Smile Analysis and Design in the Digital Era

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Smile analysis and smile design have become key elements of orthodontic diagnosis and treatment planning over the last decade.[1-3] Recent advances in technology now permit the clinician to measure dynamic lip-tooth relationships and incorporate that information into the orthodontic problem list and biomechanical plan. Digital videography is particularly useful in both smile analysis and in doctor/patient communication. Smile design is a multifactorial process, with clinical success determined by an understanding of the patient's soft-tissue treatment limitations and the extent to which orthodontics or multidisciplinary treatment can satisfy the patient's and orthodontist's esthetic goals.

Anatomy of the Smile

The upper and lower lips frame the display zone of the smile. Within this framework, the components of the smile are the teeth and the gingival scaffold (Fig. 1). The soft-tissue determinants of the display zone are lip thickness, intercommissure width, interlabial gap, smile index (width/height), and gingival architecture. Although the commissures of the lips form the lateral borders of the smile, the eye can perceive inner and outer commissures, as delineated by the innermost and outermost confluences, respectively, of the vermillion of the lips at the corners of the mouth (Fig. 2). The inner commis-

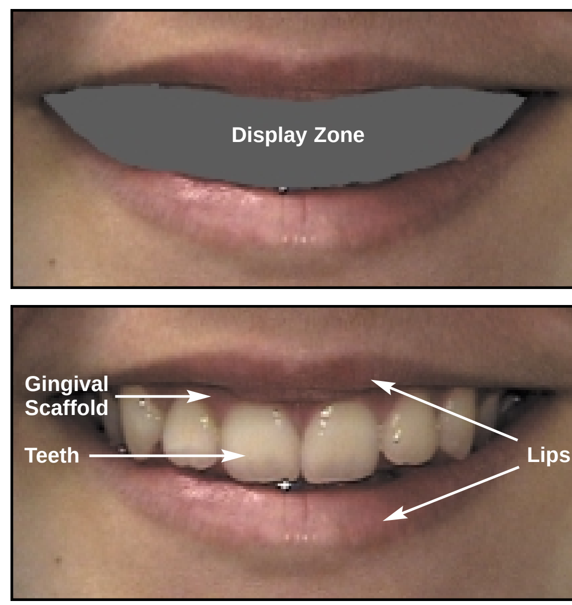

Fig. 1 Smile components.

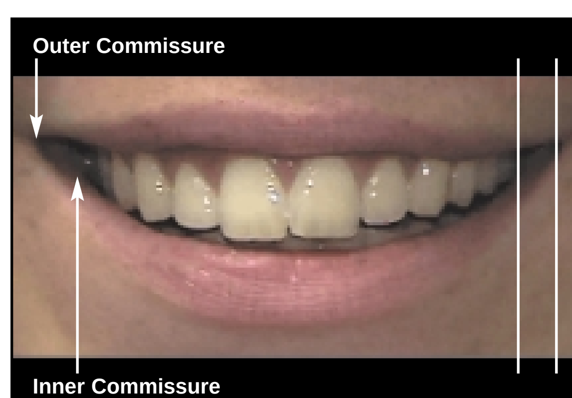

Fig. 2 Anatomy of commissures.


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sure is formed by the mucosa overlying the buccinator muscle where it inserts with the orbicularis oris muscle fibers at the modiolus.

The extent to which the orthodontist is able to differentiate between the anatomy of the inner and outer commissures is largely dependent on lighting. When a video is taken with ambient light only, the buccal corridor often appears much more pronounced than when supplemental light is added (Fig. 3). Thus, what has been called “negative space”[4] is often not space at all, but just an illusion. Professional photographers take advantage of this effect by manipulating lighting to enhance smile characteristics.

We have called the curve formed by the incisal edges of the maxillary anterior teeth the “smile arc”.[5] When there is harmony (parallelism) between the smile arc and the curvature of the lower lip,[5-9] the smile arc is described as consonant. A flat smile arc is usually less esthetic.

Two factors that contribute to the appearance of the smile arc are the sagittal cant of the maxillary occlusal plane and the archform (Fig. 4). Increasing the cant of the maxillary occlusal plane to Frankfort horizontal in natural head position will increase maxillary anterior tooth display and improve the consonance of the smile arc. The patient’s archform—and particularly the configuration of the anterior segment—will greatly influence the degree of curvature of the smile arc. The broader the archform, the less curvature of the anterior segment and the greater the likelihood of a flat smile arc.

The vertical aspects of smile anatomy are the degree of maxillary anterior tooth display (Morley ratio), upper lip drape, and gingival display. In a youthful smile, 75-100% of the maxillary central incisors should be positioned below an imaginary line drawn between the commissures[1] (Fig. 5). Both skeletal and dental relationships contribute to these smile components.

Fig. 3 Contribution of lighting to illusion of “negative space”.

