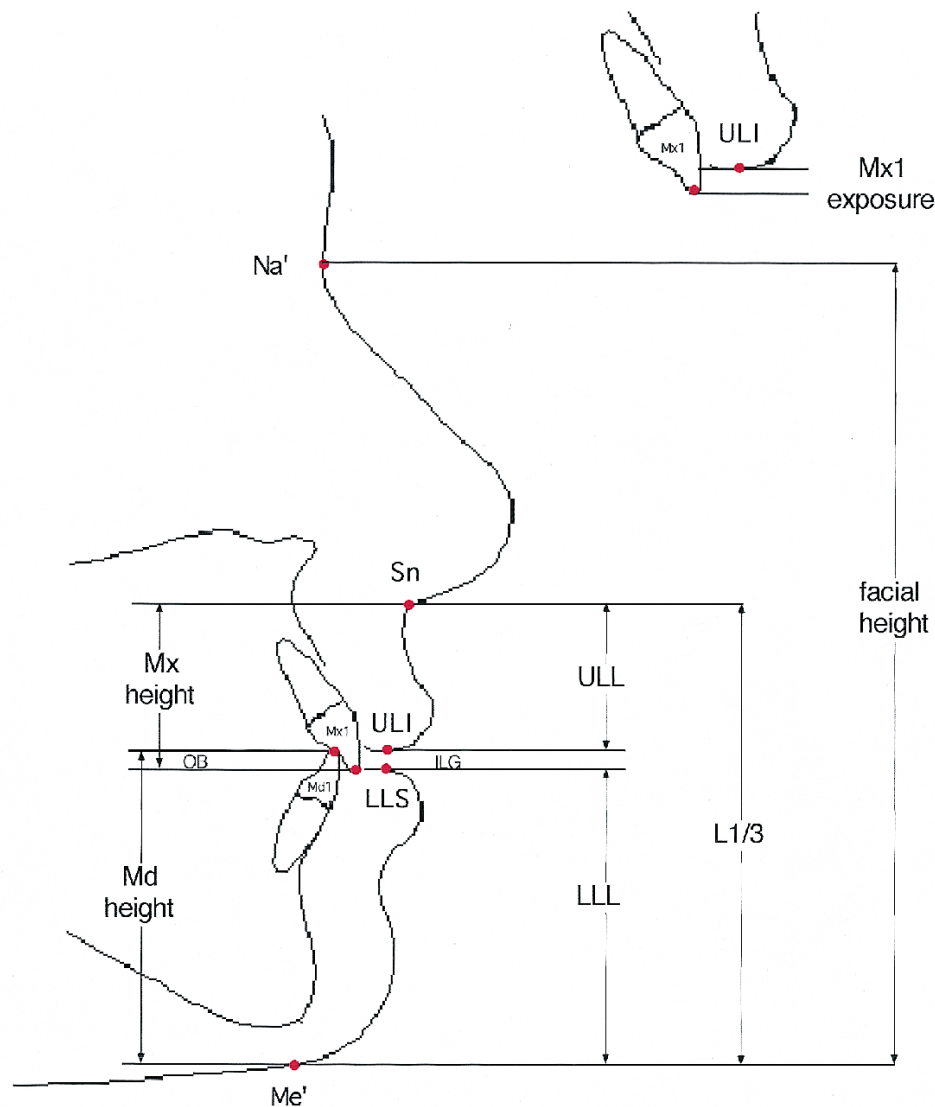


Fig 3. Facial lengths: key facial lengths are depicted. Soft tissue lengths include facial height (Na' to Me'), lower one-third height (Sn to Me'), upper lip length (Sn to upper lip inferior), lower lip length (lower lip superior to Me'), and interlabial gap (upper lip inferior to lower lip superior). Soft tissue to hard tissue measurements include maxillary incisor exposure (upper lip inferior to maxillary incisor tip), maxillary height (Sn to maxillary incisor tip), and mandibular height (mandibular incisor tip to Me'). The only hard tissue to hard tissue measurements is the overbite.

cephalogram. The midface metallic landmarks were also identified as new landmarks on the headfilm. Important hard tissue landmarks were then identified on the cephalogram. The vertical or horizontal position of soft tissue and hard tissue landmarks were then measured relative to the model's natural horizontal head position or TVL.

RESULTS

On the basis of the cephalometric soft and hard tissue landmarks measured on the 46 facially balanced

white models, dentoskeletal, soft tissue, vertical, projection, and facial harmony norms and SDs were established. Table I lists the variables, means, SDs, and *P* values.

Statistical analysis of the differences between males and females was done with *t* testing. A level of significance of 5% was assigned and *P* values were determined. Statistical analysis revealed that males and females are facially similar in some measures but different in others (Table I). Dentoskeletal means were not statistically different for males and females. All

male soft tissue thicknesses were statistically greater (ANS to Sn, A to A', UL thickness, lower lip thickness, Pog to Pog', and Me to Me') than the females. The female models demonstrated more upper lip protrusion indicated by the upper lip angle (+ 3.8°) and nasolabial angle (-2.9°); the upper lip angle was statistically different whereas the nasolabial angle was not. Male faces were statistically longer (Na' to Me' [13.1 mm], upper lip length [3.4 mm], lower lip' length [7.4 mm], lower 1/3 [10.0 mm], Mx height [2.7 mm], Md height [7.4 mm]) than female faces. The female models had statistically more incisor exposure (4.7 versus 3.9) and greater (3.3 versus 2.4) but insignificant interlabial gap than the male models. The male and female projection measurements were statistically the same (within 1.4 mm) except for midface, incisor projections, and B' point. The male orbital rim (-3.7), cheekbone (-4.6), subpupil (-3.2), upper incisor (-2.9), lower incisor (-3.0), and B point values were statistically larger (more negative to the TVL) than the females. Facial harmony values were statistically similar for all but 3 relationships. The males had statistically different harmony for A' to B', orbital rim' to Pog', and Glabella' to Pog'. With the above noted, the most significant treatment planning difference between males and females is the large vertical differences between the 2 groups and larger midface measurements for the male.

CLINICAL IMPLICATIONS

STCA provides dental and facial diagnosis. Data provided by the STCA can then be used for Cephalometric Treatment Planning (CTP).

Soft Tissue Cephalometric Diagnosis

The STCA can be used to diagnose the patient in five different but interrelated areas; dentoskeletal factors, soft tissue components, facial lengths, TVL projections, and harmony of parts.

Dentoskeletal factors (Fig 1) have a large influence on the facial profile. These factors, when in normal range will usually produce a balanced and harmonious nasal base, lip, soft A', soft B', and chin relationship. How accurately the orthodontist and surgeon manage the dentoskeletal components greatly influences the resulting profile.

