TOMAC: An Orthognathic Treatment Planning System

Part 1 Soft-Tissue Analysis

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In modern orthognathic surgery, the orthodontist and oral surgeon need to work in complete symbiosis to achieve the final objective of a facial balance in harmony with the underlying dental and skeletal structures. The orthodontist is in a unique position to govern the success of an orthognathic case by precisely positioning the teeth (decompensation) prior to surgery. Incorrect positioning of the incisors in either arch can have a profound influence on the extent of the overjet (reverse or positive), and thus on the ability of the surgeon to produce the desired profile changes. It is, therefore, the responsibility of the orthodontist to set clear goals before the start of treatment and to communicate these to the surgical colleague.

TOMAC (an acronym for the author's name) is a surgical-orthodontic treatment planning and prediction system designed to identify the best possible soft-tissue profile by testing the effects of various orthodontic and surgical options. With practice, this system will readily identify the most advantageous combination of treatment procedures. Although it was developed for orthodontists, oral surgeons will also find it useful.

Visualized Treatment Objectives

Visualized treatment objectives are important tools commonly used by orthodontists to predict growth and treatment changes in developing children.[1,2] The pioneers of the VTO were Ricketts,[3,4] who with Rocky Mountain Orthodontics developed a computerized system of prediction; Holdaway[5,6]; and Jacobson and Sadowsky,[7] who predicted the soft-tissue position of the upper lip first and then placed the maxillary incisors accordingly.

It has now become customary and, indeed, vital to perform similar predictions for adult patients requiring combined surgical-orthodontic treatment to correct dentofacial deformities. Authors such as Fish and Epker,[8] Wolford, Hilliard, and Dugan,[9] and Moshiri and colleagues[10] preferred to move the hard tissues first in their VTOs and then adapt the soft tissues. Arnett, Bergman, and colleagues emphasized a comprehensive evaluation of soft-tissue profile goals, with particular attention to positioning the incisors first.[11-14] Henderson,[15] Hohl and colleagues,[16] and Kinnebrew, Hoffman, and Carlton[17] used photographic and cephalometric cutout techniques to evaluate and predict treatment goals. Sarver and colleagues[18-20] and Cangialosi and colleagues[21] pointed out the significant role of new facial video imaging and computer-generated cephalometric techniques in planning orthognathic surgery and communicating with patients. It was Worms, Isaacson, and Speidel who initiated the idea of planning the soft-tissue profile first and then assessing the amount of dental or skeletal movement required to obtain that profile, but they confined their objectives to anteroposterior movement of the chin area.[22]

In orthodontics, the profile is often thought of as only the area between the nose and chin—the area most influenced by orthodontic treatment. Many soft-tissue analyses, such as those of Ricketts,[3,4] Merrifield,[23] Steiner,[24] and Holdaway,[5,6] understandably focus on the relationship of the lips with the nose and chin area. Other authors, however, including Muzj,[25] Mauchamp and Sassouni,[26] Subtelny,[27] Burstone,[28-30] Sushner,[31] and Worms, Isaacson, and Speidel,[22] have alerted orthodontists to the importance of considering the entire profile—not just the nose to chin—as part of the diagnostic equation. Arnett and colleagues showed the importance of midfacial soft-tissue structures such as the orbital rim,

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cheek bone, alar bases, and sub-pupillary area.[13] In the TOMAC VTO, the soft-tissue goals are traced in first, and the hard tissues are then adapted, based on known soft-to-hard-tissue responses.

Burstone,[28-30] Zylinski, Nanda, and Kapila,[32] and Nanda and Ghosh[33] have all demonstrated that the thickness of the soft-tissue integument can vary considerably from one patient to another and that the profile is not necessarily dependent on the underlying dentoskeletal structures. Patients with similar dentoskeletal structures may have very different soft tissue profiles, and vice versa. Although the orthodontist has a plethora of dentoskeletal analyses to choose from, none has been found to be consistently reliable in the diagnosis of dentofacial deformities. In fact, Wylie, Fish, and Epker tested the reliability of five different skeletal analyses and found several contradictions.[34]