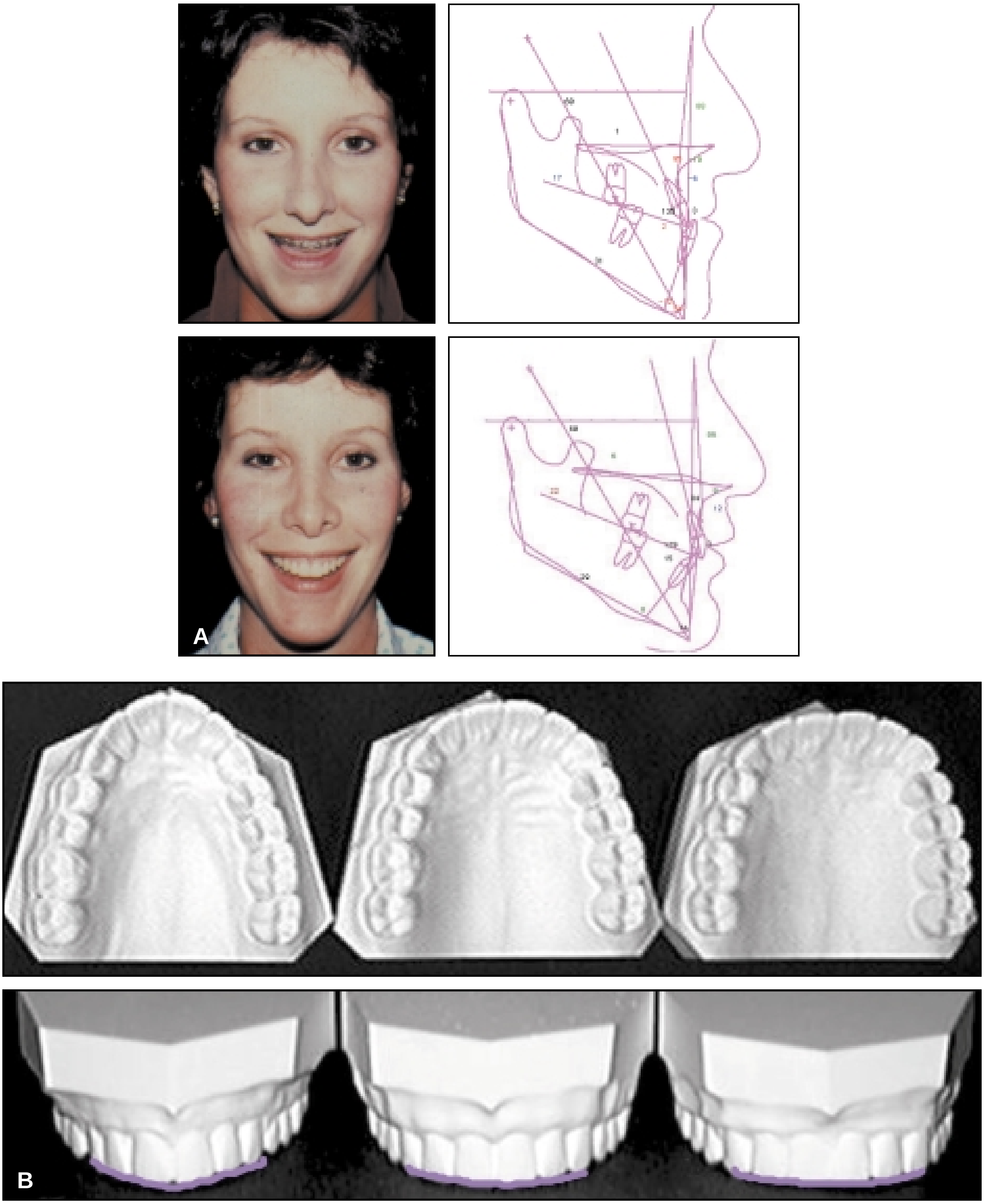


Fig. 4 A. Surgical correction of this patient's Class III malocclusion included maxillary advancement, inferior repositioning, and clockwise rotation. Maxillary occlusal plane was steepened; note effect on anterior tooth display and smile arc. B. Relationship of archform to smile arc.

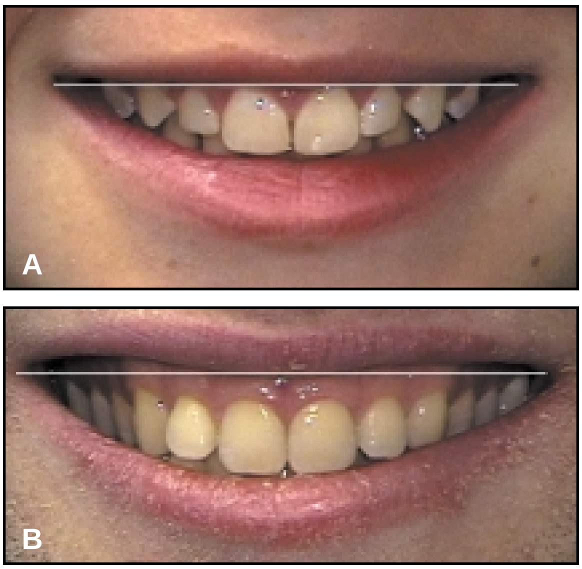


Fig. 5 A. Acceptable Morley ratio. B. Excessive incisor display below intercommissure line.

Smile Classification

There are two basic types of smiles: the social smile and the enjoyment smile. Each type involves a different anatomic presentation of the elements of the display zone (Fig. 6). The social smile, or the smile typically used as a greeting, is a voluntary, unstrained, static facial expression.[5] The lips part due to moderate muscular contraction of the lip elevator muscles, and the teeth and sometimes the gingival scaffold are displayed. The enjoyment smile, elicited by laughter or great pleasure, is involuntary. It results from maximal contraction of the upper and lower lip elevator and depressor muscles, respectively. This causes full expansion of the lips, with maximum anterior tooth display and gingival show.

Smile style is another soft-tissue determinant of the dynamic display zone. There are three styles: the cuspid smile, the complex smile, and the Mona Lisa smile[10] (Fig. 7). An individual's smile style depends on the direction of elevation and depression of the lips and the predominant muscle groups involved. The cuspid or commissure smile is characterized by the action of all the elevators of the upper lip, raising it like a window shade to expose the teeth and gingival scaffold. The complex or full-denture smile is characterized by the action of the elevators of the upper lip and the depressors of the lower lip acting simultaneously, raising the upper lip like a window shade and lowering the lower lip like a window. The Mona Lisa smile is characterized by the action of the zygomaticus major muscles, drawing the outer commissures outward and upward, followed by a gradual elevation of the upper lip. Patients with complex smiles tend to display more teeth and gingiva than patients with Mona Lisa smiles.

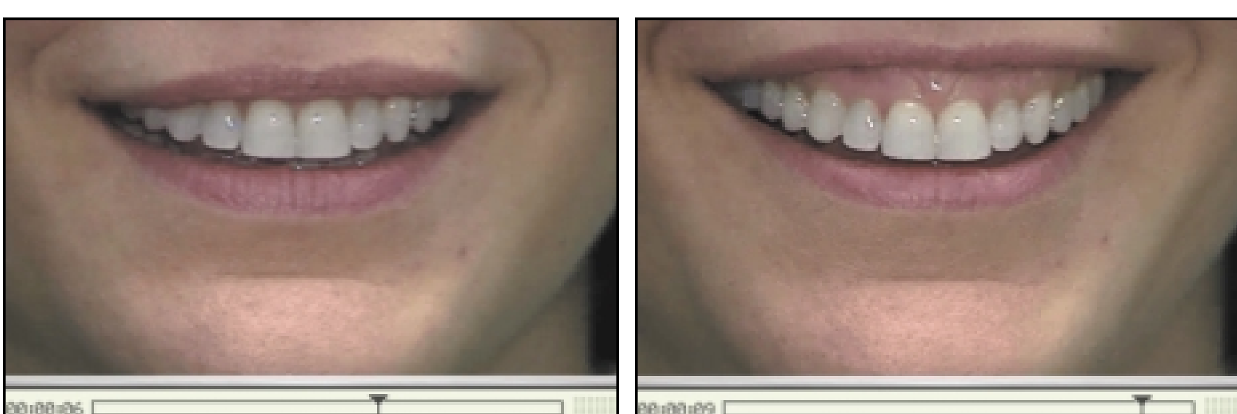


Fig. 6 Anterior tooth display in social and enjoyment smiles; note difference in gingival show.