Next, *soft tissue structures* (Fig 2) important to facial aesthetics are measured. The thickness of upper lip, lower lip, B to B', Pog to Pog', and Me to Me' alter facial profile. Soft tissue thickness in combination with dentoskeletal factors largely control lower facial aesthetic balance. The nasolabial angle and upper lip angle reflect the position of the upper incisor teeth and the thickness of the soft tissue overlying these teeth. These

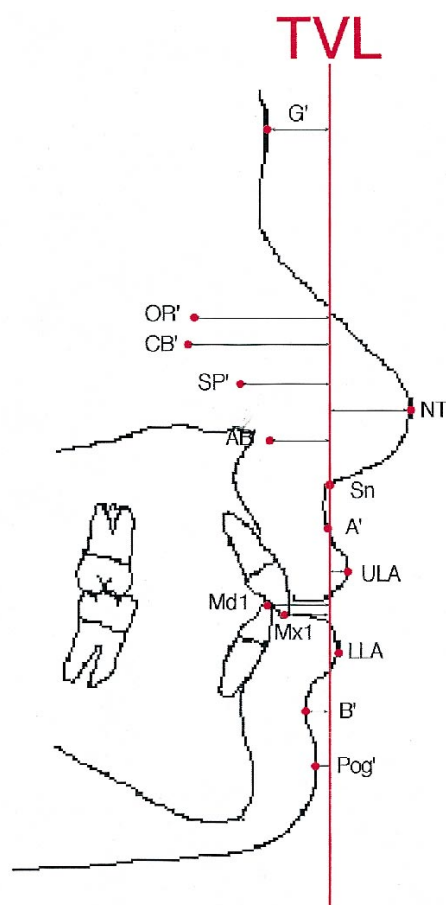


Fig 4. TVL projections: TVL is placed through subnasale except when maxillary retrusion exists. Maxillary retrusion is based on clinical nasal projection (short, normal, long), clinical orbital rim, cheek bone, subpupil, and alar base contours (depressed, flat, normal, prominent), clinical upper lip support (by incisor, gingiva, no support [air]), cephalometric upper lip angle, and cephalometric upper lip thickness. When midface retrusion is diagnosed the TVL is moved 1 to 3 mm anterior. Midface retrusion is defined by clinical factors (long nose, deficient midface structures, poor incisor upper lip support) and cephalometric factors (upright upper lip and/or thick upper lip). Profile points measured to TVL are Glabella (G'), nasal tip (NT), soft tissue A' point (A'), upper lip anterior (ULA), lower lip anterior (LLA), soft tissue B' point (B'), and soft tissue Pogonion' (Pog'). Midface, points measured with metallic beads to the TVL are soft tissue orbital rim (OR'), cheekbone height of contour (CB'), subpupil (SP'), and alar base (AB'). Hard tissue measured to the TVL are upper incisor tip and lower incisor tip.

angles are extremely important in assessing the upper lip and may be used by the orthodontist as part of the extraction decision.