The case illustrated in Figure 1A has a convex total facial profile, indicative of a Class II skeletal and dental malocclusion. The patient was treated by a maxillary dentoalveolar surgical procedure to reduce the large overjet. While a Class I skeletal and occlusal relationship was achieved, the soft-tissue profile is a failure (Fig. 1B). The nasolabial angle is much too obtuse as a result of retraction of the upper lip. The total facial profile is still markedly convex, and the nose is exaggerated. The patient's perception of his esthetic result is so unfavorable that he has grown a mustache to disguise it. This case demonstrates the necessity of following a comprehensive soft-tissue diagnosis and treatment plan, rather than treating only to dentoskeletal norms. A mandibular advancement, possibly combined with maxillary elevation to reduce lower anterior facial height, would have been more successful in this case. The TOMAC system would have pinpointed that option.

The key to TOMAC is a thorough and easy-

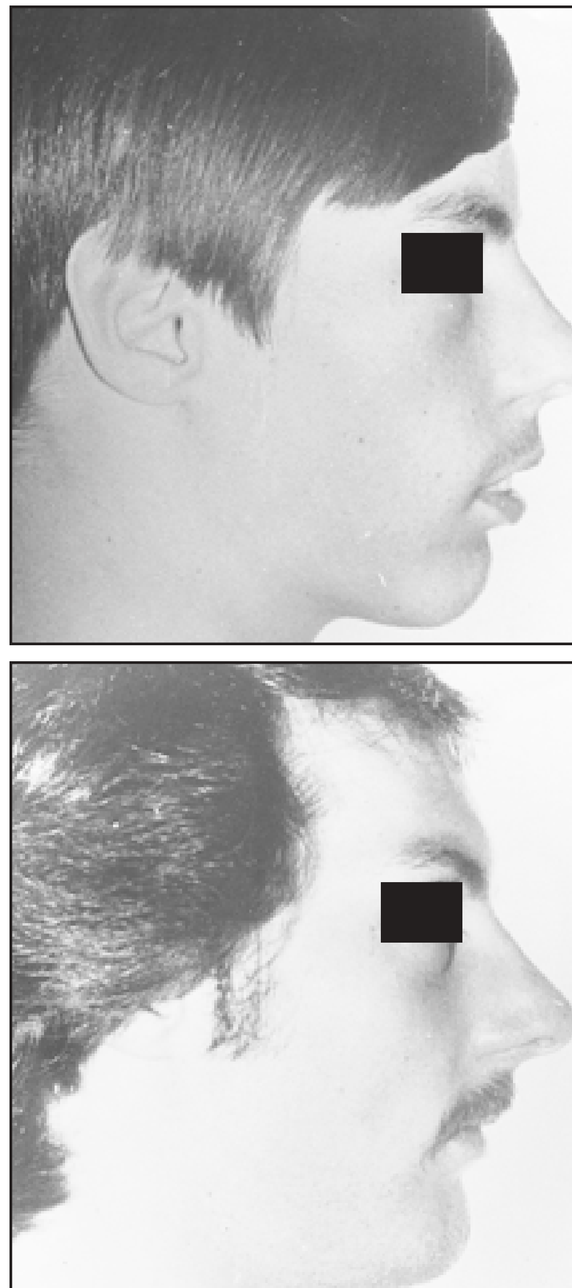

Fig. 1 A. Class II patient with convex facial profile before treatment. B. Unacceptable soft-tissue profile after maxillary dentoalveolar surgery.

to-use analysis of the *total* soft-tissue profile, from the forehead to the throat. Such an approach can be more valuable than dentoskeletal analyses alone, although these remain important in the diagnostic and treatment planning process. Analysis of the frontal view is also important, but the profile view affords the best opportunity to plan treatment. The profile analysis should be quantitative, but should meld with the clinician's intuitive diagnostic ability (the "eyeball assessment"). It must also be complemented by practical, common-sense treatment planning.

Soft-Tissue Landmarks

The soft-tissue landmarks are located according to definitions from Burstone,[28-30] Worms, Isaacson, and Speidel,[22] Riolo and colleagues,[35] Chaconas and Bartroff,[36] and Legan and Burstone[37] (Fig. 2).