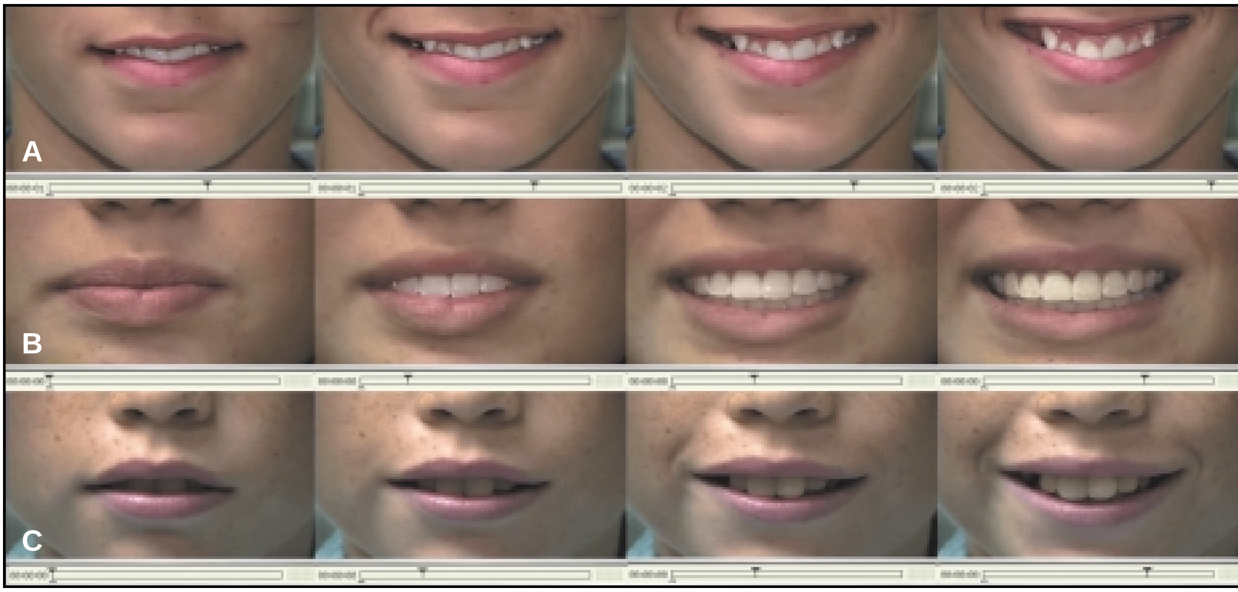


Fig. 7 Three smile styles. A. Cuspid. B. Complex. C. Mona Lisa.

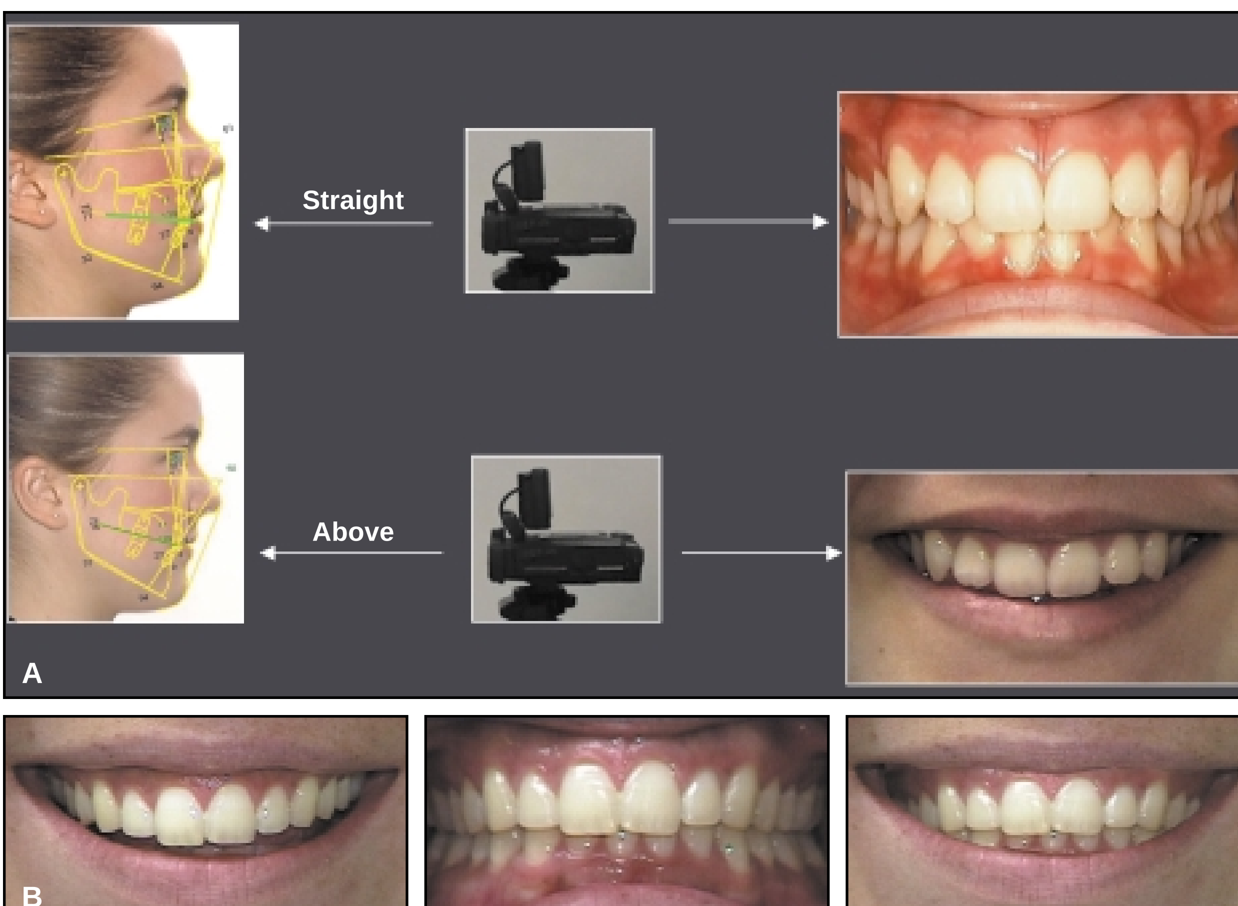


Fig. 8 A. Intraoral vs. extraoral photographic technique. B. Differences in smile arc of same patient due to camera orientation.

Fig. 9 Photographic repeatability of social smile. Patient A produced six similar social smiles consecutively, but younger sibling (Patient B) was unable to replicate social smile.