The *facial lengths* (Fig 3) are conceptualized as soft

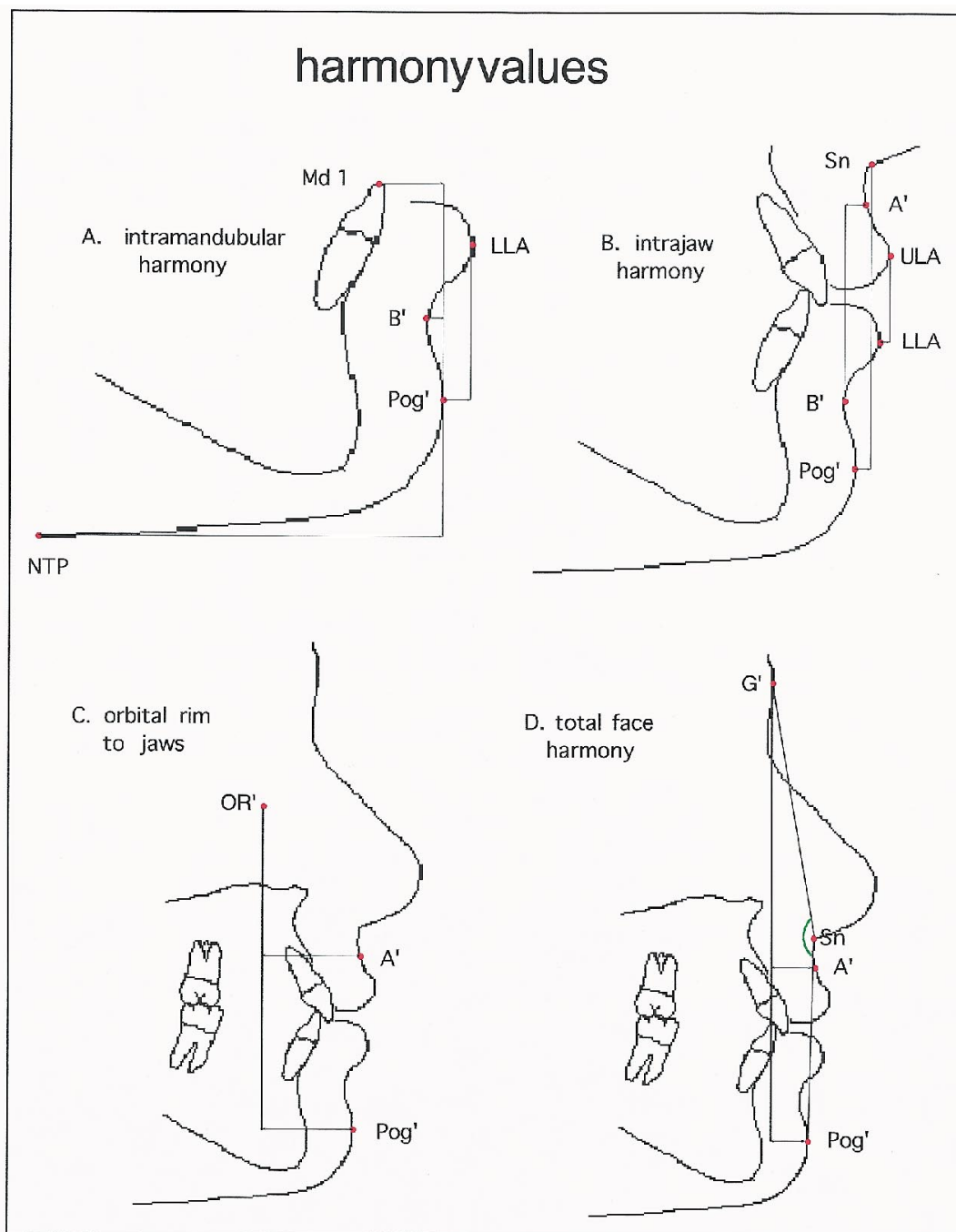


Fig 5. Harmony values: facial relationships that determine balance or harmony are represented. All values are calculated from the horizontal difference between points as calculated from the TVL. **A**, Intramandibular harmony: relationships between structures within the mandible that determine balance are measured, lower incisor to Pog', lower lip to Pog', soft tissue B' to Pog', and neck throat point to Pog' are depicted. **B**, Interjaw relationships: relationships between the upper and lower jaw soft tissues that determine balance are measured, Subnasale to Pog', soft tissue A' to soft tissue B', upper lip anterior to lower lip anterior. **C**, Orbital rim to jaws: relationships between the soft tissue orbital rim and upper and lower jaw that determine balance are measured, soft tissue orbital rim to upper jaw at soft tissue A' point and lower jaw at Pog'. **D**, Total face harmony: relationships between the forehead, upper jaw, and lower jaw that determine balance are measured, facial angle (G'-Sn-Pog'), forehead at glabella to upper jaw at soft tissue A', and forehead at glabella to lower jaw at Pog'.

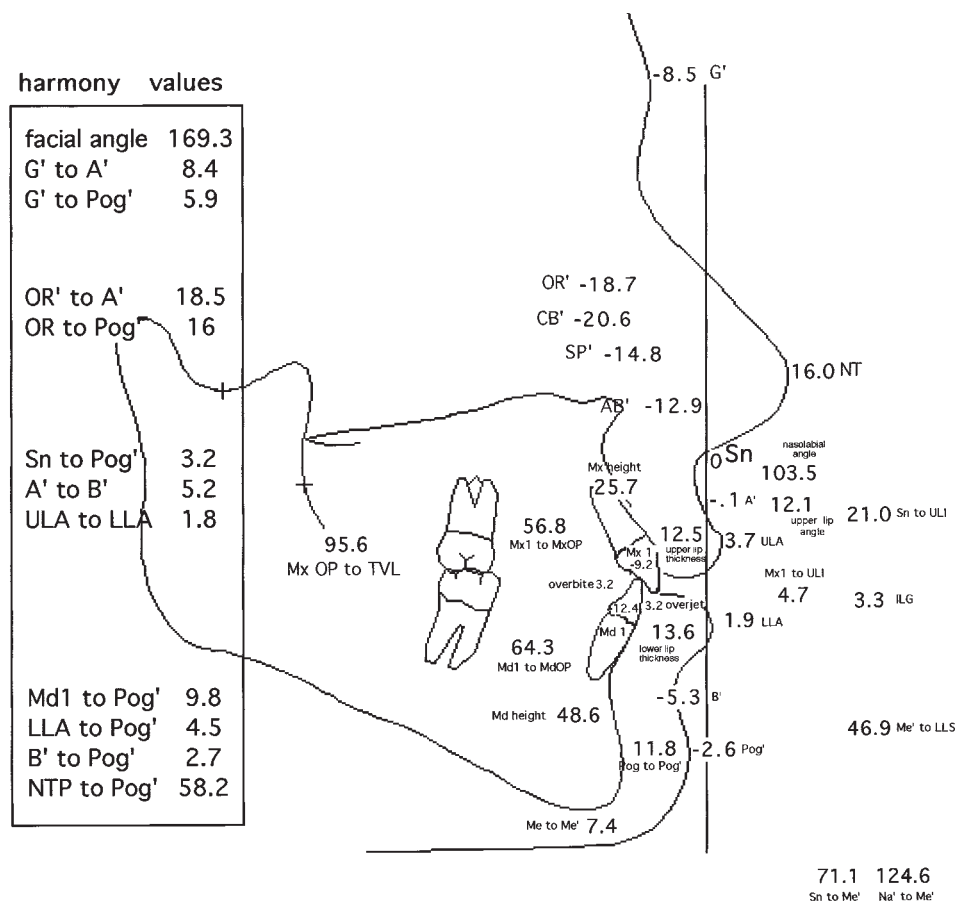


Fig 6. Female STCA: Measured soft tissue cephalometric values are labeled. Absolute values to the TVL line are indicated by their anatomic abbreviation (ie, A' or ULA). Landmarks that are not associated with the TV line are described (ie, Mx height, overbite, or Sn to Pog'). (Values are labeled to identify landmarks and measurements on Figs 7-12.)

tissue facial lengths (upper and lower lip lengths), interlabial gap, lower facial third, and total facial height. Additional essential vertical measurements include: relaxed lip upper incisor exposure, maxillary height (Sn to Mx1 tip), mandibular height (Md1 tip to Me') and overbite. The presence and location of vertical abnormalities is indicated by assessing maxillary height, mandibular height, upper incisor exposure, and overbite.

TVL projections (Fig 4) are anteroposterior measurements of soft tissue and represent the sum of the dentoskeletal position plus the soft tissue thickness overlying that hard tissue landmark. The horizontal distance for each individual landmark, measured perpendicular to the TVL, is termed the *landmark's absolute value*. Although subnasale will frequently be coincident with anteroposterior positioning of the TVL, they are not synonymous. For example, the TVL must be moved forward in cases of maxillary retrusion. Mid-face retrusion is defined by a long-appearing nose,

depressed or flat orbital rims, cheek bones, subpupils, and alar bases, poor incisor support for the upper lip, upright upper lip, thick upper lip, and retruded upper incisor. Clinical examination of the patient is necessary to verify these assessments as described by Arnett and Bergman.^{1,2}

The *harmony values* (Fig 5) were created to measure facial structure balance and harmony. Harmony or balance between different facial landmarks is an important component of beauty. It is the position of each landmark relative to other landmarks that determines the facial balance. Harmony values represent the horizontal distance between 2 landmarks measured perpendicular to the true vertical line (Fig 5, Table II).

Harmony values examine four areas of balance: intramandibular parts, interjaw, orbits to jaws, and the total face. The following harmony groupings are essential to excellent dentofacial outcomes.