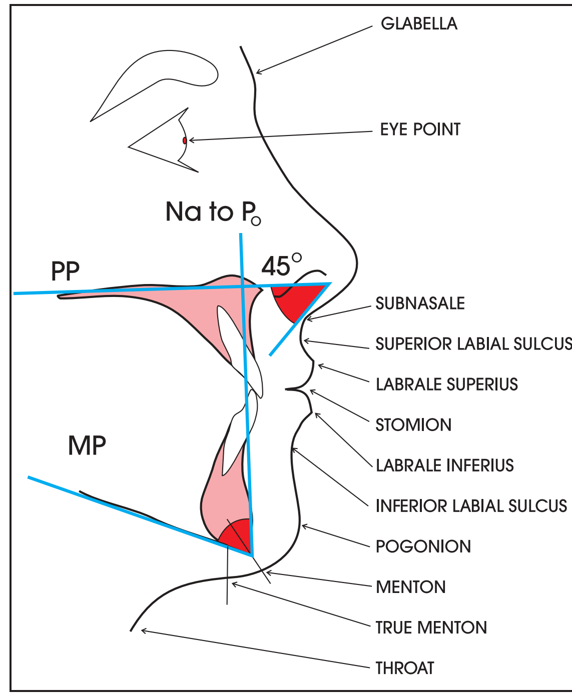

Fig. 2 Soft-tissue landmarks used in TOMAC.

Angular Measurements

Facial Contour Angle

The facial contour angle (FCA) is highly relevant to the analysis because it measures the convexity or concavity of the face (Fig. 3A). This angle is formed by tangents to glabella and soft-tissue pogonion, intersecting at subnasale. The line from glabella to subnasale is referred to as the upper facial contour plane, and that from subnasale to pogonion as the lower facial contour plane. The acute angle between these planes is the FCA, which describes the degree of anteroposterior discrepancy of the total face. Glabella is a stable, consistent point, on a contour whose shape may vary from one individual to another and seems to be altered only in the treatment of craniofacial deformities. On the other hand, the spatial positions of subnasale and pogonion can be changed by orthognathic surgery.

The normal value of FCA, according to Burstone, is –11° ± 3°.[29] FCA varies according to facial type, with leptoprosopic (long face) individuals tending to be more convex, around –16°, and euryprosopic (short face) patients tending to have more acute angles, around –7°.

Czarnecki, Nanda, and Currier asked 545 dental professionals to judge a series of constructed profiles for males and females.[38] After measuring the FCAs of these selected profiles, I found that the "ideal" for men varied between –10° and –14°, with a mean of –12°. The "ideal" in females varied between –14° and –16°, with a mean of –15°. Nanda, Ghosh, and Bazakidou found similar results in a three-dimensional facial analysis using a video imaging system, although they measured the convexity from soft-tissue nasion, not glabella.[39] Sutter and Turley found that the FCA was slightly flatter in Caucasian female models (–11.0°) than in a control group (–13.9°).[40]

Nasolabial Angle

The nasolabial angle is formed by the intersection of a line originating at subnasale and tangent to the lower border of the nose with a line from labrale superius to subnasale (Fig. 3B).