Smile Capture Method

Capturing patient smile images with conventional 35mm photography has two major drawbacks. First, it is exceedingly difficult to standardize photographs due to differences in camera angles, distances to the patient, head positions, and discrepancies between intraoral and extraoral photographic techniques. When lip retractors are used for photographing the frontal occlusal view, the lens of the camera is positioned perpendicular to the occlusal plane. When the smile is photographed, the lens of the camera is positioned perpendicular to the face in natural

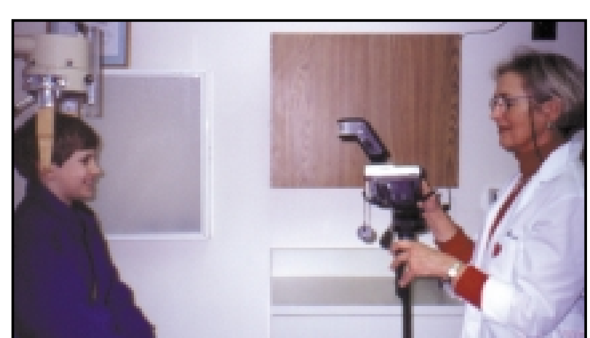


Fig. 10 Digital videography technique for smile capture.

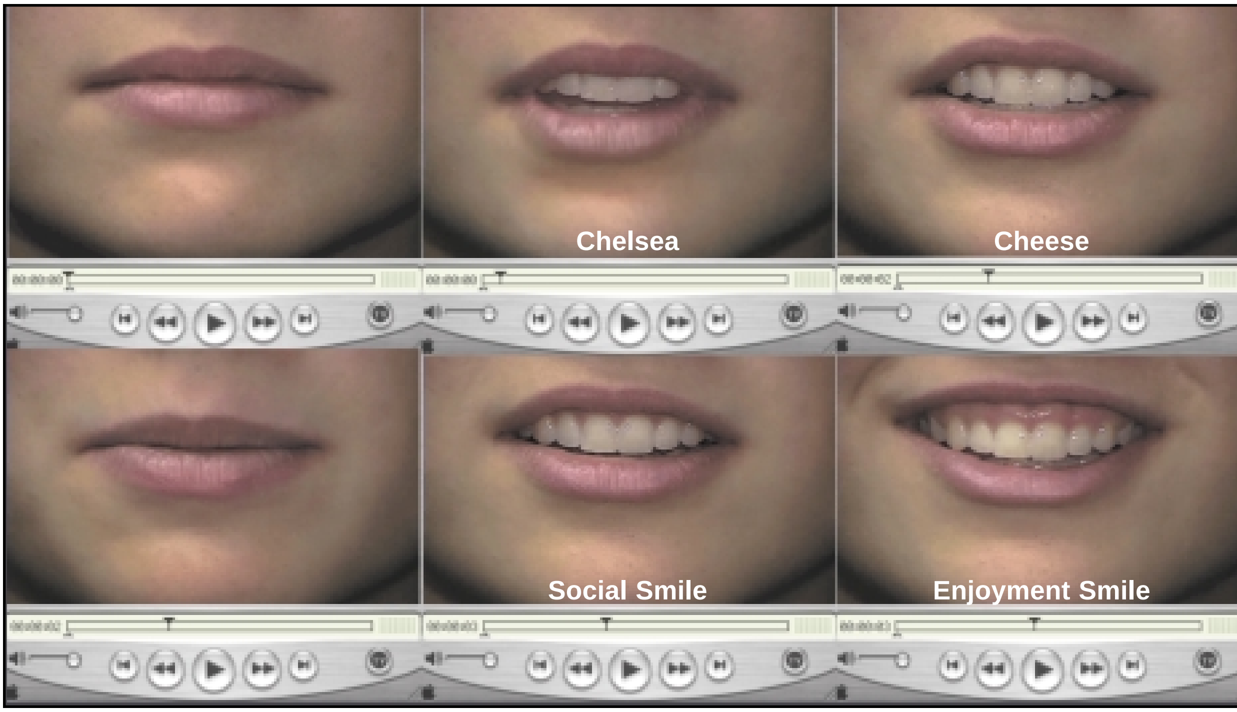


Fig. 11 Six frames from patient's video clip. Upper frames show patient moving from repose to speech, highlighting words "Chelsea" and "cheese". Lower frames show patient moving from repose to smiling. Note difference in gingival display between social and enjoyment smiles.

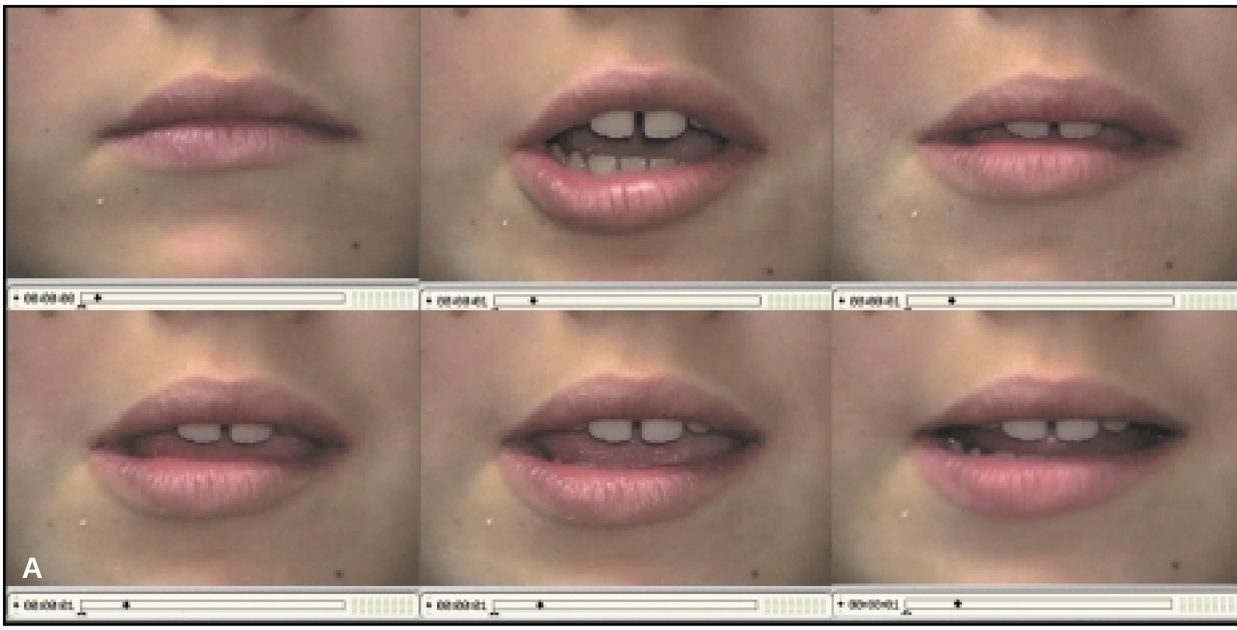
head position, effectively shooting from above the occlusal plane. The result is a difference in appearance of the smile arc in those two views (Fig. 8A). Using the simulation method of Gunther Blaseio (Quick Ceph Image Pro*), the intraoral photograph can be "pasted" into the smile display zone taken in natural head position to demonstrate the discrepancy resulting from the difference in camera orientation (Fig. 8B). Second, it is impossible to repeat the social smile exactly during one photography session, much less over a longer period of time. When several consecutive smile photographs are taken at the orthodontic records visit, the clinician will often note variations in the smile (Fig. 9). In children, this phenomenon is most likely due to relatively late maturation of the social smile.

