Biomechanics and the Paradigm Shift in Orthodontic Treatment Planning

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The current trend in orthodontic diagnosis and treatment is toward an increasing emphasis on the soft-tissue relationships that affect display of the teeth, accompanied by a declining emphasis on the correction of malocclusion. This represents a significant paradigm shift (Table 1).

In the new paradigm, orthodontic records, including models, photographs, and radiographs, are no longer the major components of an orthodontic evaluation, because they do not allow the orthodontist to evaluate the smile and soft tissue in motion. In the near future, it is likely that a digital video clip of smile motion will become a standard diagnostic record. Furthermore, in the new paradigm, a major goal of treatment is to place the teeth in the optimal position relative to the lips, vertically as well as anteroposteriorly. Modern biomechanics makes this possible with greater precision and efficiency than in the past.

The orthodontist must also consider facial balance, interlabial gap, smile arc, smile line, buccal corridors, and how orthodontic treatment in childhood or adolescence will affect the patient as a mature adult. In a patient with deep bite or open bite, the approach to leveling the arches is critically important. It is often desirable to extrude the maxillary incisors to increase tooth display, even if intrusion of the lower incisors is required to establish a correct overbite. A segmented-arch approach can facilitate appropriate vertical positioning of the anterior teeth.

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Growth and Development of the Lips

It is important to understand and consider how the lips mature during growth and development. In childhood, the upper lip lengthens more slowly than the lower face elongates vertically, but the lip catches up as the face matures[1,2] (Fig. 1). From a diagnostic standpoint, this is particularly important if treatment begins before adolescence. What appears to be a gummy smile or anterior vertical hyperplasia may actually be incomplete growth of the upper lip. If so, early treatment with an anterior intrusion arch is contraindicated.

Lip growth is completed at a younger age in girls than in boys. In girls, a mature size is usually attained by age 14 for the upper lip and age 16 for the lower lip. In boys, the lips continue to grow vertically into the late teens.[2-4] When correcting a deep bite in either sex, the maxillary incisors should not be intruded if subsequent lip growth will compromise the smile line as the patient matures (Fig. 2). As the young patient gets older, the lips become thinner and elongate, while the height of the vermillion decreases. Because of a reduction in the number of vertical muscle fibers, the upper lip flattens,[5] and the lateral commissures droop in relation to the mid-philtrum.[6]

Over time, both males and females show the maxillary incisors less and the mandibular incisors more, since the vertical length of the upper lip increases and the lower lip droops with age.[7] Biomechanically, it is important to know when and how to extrude or intrude the maxillary and mandibular incisors to enhance the smile by improving

TABLE 1
DENTOFACIAL TREATMENT PARADIGMS*

Parameter	Angle Paradigm	Soft-Tissue Paradigm
Primary treatment goal	Ideal dental occlusion	Normal soft-tissue proportions and adaptation
Secondary goal	Ideal jaw relationships	Functional occlusion
Hard/soft-tissue relationships	Ideal hard-tissue proportions produce ideal soft tissues	Ideal soft-tissue proportions define ideal hard-tissue relationships
Diagnostic emphasis	Dental casts, cephalometric radiographs	Clinical examination of soft tissues
Treatment approach	Obtain ideal dental and skeletal relationships, which determine soft-tissue relationships	Plan ideal soft-tissue relationships, then place the teeth and jaws as needed to achieve them
Functional emphasis	TMJ in relation to dental occlusion	Soft-tissue movement in relation to dental display
Stability of result	Related primarily to dental occlusion	Related primarily to soft-tissue pressures and equilibrium effect

*Adapted from Proffit, W.R.; White, R.P.; and Sarver, D.M.: *Contemporary Treatment of Dentofacial Deformity*, Mosby, St. Louis, 2003.