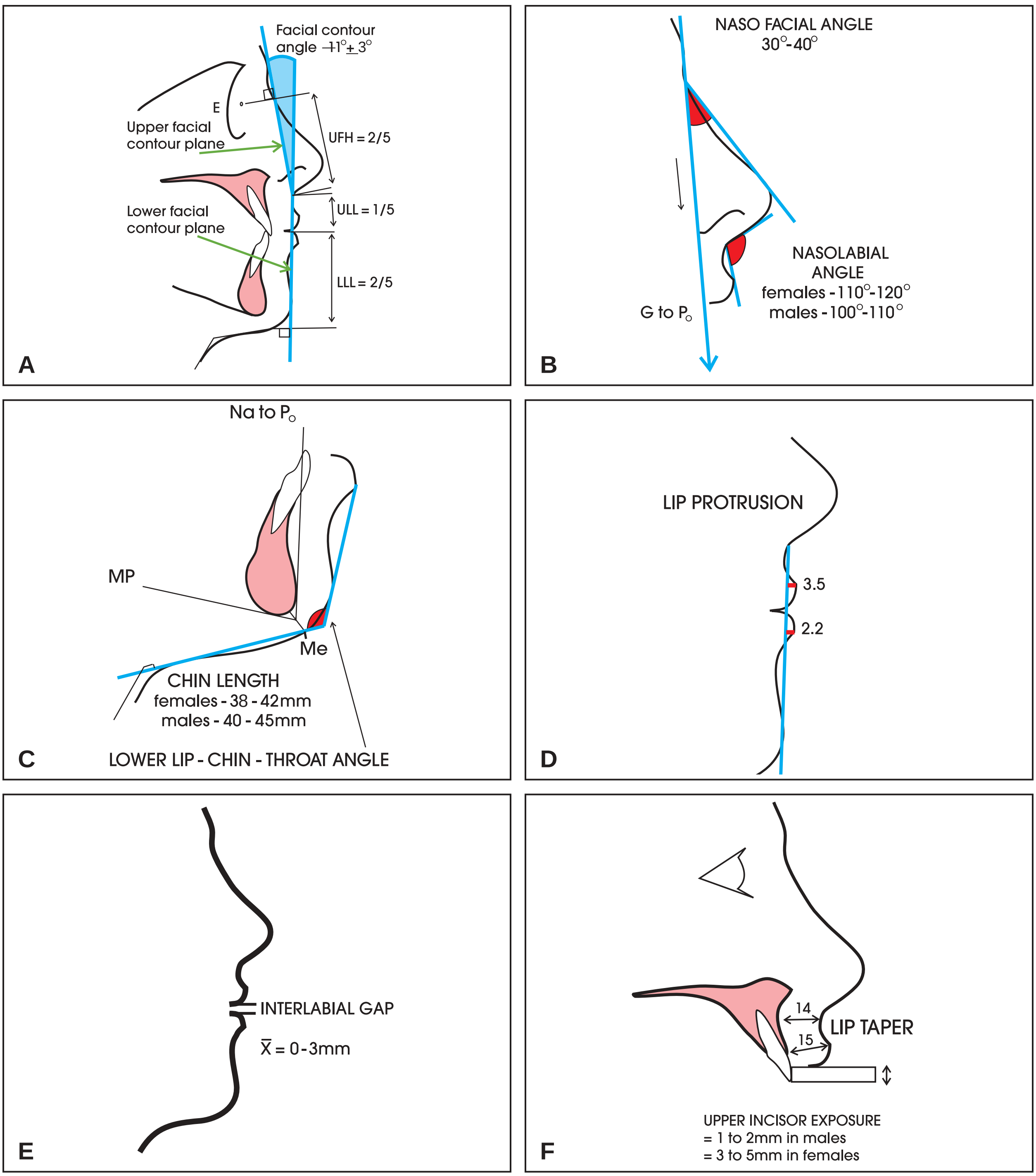

Fig. 3 Measurements used in TOMAC. A. Facial Contour Angle and facial height measurements. B. Nasolabial angle and nasofacial angle. C. Lower lip-chin-throat angle and chin length. D. Lip protrusion. E. Interlabial gap. F. Maxillary incisor exposure and lip taper.

This useful measurement indicates the protrusion of the upper lip relative to the nose, but can also be a reflection of the up or down tip of the nose. I have found the angle to vary between 110° and 120° in females and between 100° and 110° in males. The tip of the nose is more elevated in females than in males, creating a more obtuse angle. According to McNamara, Brust, and Riolo, the mean is 102.4° ± 8.2° for males and 102.2° ± 7.7° for females[41]; Burstone found the norm to be 106° ± 8°.[30]

Nasofacial Angle

The nasofacial angle, formed by the intersection of a tangent to the radix and tip of the nose with a line drawn from glabella to pogonion, is important because it describes the protrusion and slope of the nose relative to the total facial profile (Fig. 3B). A retrognathic chin will produce a large angle, which in turn will emphasize the size of the nose. This effect is greatly reduced if the mandible is advanced. If the angle is more acute, then either the slope of the nose is steep, the maxilla is recessive, or the mandible is prognathic. The norm is from 30-35° (O'Ryan and Schendel[42]) to 36-40° (Powell and Humphreys[43]).