Standardized digital videography allows the clinician to capture a patient's speech, oral and pharyngeal function, and smile at the same time. The patient is seated in a cephalostat and placed in natural head position (Fig. 10). Ear rods are used to stabilize the head and avoid excess motion. The digital video camera is mounted on a microphone stand and set at a fixed distance in the records room. The lens is positioned parallel to the true perpendicular of the face in natural head position, and the camera is raised to the level of the patient's lower facial third. The patient is asked to say the sentence "Chelsea eats cheesecake on the Chesapeake", relax, and then smile (Fig. 11).

Anterior tooth display is not the same during speech as in smiling. By taking a video clip of both, we can evaluate all aspects of anterior tooth display. The video camera captures roughly 30 frames per second; this method usually produces a five-second clip, for a total of 150

*Apple Computer, Inc., 1 Infinite Loop, Cupertino, CA 95014.

Fig. 12 A. Entire smile portion of patient's video clip. B. Comparison of different patient's pre- and post-treatment smiles.



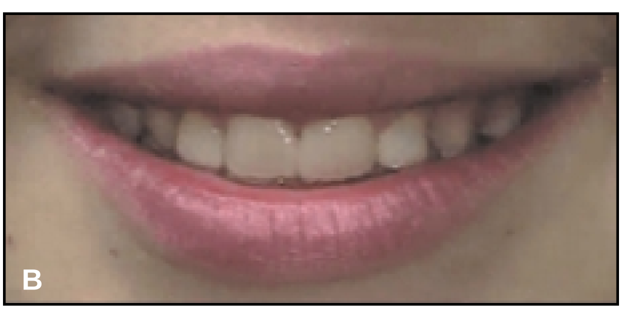


Fig. 13 A. Patient with immature oral and pharyngeal function during speech. Note tongue position in frames two through six. B. Patient's smile after esthetic bonding of maxillary central incisors.

frames. The raw clip is downloaded to Apple Final Cut Pro** for compression and conversion into an Apple QuickTime Viewer** file, which is usually about 4MB in size. The smile portion of the clip is approximately 12-20 frames, allowing pre- and post-treatment smiles to be compared (Fig. 12).

Smile Analysis

On first viewing of the QuickTime video clip, the clinician should assess tongue posture and lip function, particularly during speech. Immature oral and pharyngeal function with unfavorable tongue posture can easily be detected (Fig. 13). The frame that best represents the patient's social smile is selected, captured with a program called Screen Snapz,*** and saved as a JPEG file.

The smile image is then opened in a program called SmileMesh,† which measures 15 attributes of the smile (Fig. 14). This methodolo-

**Quick Ceph, Inc., Orthodontic Processing, 1001 B Ave., Suite 206, Coronado, CA 92118.

***Ambrosia Software, Inc., P.O. Box 23140, Rochester, NY 14692.

†The SmileMesh software was created by TDG Computing (Jon Coopersmith and Greg Cassileth) for Drs. James and Marc Ackerman. SmileMesh is a free shareware application available for downloading at www.jco-online.com.

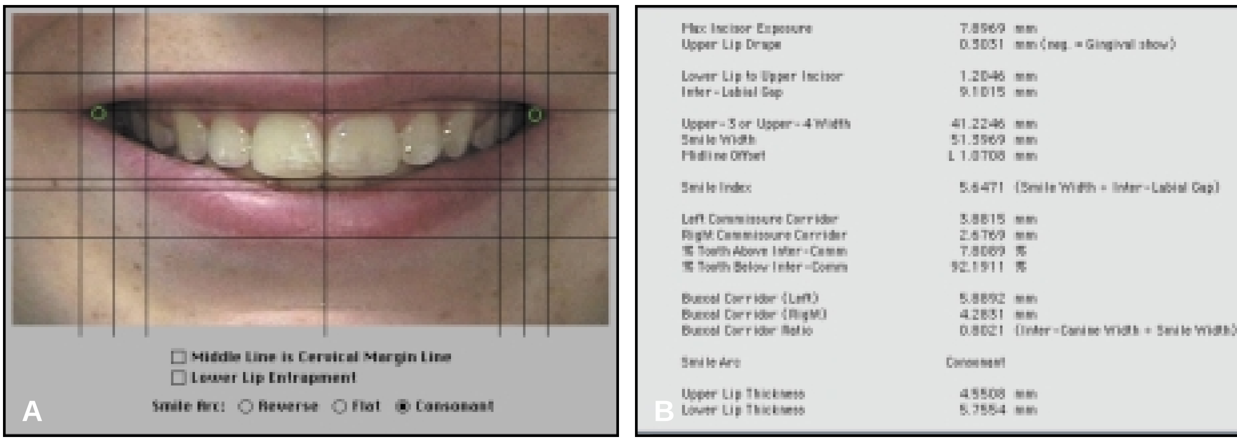


Fig. 14 A. SmileMesh applied to patient's social smile, with lines adjusted to appropriate landmarks. B. SmileMesh measurements.

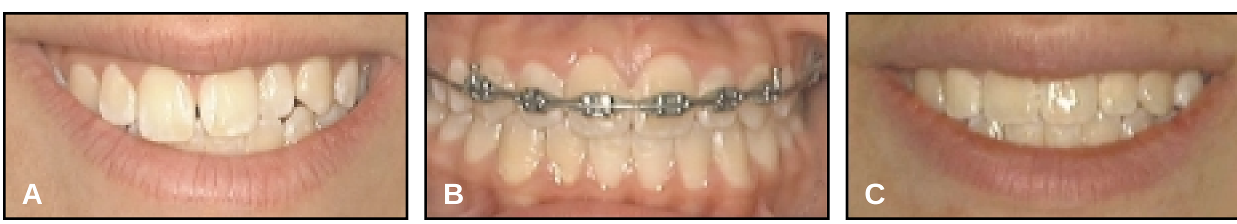


Fig. 15 A. Patient with asymmetrical cant of maxillary anterior transverse occlusal plane. B. Different bracket height on maxillary left canine vs. maxillary right canine. C. Patient after treatment.

gy was first used manually by Hulsey[7] and later modified and computerized by the present authors.[5] Its most significant advantage is that the orthodontist can quantify such aspects of the smile as maxillary incisor display, upper lip drape, buccal corridor ratio, maxillary midline offset, interlabial gap, and intercommissure width in the frontal plane. The flaw in traditional smile analysis has been that many of the vertical and anteroposterior calculations related to anterior tooth display are made from the tracing of the lateral cephalogram, which is taken in repose.[11] As a result, incisor position has been determined from a static rather than a dynamic record.