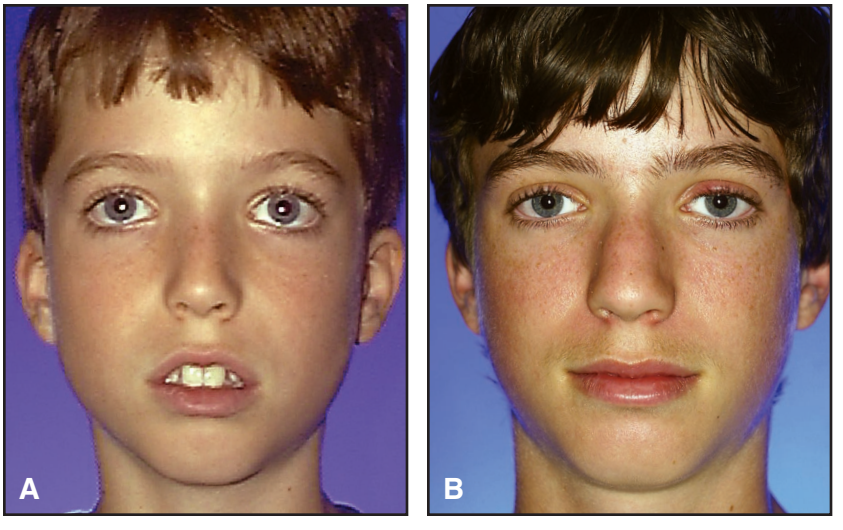


Fig. 1 A. 9-year-old male patient with lip incompetence at rest. B. Same patient at age 18.

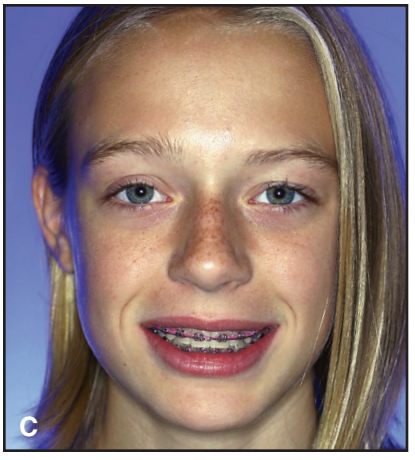
tooth-lip relationships, keeping in mind the impact of aging on the treatment plan.

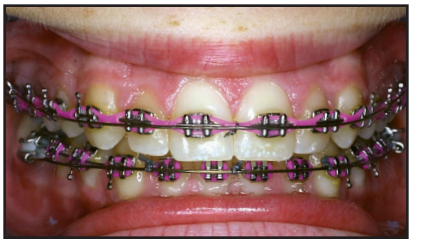
Development of the Chin and Nose

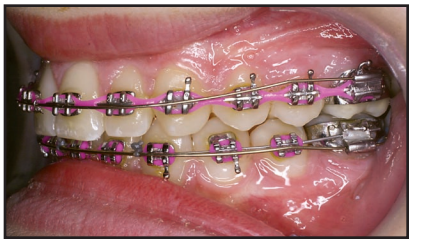
Before the adolescent growth spurt, the soft-tissue thickness of the chin is greater in girls than in boys. During the growth spurt, however, the girls' chins do not thicken as much as the boys', and by late adolescence, males and females have a similar soft-tissue thickness over the anterior portion of the chin (mean = 13.3mm).[4] Before and during adolescence, most of the increase in chin projection is not from soft-tissue growth, but from skeletal change. Beyond adolescence, skeletal changes virtually cease; the soft-tissue thickness at pogonion increases in males, but decreases in females.[8]

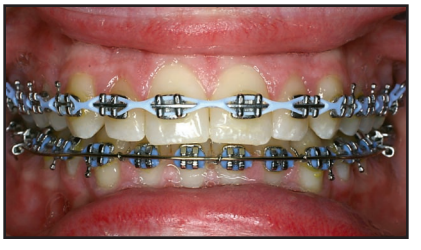
The size and shape of the nose have an impact on facial harmony and facial esthetics. In both

Fig. 2 A. Female patient with flat smile arc and insufficient incisor display. B. Anterior deep bite of same patient. C. Sectional extrusion wires (not shown) and mechanics used to extrude maxillary incisors and intrude mandibular incisors. D. Stabilization of maxillary incisors with continuous archwire and intrusion of mandibular incisors with intrusion arch. E. Improvement in smile arc and incisor display after correction of deep bite.