Lower Lip-Chin-Throat Angle

This angle is formed by a line drawn from labrale inferius and tangent to pogonion, intersecting with a tangent to the throat that passes through throat point and soft-tissue menton (Fig. 3C). It is helpful in determining the position of the lower lip in relation to the chin. In prognathic mandibles, it will tend to be acute; in retrognathic mandibles, obtuse. The normal intersecting angle is 110° ± 8° (Worms, Isaacson, Speidel[22]).

Linear Measurements

Lip Protrusion

Hsu analyzed the lip positions of 110 students selected from a pool of 1,000 for the attractiveness of their profiles.[44] Five reference lines—Ricketts's "E" line,[4] Holdaway's "H" line,[5,6] Steiner's "S" line,[24] Burstone's "B" line,[30] and Sushner's "S2" line[31]—were statistically analyzed for consistency (the smallest coefficient of variation) and sensitivity (the ability to differentiate attractive profiles from unattractive ones). The "B" line of Burstone was found to be the most consistent and sensitive of these reference lines in measuring lip position. This line, drawn from subnasale to pogonion, is the same as the lower facial contour plane (Fig. 3A). The lips are measured at right angles from the lower facial contour plane to labrale superius and labrale inferius (the most anterior points of the lips).

Upper lip protrusion is an excellent measurement of lip protrusion or retrusion when used in conjunction with the nasolabial angle. The norm is +3.5mm ± 1.4mm (Fig. 3D). Lower lip protrusion should be used in conjunction with the lower lip-chin-throat angle. The norm is +2.2mm ± 1.6mm.

In planning lip position, every attempt should be made to obtain the ideal. If this is not possible, however, then upper and lower lip protrusion should be approximately equal. The lips become unesthetic if one protrudes or retracts more than 1.6mm relative to the other.

Nasal length (the inferior base of the nose to the tip) has twice as large a standard deviation as that of lip protrusion. Therefore, it is not advisable to relate the lips to the nose, as is done in some lower-face analyses.[4-6]

Chin Length

Chin length is measured from constructed soft-tissue menton to the intersection of tangents to the chin and the throat (Fig. 3C). This factor is difficult to measure accurately, because it is subject to a number of variables: the amount of fat present, the posture of the head, and the shape of the mandible and throat. Nevertheless, it is a reasonable guide in treatment planning. There are few profiles as unesthetic as that produced by a mandibular reduction osteotomy in a Class III patient with a short chin before surgery. Postoperatively, the chin becomes even shorter, with a roll of soft tissue beneath the chin and an ill-defined neck-chin junction.

The reference norm, according to Worms, Speidel, and Isaacson,[22] is 57mm ± 6 mm. I have found this value to be too large and recommend using 38-42mm in females and 40-45mm in males. Further investigation is warranted.

Facial Height

There are several skeletal analyses that measure facial height, but the soft tissue overlying the skeletal and dental structures does not necessarily reflect the hard-tissue measurements.[26] Cutcliffe's unpublished research divided the face into fifths between eye point (E), bisecting the distance between supraorbitale and infraorbitale, and constructed soft-tissue menton (Fig. 3A).[45] Upper Facial Height (UFH), measured from eye point to subnasale, makes up two-fifths. Middle Facial Height (MFH) or Upper Lip Length (ULL) is measured from subnasale to stomion and contributes one-fifth. The norm for females is 20mm; for males, 24mm. Lower Facial Height (LFH) or Lower Lip Length (LLL), from stomion to constructed menton, makes up the final two-fifths. This is an excellent proportional analysis of facial height, but must be used in combination with measurements of the interlabial gap and maxillary incisor exposure.

Interlabial Gap

The interlabial gap is the space between the upper and lower lips when they are relaxed, with the head in a normal upright position and the teeth in centric occlusion (Fig. 3E). The norm is 1.8mm ± 1.2mm (Burstone[29,30]), with a range of 0-3mm. If the measurement exceeds 3mm, it indicates an excessive lower facial height. When lips that are this far apart are closed, the lip musculature is strained.