The diagnostic part of smile analysis begins with the creation of a problem list. The first set of records analyzed is the extraoral photo gallery, consisting of the captured social smile, the full facial portrait at rest, the three-quarter smiling view, and the profile view. Consideration should be given to the vertical and lateral attributes of the smile as well as to the cant of the transverse occlusal plane. The smile image is a better indication of transverse dental asymmetry than the frontal intraoral view or even an anteroposterior cephalogram (Fig. 15). Next, the cant of the maxillary occlusal plane relative to Frankfort horizontal should be assessed visually on the lateral cephalogram and measured on the tracing. Vertical and anteroposterior skeletal and dental relationships are noted. Panoramic and supplemental intraoral radiographs are also analyzed. Finally, the plaster study casts are evaluated for static occlusal relationships and tooth-size discrepancies. The reader should note that this sequence of analysis is the exact opposite of the method currently taught in most orthodontic res-

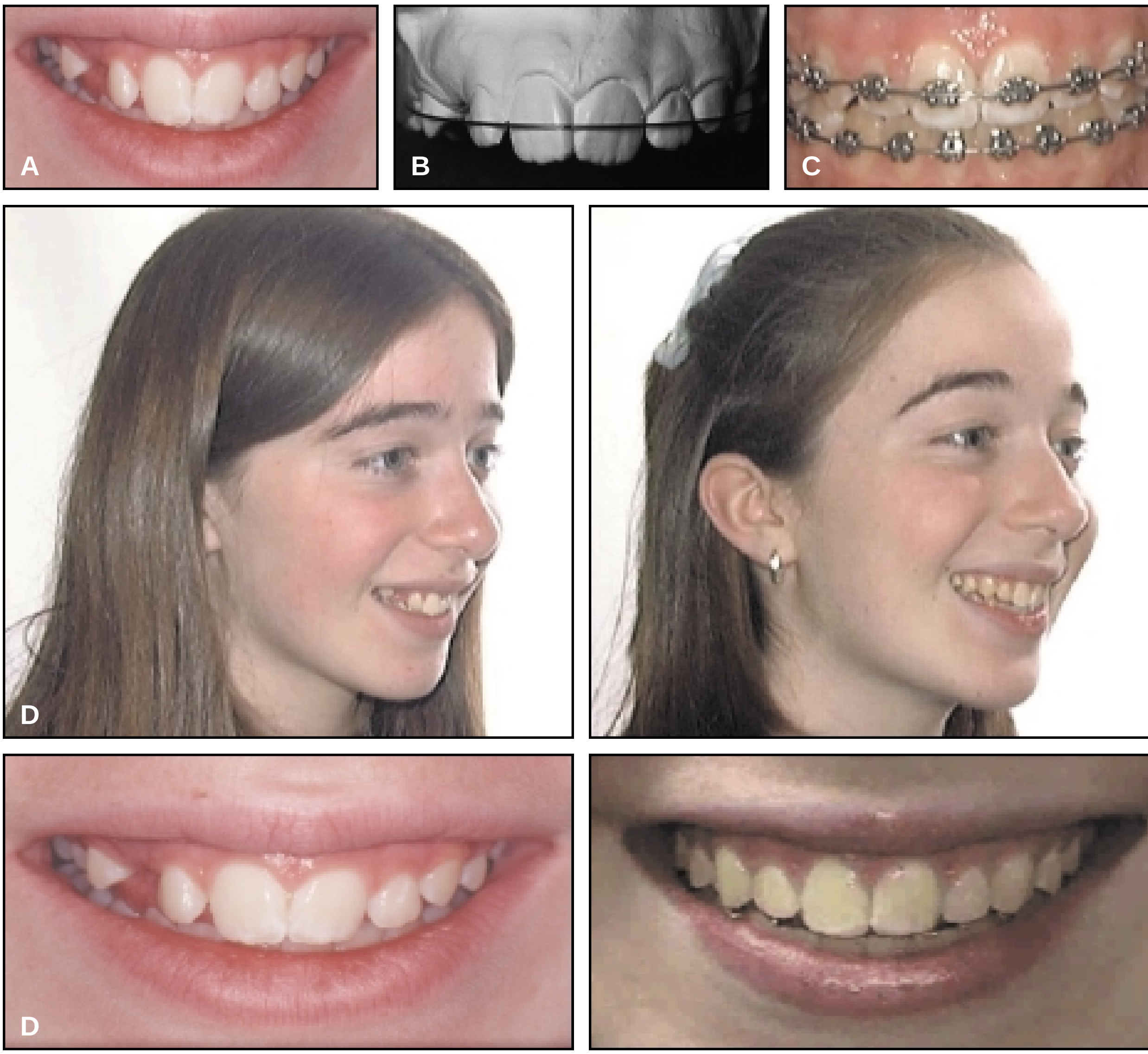


Fig. 16 A. Patient with consonant smile arc, but excessive gingival display. Smile design had to intrude maxillary anterior teeth without flattening smile arc. B. Archwire blank was placed across anterior segment of study casts to indicate positions of maxillary incisor bracket slots needed to preserve smile arc. C. Difference in distances from incisal edges to maxillary central incisor and lateral incisor brackets is more than .5mm called for in conventional preadjusted appliance prescriptions. D. Pre- and post-treatment social smiles demonstrate that smile arc was preserved and gingival display was reduced. Distance from superior border of lower lip to maxillary incisal edges increased, which was not "ideal", but best "balance" that could be achieved for this smile.

idency programs.

The smile component of the orthodontic problem list consists of descriptive terms such as inadequate maxillary incisor display, unfavorable Morley ratio, excess gingival show, flat or reverse smile arc, asymmetric cant of the maxil-

Fig. 17 Continuous leveling can lead to flattening of smile arc and overintrusion of maxillary incisors (poor Morley ratio).

lary anterior transverse occlusal plane, and obliterated buccal corridors, to name a few. The clinician should rank these smile attributes in order of their importance in creating a balanced smile. The final problem list will help the orthodontist to assess the viability of different treatment options and select the appropriate mechanotherapy for optimal smile design.