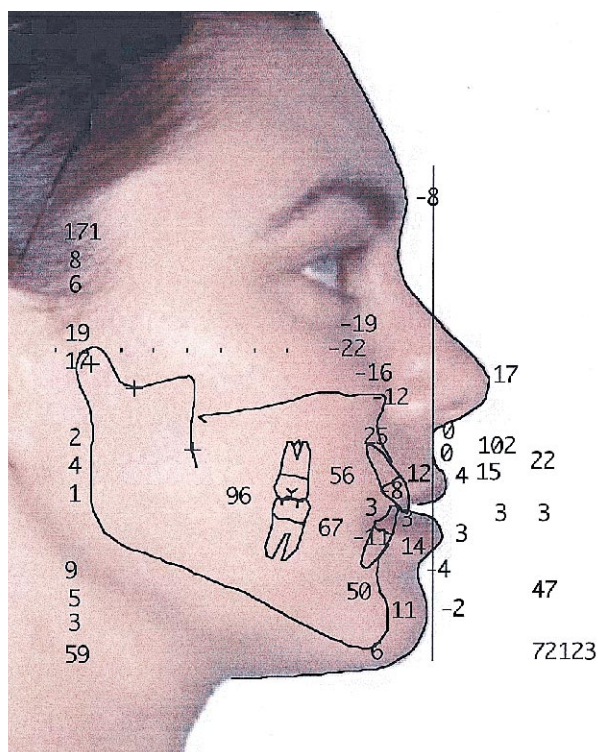


Fig 7. Normal female soft tissue cephalometric analysis: soft tissue cephalometric values for this patient are within 1 SD (black) of female mean values. (Refer to Fig 6 for landmark and measurement clarification.) (Black = within 1SD; green = within 2SD; blue = within 3SD; red = >3SD).

Intramandibular harmony (Fig 5A) values assess chin projection relative to the lower incisor, lower lip, soft tissue B' point, and the neck throat point. Analysis of these structures indicates chin position relative to other mandibular structures and which, if any, structure is abnormally placed. For example, excessive distance from mandibular incisor tip to the chin may indicate an upright lower incisor, or hard tissue pogonion enlargement, or increased thickness of the chin soft tissues (Pog to Pog'). All of these possibilities are examined within the intramandibular harmony group, and a diagnosis is made so that treatment can be rendered to harmonize structures within the mandible.

Next, *interjaw harmony* (Fig 5B) is examined. These relationships directly control the lower one third of facial aesthetics. Values indicate the interrelationship between the base of the maxilla (Sn) to chin (Pog'), soft tissue B' to soft tissue A' and upper to lower lips. Dentoskeletal factors (upper incisor angulation, lower incisor angulation, maxillary occlusal plane) are the primary determinants of interjaw harmony, but soft tissue thickness is also a factor.

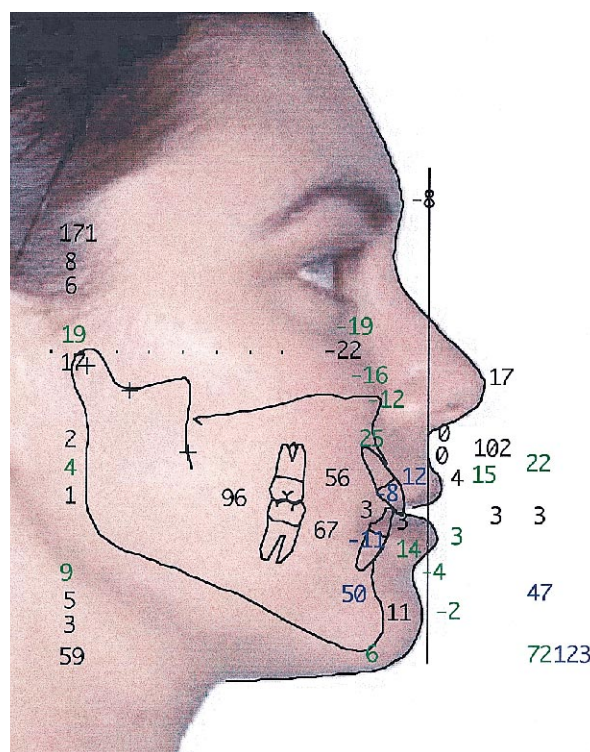


Fig 8. Male means and SDs have been applied to the female patient depicted in Fig 7; multiple 2 and 3 SD errors occur when opposite sex norms and SDs are applied. This figure demonstrates why separate norms, appropriate specifically to males and females, must be used when measuring and planning dentofacial changes. (Black = within 1 SD; green = within 2 SD; blue = within 3 SD; red = >3 SD.)

Inspection then focuses on *orbital rim to jaw harmony* (Fig 5C). The position of the soft tissue inferior orbital rim relative to the upper jaw (OR'-A') and the lower jaw (OR'-Pog') are measured. Measurements between these areas assess high midface to jaw balance.

The last step of the harmony examination is *total facial harmony* (Fig 5D). The upper face, midface, and chin are related via the facial angle (G'-Sn-Pog'). Then the forehead is compared to two specific points, the upper jaw (G'-A') and chin (G'-Pog'). These three measures give the broad picture of facial balance.

The complete female STCA is shown in Fig 6. When the analysis is hand drawn on acetate film, the location of landmark measurements is operator defined. For this article, measurements are identified and placed in standard positions as in Fig 6. Fig 6 serves as a reference drawing to help understanding of Figs 7 to 12. Fig 7 depicts a female patient with all measurements within 1 SD of the mean (black num-

Table II. Facial harmony

	Mean \pm SD Females	Mean \pm SD Males	Female to male difference significant when $> .05$
Intramandibular relations			
Md1-Pogonion'	9.8 \pm 2.6	11.9 \pm 2.8	.0076
Lower lip anterior-Pogonion'	4.5 \pm 2.1	4.4 \pm 2.5	.8915
B point'-Pogonion'	2.7 \pm 1.1	3.6 \pm 1.3	.0192
Throat length (neck throat point to Pog')	58.2 \pm 5.9	61.4 \pm 7.4	.1213
Interjaw relations			
Subnasale'-Pogonion'	3.2 \pm 1.9	4.0 \pm 1.7	.1191
A point'-B point'	5.2 \pm 1.6	6.8 \pm 1.5	.0010
Upper lip anterior-lower lip anterior	1.8 \pm 1.0	2.3 \pm 1.2	.1236
Orbit to jaws			
Orbital rim' - A point'	18.5 \pm 2.3	22.1 \pm 3	8.645E-05
Orbital rim'-Pogonion'	16.0 \pm 2.6	18.9 \pm 2.8	.0009
Full facial balance			
Facial angle	169.3 \pm 3.4	169.4 \pm 3.2	.9609
Glabella'-A point'	8.4 \pm 2.7	7.8 \pm 2.8	.4609
Glabella'-Pogonion'	5.9 \pm 2.3	4.6 \pm 2.2	.0511