Maxillary Incisor Exposure

The maxillary incisor should be exposed below the relaxed upper lip by 1-2mm in males and 3-5mm in females, according to Wolford, Hilliard, and Dugan[9] (Fig. 3F). This is a critical measurement on which much of the vertical planning for surgical-orthodontic treatment depends. Excessive exposure indicates an increased maxillary height. Treatment planning to a gummy smile should be avoided, because lip function exaggerates the exposure. Conversely, if the maxillary incisors are underexposed beneath the relaxed upper lip, a maxillary height deficiency or attrition of the teeth may be suspected.

Incisor exposure should be considered in conjunction with lip length and the degree of cupid's bow of the upper lip, which is greater in females. According to Nanda, Ghosh, and Bazakidou, lip length can increase with age by as much as 1mm.[39] This should be taken into account when planning the correction of vertical maxillary excess.

Lip Taper

Upper lip thickness can be measured in both relaxed and lips-together postures. The measurement is made from the point of maximum thickness of the upper lip, just below subnasale, to the underlying bone, usually about 3mm below A point (Fig. 3F). This measurement is compared with that from the incisor crowns to the vermillion border.

The norm is 14mm for the upper measurement and 15mm for the lower, resulting in a 1mm taper (Holdaway[5,6]). According to McNamara, Brust, and Riolo, however, average lip thickness at the incisor tip is 12.7mm in males and 9.4mm in females[41]—considerably thinner than Holdaway's measurements.

In some patients, the lips show strain or an increased taper even in the relaxed position. This appears to be more prevalent in older patients, and must be allowed for when retracting proclined maxillary incisors.

Additional soft-tissue analyses are described in essential articles by Arnett, Bergman, and colleagues.[11-14]

Soft-Tissue Changes from Various Surgical Procedures

To predict the soft-tissue profile, it is vital to have an in-depth knowledge of the soft-tissue reactions caused by different surgical movements of the jaws.

Mandibular Advancement

Soft-tissue pogonion advances in an almost 1:1 (100%) ratio with hard-tissue pogonion, according to Gardner.[46]

The inferior labial sulcus responds in a .69:1 (70%) ratio with hard-tissue B point.

Labrale inferius advances in a .77:1 (75%) ratio with the lower incisor tip.

The soft-tissue chin advances in harmony with the underlying bony chin. The thickness of the lip also plays a role—the thicker the lip, the less it will advance, and the thinner the lip, the more it will respond. The lower lip advances less than the soft-tissue chin because of its status before surgery, when it can be curled, everted, and already forward.

Mandibular Setback

Soft-tissue pogonion follows hard-tissue pogonion at a 1:1 (100%) ratio (Betts and Fonseca[47]). The inferior labial sulcus responds in a .77:1 (75%) ratio with hard-tissue B point .

Labrale inferius responds to distal movement of the mandibular incisor in a .79:1 (75%) ratio (Dancaster[48]).

The lower lip shortens slightly and becomes more protrusive by curling out, and the labiomental fold becomes more accentuated. Only minor effects occur in the upper lip and nasolabial angle.

Genioplasty

According to Gardner's research on enhancement genioplasties, the soft-tissue chin advances in a 1:1 ratio with the hard-tissue chin.[46] The chin advancement has no influence on the lower lip at labrale inferius, but the inferior labial sulcus deepens.

In reduction genioplasties, the soft-tissue chin also follows the bony contours in a 1:1 ratio.

Genioplasties should only be performed if they complement and balance lip position. For a further comparison of soft-tissue changes reported by many authors, refer to Betts and Fonseca.[47]

Maxillary Advancement

The nose tip responds to the maxillary advancement measured at maxillary incisor anterius in a ratio of .26:1 (25% of the hard-tissue movement), as shown by Dancaster.[48]

Subnasale advances in a .52:1 (50%) ratio with maxillary incisor anterius, and in a .56:1 (55%) ratio with subspinale (A point).

The superior labial sulcus moves horizontally in a ratio of .69:1 (70%) with maxillary incisor anterius; in other words, the middle of the upper lip becomes less concave as it flattens.