Smile Design

It must be understood that there is no universal "ideal" smile. The most important esthetic goal in orthodontics is to achieve a "balanced" smile,[12] which can best be described as an appropriate positioning of the teeth and gingival scaffold within the dynamic display zone. As mentioned above, this includes lateral, vertical, and anteroposterior aspects, as well as the cant of the maxillary anterior transverse occlusal plane and the sagittal cant of the maxillary occlusal plane. Smile design and mechanotherapy must be built around this esthetic plane of occlusion, which is often different from the natural plane of occlusion.[13]

The first consideration in obtaining a consonant smile arc, or preserving an already consonant smile arc, is bracket positioning (Fig. 16). Smile design also necessitates changes in overall treatment mechanics. In cases with high labial ectopic maxillary canines, for instance, leveling with a continuous archwire will intrude the maxillary central and lateral incisors and thus flatten the smile arc (Fig. 17). We have found that the segmented-arch technique using cantilever springs[14] offers better control of leveling and of the esthetic plane of occlusion (Fig. 18).

Fig. 18 Segmental leveling and use of cantilever springs for high labial ectopic maxillary canines.

Smile Simulation and Interdisciplinary Care

Orthodontists today almost routinely use video imaging to simulate potential profile changes resulting from orthodontics or orthognathic surgery.[15] There is no reason why the same technology should not be extended to simulate changes in the components of the dynamic display zone in frontal view. Maxillary incisor shape, size, color, position, and degree of display

Fig. 19 A. Patient with maxillary anterior spacing, excessive gingival display, and short clinical crowns, after orthodontic space closure and clinical crown lengthening. B. Computer simulation of esthetic bonding of maxillary lateral incisors.

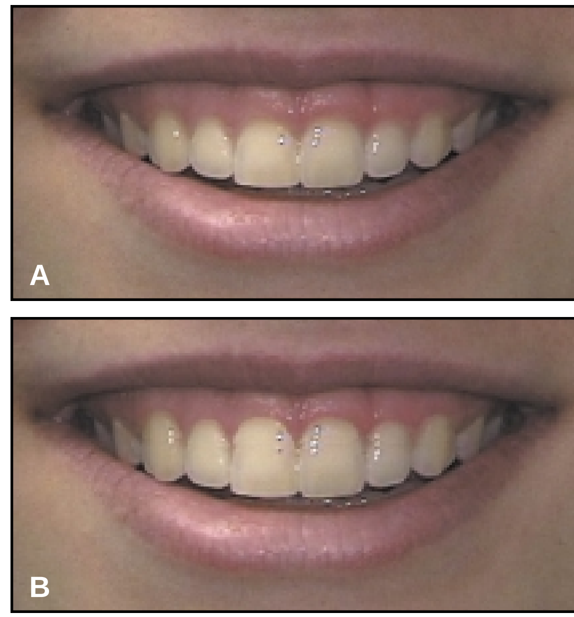


Fig. 20 A. Patient with excessive gingival display in social smile, but balanced dentition. B. Computer simulation of clinical crown lengthening.

can all be manipulated, and the gingival architecture can also be modified. Interdisciplinary care involving periodontics, restorative dentistry, and orthodontics can be simulated and presented to the patient for weighing the risks and benefits of all treatment options, as the following cases demonstrate.

The first patient had maxillary anterior spacing and excessive gingival display with short clinical crowns (Fig. 19). The multidisciplinary treatment plan, simulated for the patient before commencing therapy, was to redistribute the space mesial and distal to the maxillary lateral incisors orthodontically, followed by clinical crown lengthening and esthetic bonding.

Another patient presented with the chief complaint of excessive gingival display during the social smile (Fig. 20). Her posterior occlusion was ideal, and the dental attributes of the social smile were balanced. After a simulation of clinical crown lengthening was performed, this approach was recommended instead of orthodontics or restorative dentistry.

The third patient presented with a Class II, division 1 malocclusion characterized by maxillary protrusion (Fig. 21). Her smile showed acceptable anterior tooth display, a slightly flat smile arc (three-quarter view), and lower lip entrapment. Computer simulation of labiolingual tooth movement using preadjusted mechanics and Class II elastics demonstrated an acceptable profile change. This smile design would increase maxillary incisor display, provide a more consonant smile arc, and eliminate lower lip entrapment.

The next patient had a similar Class II, division 1 malocclusion, but with mandibular retrusion and dental compensation (Fig. 22). Her smile demonstrated acceptable anterior tooth display and a consonant smile arc. Two computer simulations were performed to compare the treatment options of extracting maxillary first premolars and surgically advancing the mandible. With