Table III. Cephalometric treatment planning

1. Correct Md incisor axial inclination: (female 56.8 \pm 2.5°) (male 57.8 \pm 3.0°) to Md occlusal plane
2. Correct Mx incisor axial inclination: (female 64.3 \pm 3.2°) (males 64.0 \pm 4.0°) to Mx occlusal plane
3. Set Mx incisor position
Vertical: (females 4.7 \pm 1.6 mm) (males 4.0 \pm 1.4 mm) incisor exposure under relaxed lip a-p:
Clinical nasal projection (long, normal, short)
Clinical orbital rim, cheekbone, subpupil, and alar base contours (depressed, flat, normal, prominent)
Clinical upper lip support (by incisor, gingiva, no support [air])
Cephalometric upper lip angle: (females 12.1 \pm 5.1°) (males 8.3 \pm 5.4°)
Cephalometric upper lip thickness: (females 12.5 \pm 1.8 mm) (14.8 \pm 1.4 mm)
4. Autorotate Md to 3.2 mm incisor overbite when the following occurs at 3.2 mm of overbite:
CI overjet LFI only has corrected the bite
CII overjet Md advancement will be necessary in step 5
CIII overjet Md setback will be necessary in step 5
5. Move Md to Mx
3.2 mm incisor overjet
3.2 mm incisor overbite (done in step 4)
1.5 mm first molar overbite
6. Set occlusal plane
Anterior: Mx incisor position set in step 3 is center of occlusal plane rotation
Posterior: move Mx first molar superior or inferior with Mx incisor as center of rotation
Occlusal plane determinants:
Mx occlusal plan to TV line (females 95.6 \pm 1.8°) (males 95.0 \pm 1.4°)
Chin to TV line: (females -2.6 \pm 2.5 mm) (males -3.5 \pm 1.8 mm)
Appropriate facial change at alar base
7. Set ideal chin projection
Chin osteotomy
Sn to Pog': (females -2.6 \pm 2.5 mm) (males -3.5 \pm 1.8 mm)

bers). Fig 8 represents the same female patient but with male means and SDs used. Multiple 2 and 3 SD errors occur. This demonstrates the need for separate male and female values.

Landmark absolute values (Fig 7) are dependent on TVL placement. When the TVL line is moved anteroposteriorly, all landmark absolute values change (Fig 9), but by the same amount. Harmony between facial parts is independent of the anteropos-

terior location of the TVL. The TVL can be placed at any location, and the harmony value between two facial structures will be unchanged (Figs 7 and 9). This unalterable consistency of the harmony values provides diagnostic reliability. If TVL position is difficult to locate with confidence, the diagnosis and treatment plan can usually be confidently and accurately based on harmony analysis. The exception to this is bimaxillary retrusion.

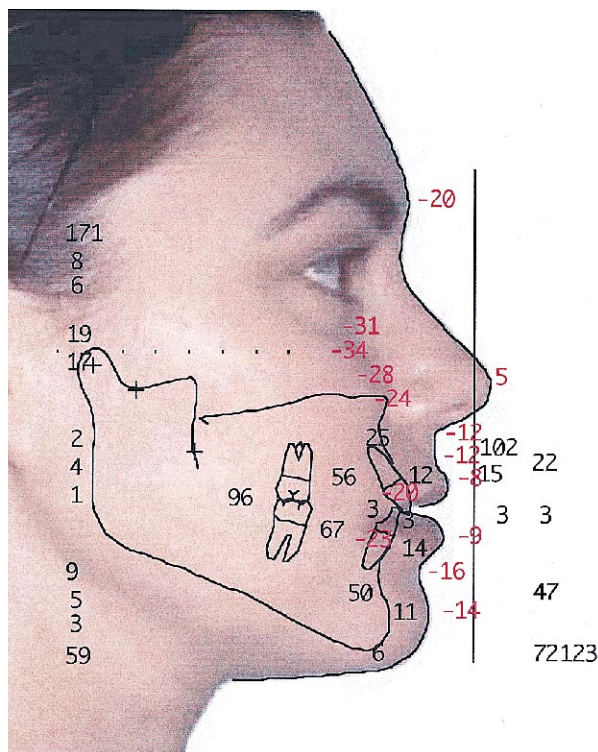


Fig 9. TVL movement: same patient shown in Fig 7. TVL used in Fig 7 has been moved 10 mm to the right. After moving the TVL, absolute values are (>3SD) red, reflecting the change in TVL position. Note that measurements not dependent on TVL placement including the harmony values are unchanged from Fig 7. Harmony values do not change with TVL position change and are therefore diagnostically reliable. (Refer to Fig 6 for landmark and measurement clarification.)

Cephalometric Treatment Planning (CTP)

Diagnosis generated by the STCA is used to guide cephalometric treatment planning. Seven steps are involved in CTP to optimize occlusal and facial results (Table III).

1. The initial step of CTP is *proper angulation* (Table III) of the lower incisor teeth.
2. The second step of CTP is *proper angulation* (Table III) of the upper incisors.

When these incisor angles are achieved, the true skeletal overjet is revealed without masking by dental compensations. Correct incisor angulations are necessary for ideal facial outcomes. For instance, if the upper incisor is upright ($> 58^\circ$) or the lower incisor is procumbant ($< 60^\circ$) the lower lip, B' point, and Pog' will be retrusive relative to the rest of the face. In this example, the incisor angulations create an undesirable convex profile. These examples describe the significant facial impact the orthodontist has through control of incisor angulations.