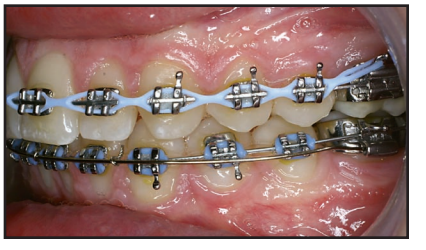


Fig. 3 Typical changes in nose and chin profile with aging. A. In male patient, soft tissue at pogonion increases in size in all dimensions. B. In female patient, chin thickness and nose size are relatively stable.

males and females, the nose grows more in a vertical direction than anteroposteriorly. Most girls do not have a growth spurt of the nose during adolescence, but boys do.[9] As males age, the nose increases in size in all dimensions; in females, the nose also continues to grow, but not as much[8] (Fig. 3).

Growth of the nose and chin plays a major role in biomechanics and in positioning of the teeth. It is important to maintain lip support and prominence, because nose-chin growth makes the lips and teeth less prominent in the face.

Smile Esthetics

The smile is the major facial characteristic used by parents and patients to judge an orthodontic result.[10] Orthodontic treatment sometimes corrects a malocclusion, but compromises the smile.[11] Therefore, an important goal in planning orthodontic treatment should be smile enhancement. This requires evaluating the smile in all three planes of space. Although the dentition can easily be assessed when the patient is in the examination chair, a full analysis of the tooth-lip relationships and facial soft-tissue proportions requires the patient to be seated directly in front of the examiner, so that anterior tooth display can be evaluated during smiling and speaking, with and without animation.[12]

Dong and colleagues reported that the incisor display during speech and at rest changes much more than the smile with age.[13] Spears and col-

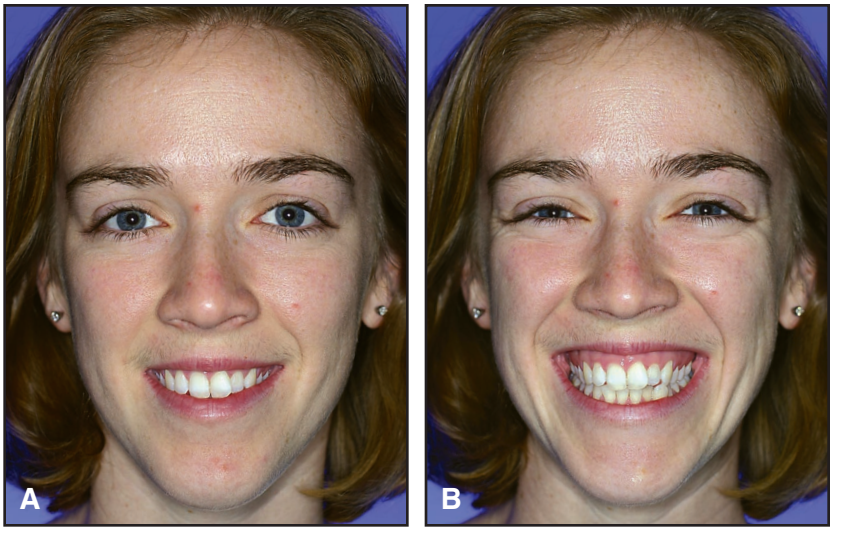


Fig. 4 A. Posed smile appears natural and reproducible. B. Spontaneous smile expresses emotion and shows more lip elevation.

Fig. 5 A. Consonant smile arc: curvature of incisal edges of maxillary incisors, canines, premolars, and molars follows curvature of lower lip. B. Non-consonant smile arc: curvature of maxillary teeth and contour of lower lip diverge.

leagues noted that incisal display decreases with age due to the decreased resiliency of tone of the upper lip; they recommend that treatment planning include an evaluation of the relationship of the maxillary incisors to the upper lip at rest.[14] Van Der Geld and colleagues also advised that aging-related changes in lip length and maxillary lip coverage of the incisors should be considered in treatment planning.[15] The relationship of the teeth to the soft tissues should be studied at rest, during speech, in a social smile, and in a spontaneous smile—one that expresses emotion and has more lip elevation than a posed smile (Fig. 4).