Labrale superius responds in a .55:1 (55%) ratio with maxillary incisor anterius. Carlotti, Aschaffenburg, and Schendel reported a ratio of .9:1 (90%) using their VY soft-tissue wound-closure technique.[49] According to Freihofer, leaving the anterior spine intact causes greater forward movement of the upper lip and subnasale.[50]

While the VY closure technique could not be shown to produce predictable horizontal soft-tissue changes in the upper lip at labrale superius, stomion superius was found to advance about 25% more than when no VY closure was used. The VY technique also reduced the amount of lip shortening from .26:1 to .1:1.

Labrale superius and stomion superius move vertically in a .1:1 (10%) ratio with the maxillary advancement.

Thin lips (less than 15mm) advance 2.8 times farther than thick lips.

Nasal width is controlled by the alar cinch suture technique; only a 2.8% increase was reported by Guymon, Crosby, and Wolford, as against a 10% increase when the technique was not performed.[51]

As the maxilla advances, the nose tip advances slightly, the alar bases widen marginally, subnasale advances, the superior labial sulcus flattens, and labrale superius advances. For a further comparison of research results, refer to Betts and Fonseca.[47]

Maxillary Impaction

Undesirable nasal tip elevation can occur as a result of maxillary superior repositioning.[52,53] Radney and Jacobs found about 1mm of elevation for every 6mm of maxillary superior repositioning (15%).[54] Schendel and Williamson, in a sample of 10 cases with an average maxillary vertical movement of 6.3mm, found as much as 2.4mm.[55] If the maxilla is also advanced in the elevation process, then the nasal tip will be further advanced and elevated.[56] This is important for orthodontists to remember, because the maxillary incisors must be decompensated (retroclined) so that surgical advancement of the dentition is minimized unless otherwise desired.

The alar bases widen with maxillary impaction,[52] but this may be controlled by the alar-base cinch suture,[57] which, according to Guymon, Crosby, and Wolford, restricts such widening to only 2.8%.[51] If the alar bases are particularly narrow, however, it may not be necessary to perform a cinch suture.

The nasolabial angle decreases with maxillary impaction, according to O'Ryan and colleagues,[52,53] although Sarver and Weissman found this change to be insignificant.[58] McFarlane and colleagues quantified nasal morphologic features that predispose patients having Le Fort I osteotomies to greater or lesser nasal tip deflection.[59] Their simple Deflection Resistance Index is derived from facial photographs, using a numerical rating based on the three-dimensional perception of the bulk of the tissue anterior to the nostril in relation to the total horizontal size of the nose (alar base to tip). The area anterior to the nostrils is normally one-third of the total horizontal length. The larger the area anterior to the nostrils, the greater the deflection of the tip. The greater the maxillary movement, the more the tip will advance and deflect. In addition, the greater the columellar angle (the obtuse angle of nasion vertical to a tangent to columella), the more the nose will tip up, and the nostrils will flare anteriorly (similar to Porsche headlights). These anatomic features must be seriously considered when planning treatment.

The upper lip elevates superiorly with the impacted maxilla by about 40% (Radney and Jacobs[54]). Sarver and Weissman noted minimal shortening of the upper lip, measured from subnasale to stomion, in a five-year follow-up study.[58] Rosen warned that the upper lip will shorten more if the maxilla is advanced as well as impacted.[56] The amount of vertical soft-tissue change increases progressively from nose tip to stomion superius. The VY surgical closure technique can help prevent undesirable loss of vermillion exposure and reduce lip shortening.[5]

Sarver and Weissman noted little soft-tissue thinning of the upper lip in the short term, but it became mildly significant in the long term (five years).[58] On the other hand, O'Ryan and Schendel listed lip thinning as an important factor in treatment planning.[52]

Autorotation

The soft tissue of the chin follows the autorotation of the mandible in an approximate 1:1 ratio, according to Radney and Jacobs[54] and Mansour, Burstone, and Legan.[60]

The lower lip becomes slightly recessive at labrale inferius, and the labiomental angle increases.

(TO BE CONTINUED)

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