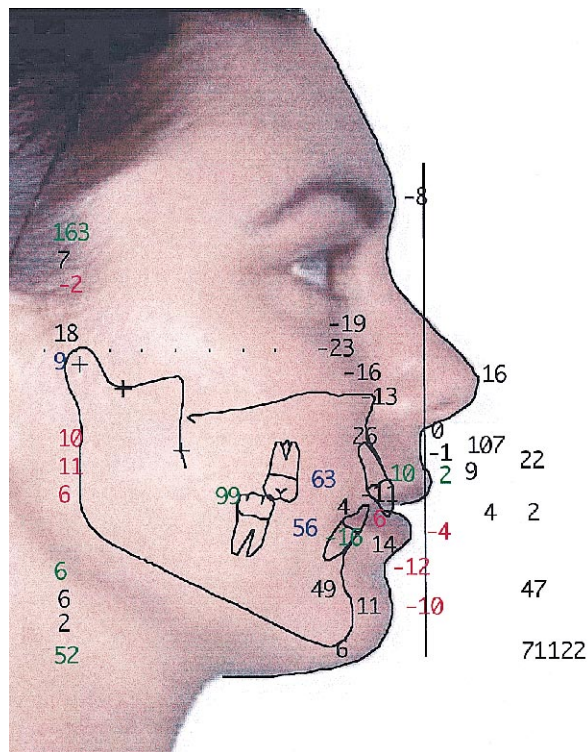


Fig 10. Class II malocclusion: overbite is normal (4 mm), but overjet (6 mm) is excessive. Overjet indicates Class II malocclusion but does not indicate cause, maxillary protrusion, vertical maxillary excess, or mandibular retrusion. Comparing the patient to female STCA normal values, the cause is established as mandibular retrusion (Pog' to TVL, -10 mm; B' to TVL, -12 mm; Md1 to TVL, -16 mm; facial angle 163° ; G' to Pog', -2 mm; OR' to Pog', 9 mm; Sn to Pog', 10 mm; A' to B', 11 mm; ULA to LLA, 6 mm; and NTP to Pog', 52 mm). Other measurements reveal typical compensations associated with mandibular retrusion: upright upper incisors (Mx1 to MxOP, 63°), and flared lower incisors (Md1 to MdOP, 56°). All facial lengths are within normal limits, indicating that the 6 mm overjet is not the result of vertical maxillary excess rotating the mandible down and back. Treatment corrects the malocclusion within the context of the face. CTP is used to plan both the occlusal and facial changes and is based on the STCA findings.

3. Next, *maxillary incisor positioning* (Table III), the key to dentofacial reconstruction, is accomplished. The upper incisor is placed so that 4 to 5 mm of incisor is exposed beneath the relaxed upper lip. Horizontally, the upper incisor is positioned according to a combination of clinical and cephalometric findings. Clinical factors are orbital rim, cheekbone, subpupil, and alar base contours, nasal projection, and upper lip support. Cephalometric factors are upper lip thickness and upper lip angle. The incisors and maxilla should be moved forward when the

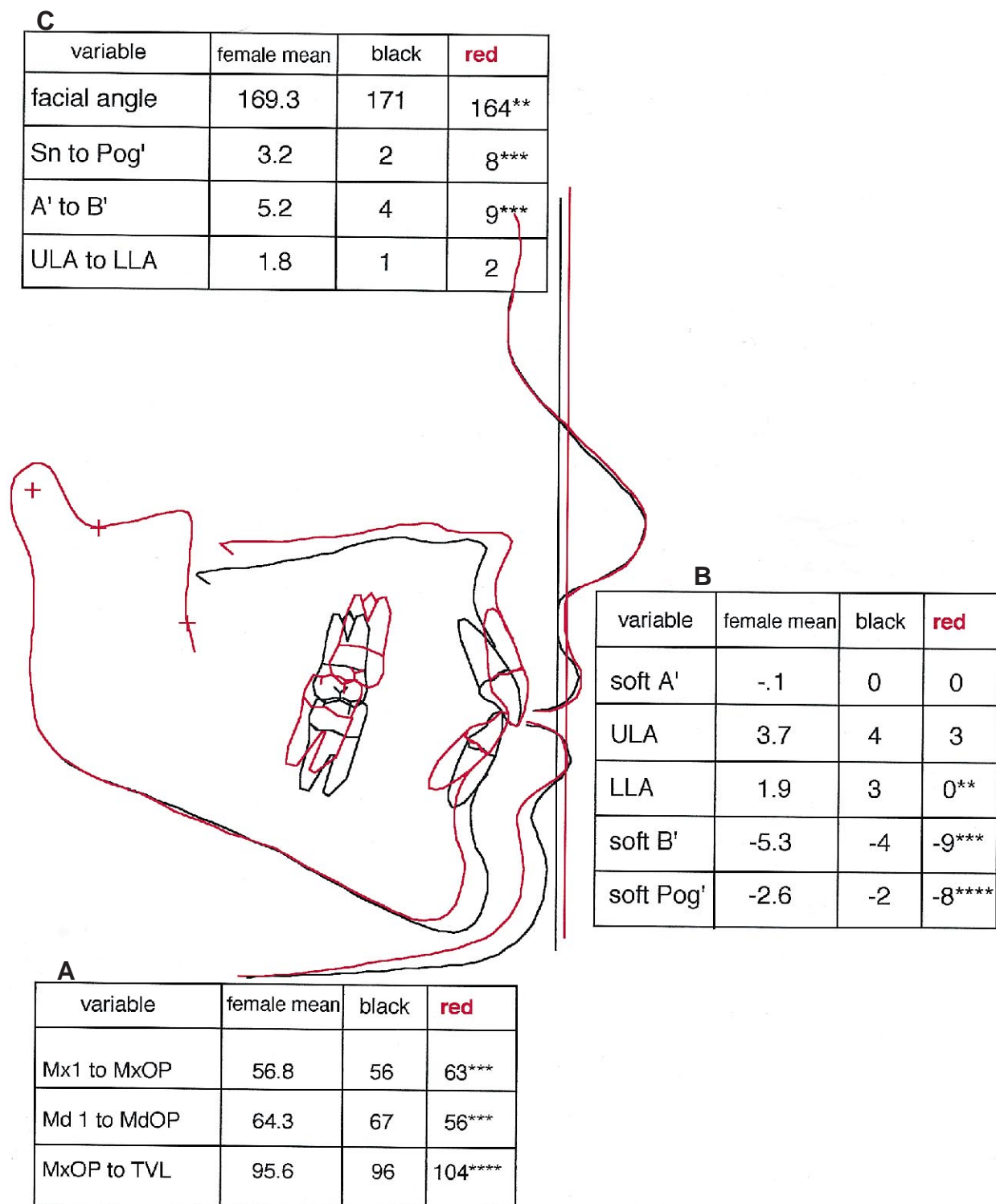


Fig 11. Double jaw surgery is indicated for the patient in Fig 10. Maxillary surgery is required to widen the upper arch; mandibular surgery is necessary to correct the overjet and mandibular retrusion. Fig 11 is an overlay of appropriate and inappropriate surgical treatments: profile differences are compared between inappropriate (*red*) and appropriate (*black*) cephalometric treatment planning. Upper incisor positions are identical. Only treatment differences are upper and lower incisor inclinations and occlusal plane (box A). Note that the red TVL line has been moved forward in response to the inappropriate advancement of the maxilla that has changed the position of subnasale and the TVL. These changes produce different profiles (box B) and harmony (box C). (*1 SD; **2 SD; ***3 SD; ****>3 SD.).