It is generally agreed that the elevation of the lip in a social smile should stop near the gingival margin of the maxillary incisors.[16,17] Showing some gingiva in smiling is a youthful characteristic. Showing less than 75% of the maxillary incisors makes the smile less attractive. The smile arc—the relationship of the curvature of the incisal edges of the maxillary teeth to the curvature of the lower lip in a social smile—must also be noted. A consonant smile arc, in which the curvatures of the teeth and lip match, is esthetic and youthful in appearance; a flattened smile arc is less esthetic and a sign of age (Fig. 5).

If smile dynamics are properly understood, appropriate orthodontic mechanics can be designed to enhance smile esthetics. For example, in a patient with a low smile line (75% or less of the maxillary incisors showing during a posed smile), a deep overbite should not be corrected by using intrusion mechanics in the maxillary arch. Instead, the maxillary incisors should be extruded and the mandibular incisors intruded. On the other hand, a patient with an anterior open bite who shows too

Fig. 6 A. Anterior open bite with flat smile arc results in insufficient incisor display during smiling. B. One-couple segmental extrusion system: maxillary anterior segment extruded with extrusion arch (see Figure 7). C. Continuous archwire used for leveling while vertical correction is maintained with extrusion arch. D. Correction of open bite. E. Smile arc much improved and incisor display increased.

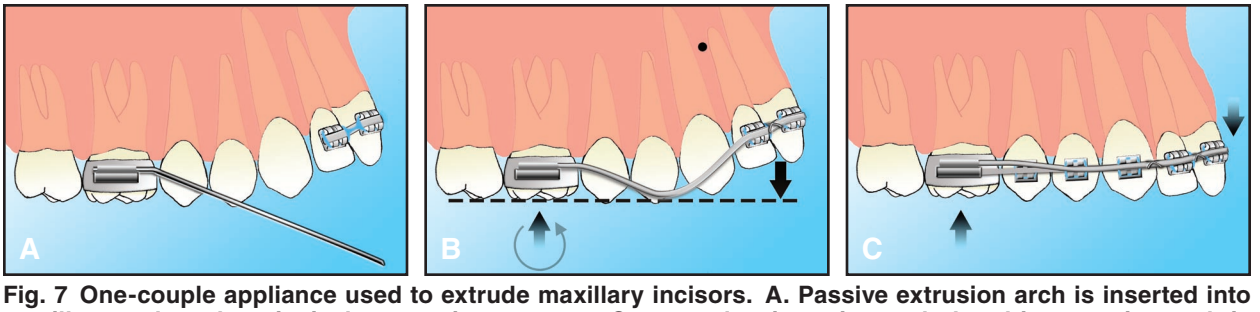


Fig. 7 One-couple appliance used to extrude maxillary incisors. A. Passive extrusion arch is inserted into maxillary molar tubes, incisal to anterior segment. Compared to intrusion arch, bend in extrusion arch is reversed, and slightly more force is applied to each tooth. B. Extrusion arch is activated by tying to base archwire, creating 2nd-order couple at molar, intrusive force at molar, and extrusive force at incisal segment. C. Force system is defined by site of attachment of extrusion wire to base archwire relative to center of resistance.