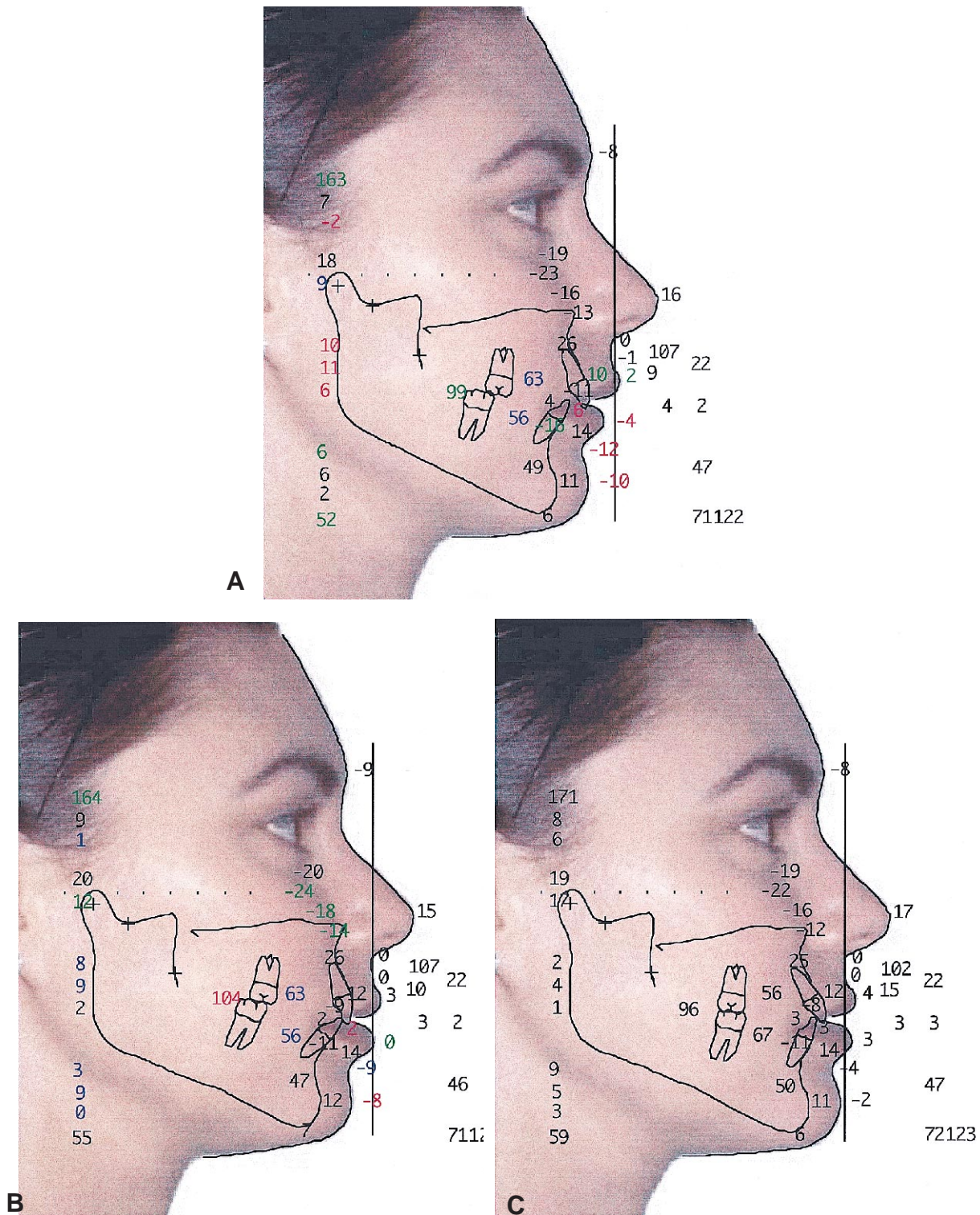


Fig 12. STCA profile comparisons of patient with Class II malocclusion: **A**, original Class II malocclusion from Fig 10 with STCA revealing mandibular retrusion; **B**, mandibular retrusion treated with inappropriate incisor inclinations and occlusal plane. STCA reveals facial imbalance; **C**, mandibular retrusion treated with appropriate incisor inclinations and occlusal plane. STCA indicates facial balance. (Black = within 1SD; green = within 2SD; blue = within 3SD; red = >3 SD.)

nose is long, midface contours are flat, the upper lip lacks incisor support, the upper lip is thick, and the angle of the upper lip is upright. If the orbital rims and cheekbones are flat, an onlay graft is necessary to produce simultaneous augmentation in those areas. When the maxillary incisor position is aesthetically correct without treatment, no maxillary surgery is indicated unless other reasons exist (ie, dual plane occlusion, dissimilar arch form or width, etc).

4. *Autorotation of the mandible* to 3 mm of overbite is the next CTP step. When autorotation produces a Class I overjet, this indicates that an isolated LeFort I is the only indicated surgery. If, however, autorotation to 3 mm of overbite leaves a Class II or Class III overjet a mandibular advancement or setback is indicated in step 5.
5. Then the *mandible is moved* anteriorly or posteriorly to correct the overjet with the maxillary arch.
6. After the overbite and overjet have been set, the *maxillary occlusal plane* is defined. Changing the maxillary occlusal plane affects chin position and alar base support. The anterior point of the occlusal plane is the maxillary incisor tip. The anterior point is set to expose the incisor edge as described above (Step 3) under maxillary incisor positioning. The posterior point of the occlusal plane line is the mesial buccal cusp tip of the first molar. In general, the more superiorly the first molar is placed relative to the incisor tip, the more convex and less pleasing the facial profile. The profile is usually optimized when the occlusal plane is normal (Table III) to the true vertical line, Pog' is normal to the TVL, and alar base change appropriately corrects the existing facial condition.
7. The last step of CTP is chin projection and height assessment. Normal Pog' position to the TVL is -2.6 ± 2.5 for females and -3.5 ± 1.8 for males. Chin position is adjusted in two ways: with a sliding chin osteotomy or by changing the maxillary occlusal plane to increased or decreased projection. Steepening the occlusal plane decreases chin projection, and flattening the occlusal plane increases chin projection. If the chin has poor contour, the occlusal plane can be steepened allowing a chin augmentation to improve the contour and projection. The mandibular heights (chin height) for males and females are 56.0 and 48.6 respectively. The ratio of maxillary height to mandibular height is essentially one to two—53% for females and 51% for males. A chin osteotomy with lengthening or shortening may be used to normalize chin height.