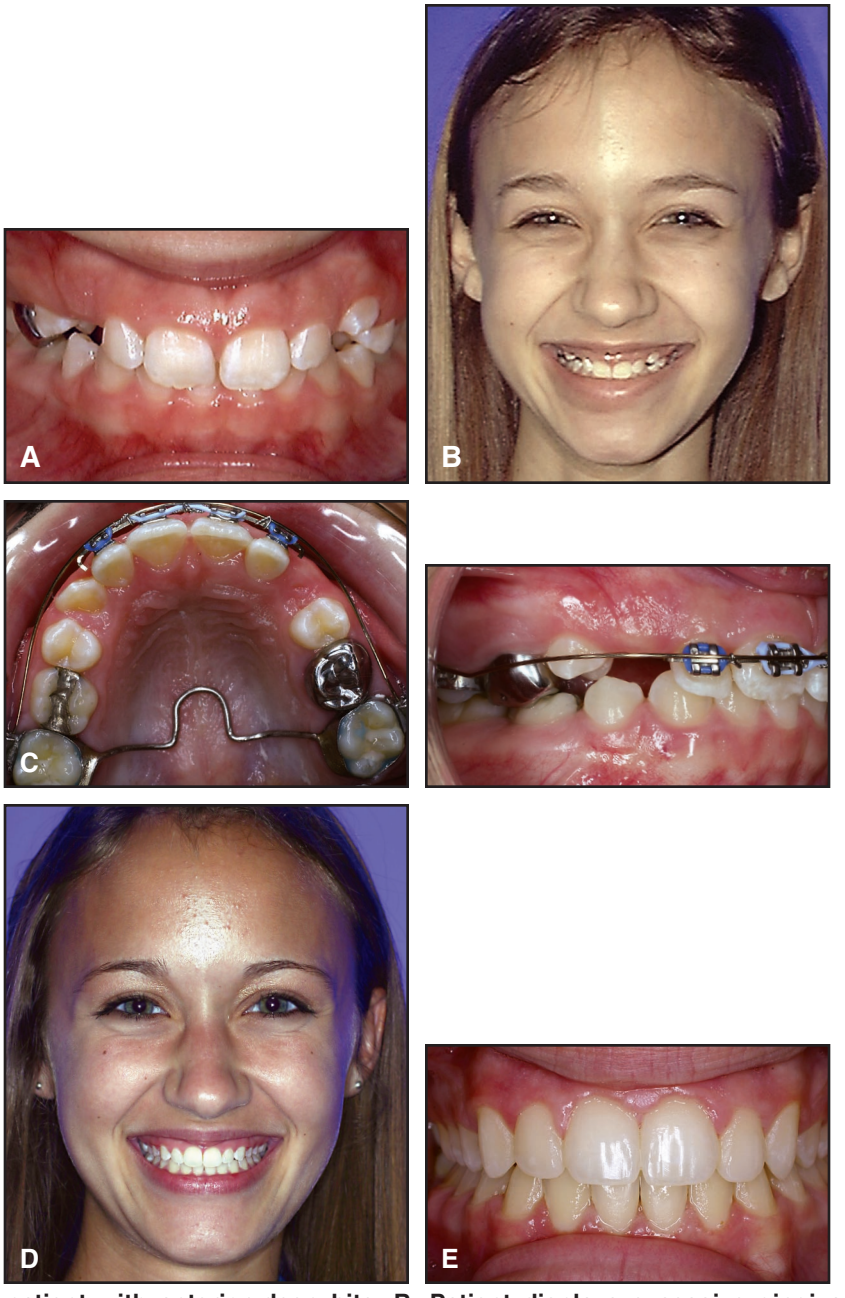


Fig. 8 A. Female patient with anterior deep bite. B. Patient displays excessive gingiva in posed smile. C. One-couple system (intrusion archwire) used to open bite and improve gingival display. D. Deep bite corrected, creating consonant smile arc with much-improved anterior gingival display. E. Improved relationship between maxillary incisors, lip, and gingiva.

much gingiva needs the maxillary incisors to be intruded. This can be accomplished with intrusion arches stabilized by high-pull headgear or temporary skeletal anchorage, reserving orthognathic surgery for the most severe cases. A patient with anterior open bite and insufficient incisor display can be treated with anterior extrusion arches that enhance the smile arc and help close the open bite (Figs. 6,7). On the other hand, in a deep-bite patient with excessive gingival display, the overbite should be corrected with a maxillary intrusion arch, rather than opening the bite by leveling the curve of Spee (Figs. 8,9). Bracket placement and the approach to correcting a deep bite or an open bite all have a considerable influence on the smile arc.

Biomechanics and the Aging Face

As a patient ages, especially beyond age 40, the lips become thinner (the upper lip more so than the lower) and lose their youthful morphology. The tendency for the lips to move downward relative to the teeth with advancing age reduces the maxillary incisor display and increases the mandibular

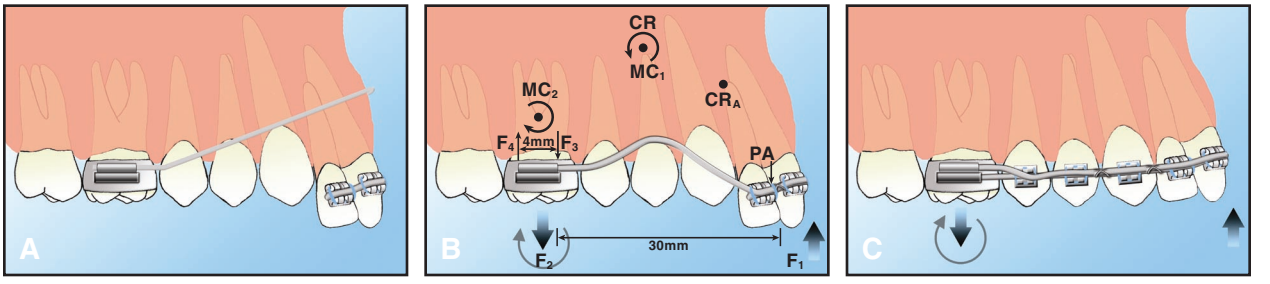


Fig. 9 One-couple appliance used to intrude maxillary incisors. A. Passive anterior wire segment keeps incisors aligned. Intrusion arch is inserted into molar tubes so that passive anterior portion will lie apical to incisors. B. Intrusion arch is activated by tying it to anterior segment, creating 40g of intrusive force (10g per tooth) and 40g of extrusive force on molars (20g per molar). Moment of couple (MC_1), formed by forces F_1 and F_2, is 30mm × 40g = 1,200gmm. To keep system in equilibrium, equal moment is needed at molar; therefore, if molar tube is 4mm long, forces F_3 and F_4 at molar must be 300g each. Point of attachment (PA) further defines system: if intrusion arch is tied in front of center of resistance of anterior teeth (CR_A), moment of force is created; if tied so that force passes through CR, no moment is created, and pure intrusion occurs with no rotation. C. After intrusion of anterior segment, remaining brackets are placed for leveling, and intrusion arch is overlaid on light leveling wire to maintain intrusive correction.

Fig. 10 Facial changes in one patient over 20 years (continued on next page).

Fig. 10 (cont.) Facial changes in one patient over 20 years.

incisor display. The nose increases in size, and the nasolabial angle becomes more acute (Fig. 10).

Biomechanical principles can be used to design force systems that enhance the beauty of an aging face. First, the clinician must determine which teeth or segment needs to be repositioned. For example, if a patient doesn't show enough of the maxillary incisors, segmental archwires are needed to increase the incisor display and enhance the smile; if the mandibular incisors have overerupted, then they should be segmentally intruded. If the mandibular arch is somewhat level, but the patient has too much mandibular incisor display, a light, continuous archwire might be used with an overlay intrusion arch. The orthodontist must also be cognizant of the anteroposterior positions of the teeth and the need to reposition them to maintain lip support. Finally, the force system required to accomplish these goals must be determined at the center of resistance of the appropriate tooth segments, and the forces and moment calculated at the brackets (using center of resistance equivalents) to determine the appliance design (Fig. 9).

Orthodontic treatment affects the display of the teeth for the life of the patient, from youth to old age. In the mid-to-late 20th century, many deep bites and open bites were treated without regard to facial soft-tissue relationships. Typically, the curve of Spee was leveled indiscriminately by extruding or intruding the teeth to make the teeth fit together. Unfortunately, this often reduced lip support, inappropriately decreased the amount of maxillary incisor display, and flattened the profile. As the patient aged, the orthodontic treatment accelerated unesthetic changes in the soft tissues.

Conclusion

Orthodontic treatment plans should be based on an understanding of incisor display in relation to facial esthetics and how this changes over time. Treatment should also be based on biomechanical principles that allow control of the vertical and anteroposterior positions of the anterior teeth. With such an approach, the clinician can produce normal occlusions while enhancing facial esthetics and creating beautiful smiles.

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