Fig 10 represents a Class II patient with abnormal STCA measurements. The profile differences created by correct and incorrect cephalometric treatment planning of this Class II are shown in overlay (Fig 11). Correct presurgical orthodontic preparation produces

normal upper and lower incisor angulations. Then, bimaxillary surgery moves the upper incisor to an ideal position, normalizes the maxillary occlusal plane, and advances the mandible to correct the overbite and overjet. Ideal CTP and treatment for this patient result in ideal facial changes and normal range STCA values (Fig 11, *black*). When the same patient is treated to identical upper incisor position (Fig 11, *red*) but with incorrect incisor angulations and maxillary occlusal plane, poor facial balance results with abnormal STCA values. Fig 12 demonstrates the side-by-side facial STCA for the original class II patient (Fig 10), incorrect CTP (Fig 11, *red*), and correct CTP (Fig 11, *black*).

DISCUSSION

The STCA is a vertical and horizontal profile tool. As stated previously, the Soft Tissue Cephalometric Analysis is a radiographic instrument that represents the clinical extension of the philosophy detailed in "Facial keys to orthodontic diagnosis and treatment planning."^{1,2} This cephalometric soft tissue analysis guides soft tissue examination, as do these earlier articles, but with added advantages. The original articles suggested facial measurement in the clinical setting, which is difficult to achieve with accuracy. Because the STCA is a cephalometric analysis, profile soft tissue landmarks are easily seen, marked, and measured cephalometrically. Importantly, the midface metallic markers, for the first time, allow important soft tissues (orbital rim, cheekbone, subpupil, and alar base) to be easily seen, marked, and measured. In addition, the cephalometric radiograph reveals very important dental and skeletal relationships that the clinical technique in the original articles did not show (ie, incisor angulations, maxillary occlusal plane).

The STCA integrates occlusal correction and soft tissue balance. Of the 45 STCA measurements, only five relate hard tissue to hard tissue points: maxillary occlusal plane, maxillary incisor to maxillary occlusal plane, mandibular incisor to mandibular occlusal plane, overbite, and overjet. These hard tissue relationships are measured because to a large extent they control the esthetic outcome of occlusal treatment. The remaining measurements of the STCA emphasize soft tissue dimensions (ie, upper lip length) or soft tissue to hard tissue dimensions (ie, upper incisor to upper lip exposure).

The STCA is not meant as a stand-alone cephalometric analysis. It is meant to be used in combination with clinical facial examination and cephalometric treatment planning, to provide clinically

relevant soft tissue information with checks and balances (between cephalometric and clinical facial findings).

In our study, the natural or postural head position was the horizontal reference. This posture is determined by the patient except as noted by Lündström and Lündström.¹⁸ It is the position that a person would assume when looking out to a distant object on the horizon. It is the most frequently assumed, the most realistic, and the most reproducible head position.¹³⁻¹⁸ Natural head position has demonstrated a 2° SD¹³⁻¹⁸ compared to the 4° to 6° SD for the various cranial based landmarks that are more commonly used.^{13,14}

TVL position, as described earlier,¹⁶ is based only on where subnasale appears on the cephalometric film. Improved accuracy of the TVL position, as suggested in this article, involves both clinical and cephalometric examination of the patient. This involves a clinical appraisal of nasal projection, midface contours, upper lip support, and two cephalometric measurements, upper lip thickness and angle. These factors establish the TVL line placement used in the STCA. These factors are also used to determine upper incisor projection during Cephalometric Treatment Planning.

The STCA has five distinct but cross-contributory elements. First, the system analyzes key dentoskeletal structures controlled by the orthodontist (Mx1 to MxOP, Md1 to MdOP) and surgeon (MxOP to TVL). Orthodontic and surgical manipulation of the dentoskeletal factors is key to facial profile and esthetics. Second, it measures key soft tissue structures that affect facial appearance. Third, it measures important vertical soft tissue lengths and soft tissue to hard tissue relationships. Fourth, it measures soft tissue points relative to the TVL, thus producing absolute projection values for each point. And fifth, the absolute values are then related to one another to test facial harmony. Harmony numbers provide a test of facial balance within the individual's face and, importantly, are independent of the true vertical anteroposterior placement. Occasionally with a balanced face, TVL projection values are abnormal as a result of unusual placement of the TVL. If this is the case, the harmony values, independent of the true vertical line, will indicate facial balance, except in the case of bimaxillary retrusion.

Finally, the use of the STCA demonstrates the implications of orthognathic surgery and orthodontics on facial change. For instance, with the STCA we can appreciate that an upright maxillary central incisor can reduce the projection of the upper lip, lower lip, and chin. In addition, the same upright incisor will produce

incorrect harmony between the Sn-Pog', A'-B', and upper and lower lips.

CONCLUSION

The cephalometric analysis presented in this article contains the following features:

1. Natural head position, seated condyles, and relaxed lip positions are essential.
2. Natural head position must be adjusted for some patients using clinical judgement.
3. The Soft Tissue Cephalometric Analysis (STCA) is a facial diagnostic tool.
4. STCA diagnosis is used for cephalometric treatment planning (CTP).
5. Clinical facial analysis is used to augment cephalometric information.
6. Absolute projection values for important soft tissue structures are measured to the true vertical reference line.
7. The true vertical reference line is placed through subnasale.
8. The true vertical reference line is moved forward from subnasale when maxillary retrusion is indicated by clinical and cephalometric findings.
9. Soft tissue analysis of midface structures is expanded by the use of metallic markers.
10. Harmony between facial parts is measured; it is independent of TVL placement.
11. Treatment guidelines for incisor and occlusal plane angulations that influence facial outcome are defined for the orthodontist and surgeon.
12. Separate values are suggested for male and female patients.

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Editor's Note

This provocative study highlights a deficiency in conventional cephalometric analysis based essentially on radiographic images of osseous structure. Yet the draping soft tissue is a vital component of the total facial analysis. Readers are invited to comment in the Readers' Forum of this Journal.

T. M. Graber

AAO MEETING CALENDAR

2000 — Chicago, Ill, April 29 to May 3, McCormick Place Convention Center (*5th IOC and 2nd Meeting of WFO*)

2001 — Toronto, Ontario, Canada, May 5 to 9, Toronto Convention Center

2002 — Baltimore, Md, April 20 to 24, Baltimore Convention Center

2003 — Hawaiian Islands, May 2 to 9, Hawaii Convention Center

2004 — Orlando, Fla, May 1 to 5, Orlando Convention Center

2005 — San Francisco, Calif, May 21 to 26, Moscone Convention Center

2006 — New Orleans, La, April 29 to May 3, Ernest N. Morial Convention Center