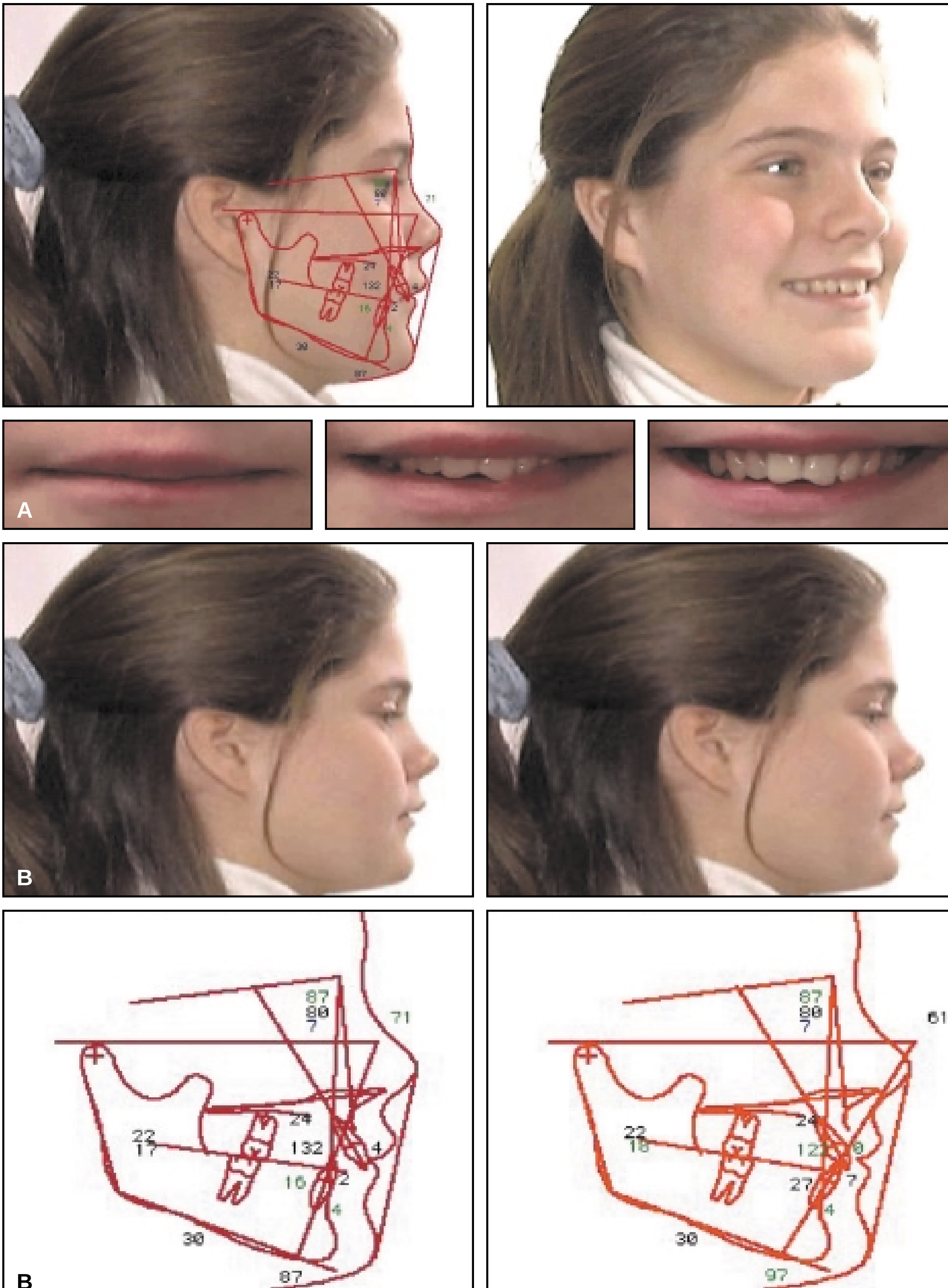


Fig. 21 A. Patient with Class II, division 1 malocclusion and maxillary protrusion. B. Computer simulation of labiolingual tooth movement and anticipated profile change.

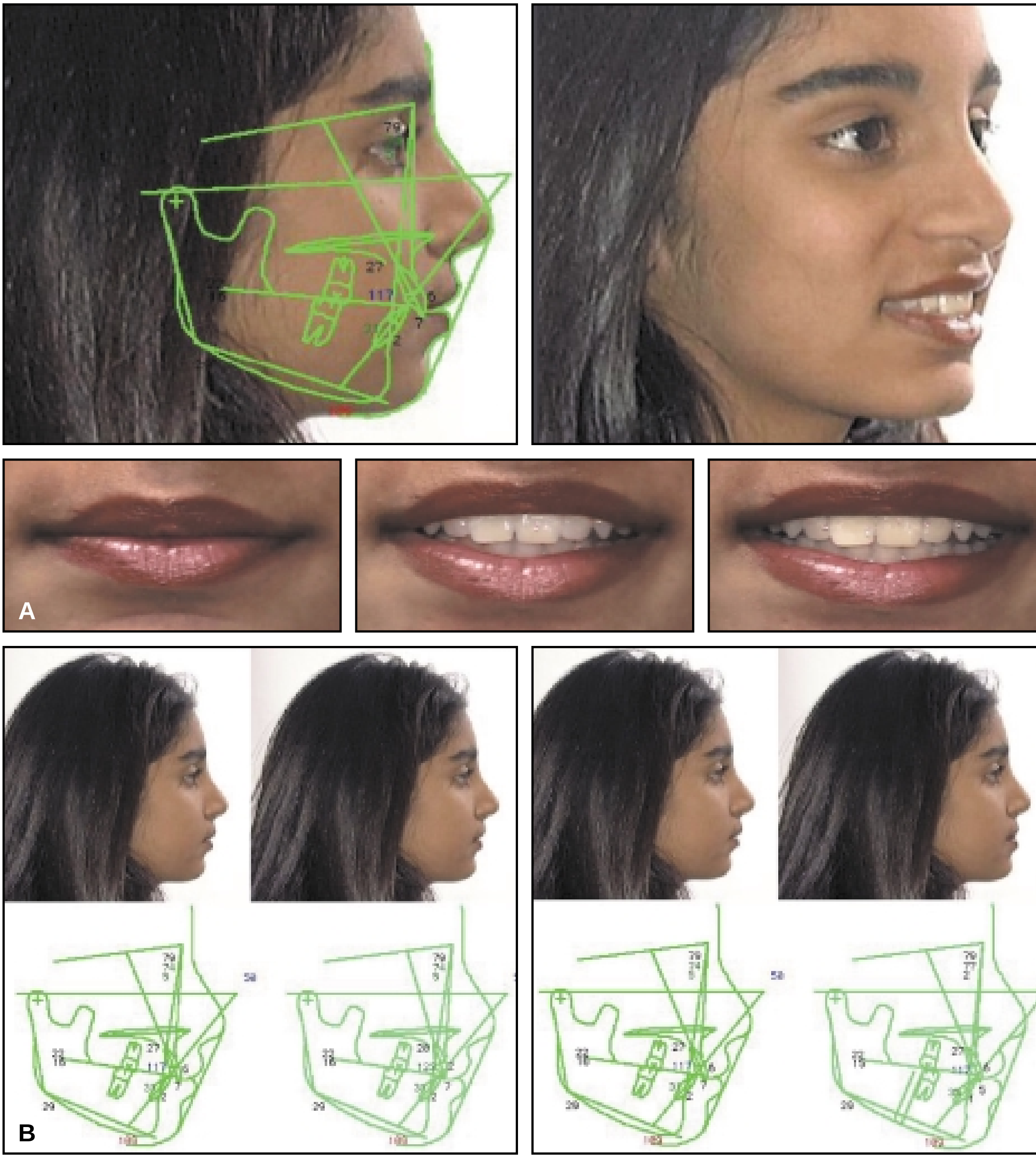


Fig. 22 A. Patient with Class II, division 1 malocclusion and mandibular retrusion. B. Computer simulation of extraction of maxillary first premolars (left) and surgical mandibular advancement (right).

extractions, the profile change would be minimal, but subsequent retraction of the maxillary anterior teeth would create a less balanced and less attractive smile. Surgical advancement of the mandible appeared to produce a less attractive profile. Although the patient's occlusion was not optimal, the risks of treatment seemed to outweigh the benefits from an appearance perspective. Based on this analysis, no treatment was recommended.

The final patient presented with a Class I malocclusion with an anterior deep bite, diminutive maxillary lateral incisors, and excessive gingival display coupled with short clinical crowns

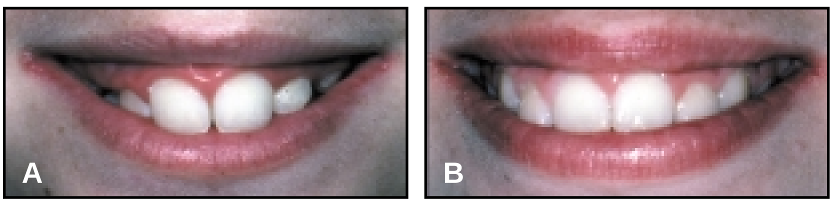


Fig. 23 A. Patient with Class I malocclusion, anterior deep bite, diminutive maxillary lateral incisors, excessive gingival display, and short clinical crowns before treatment. B. After orthodontic treatment. C. After clinical crown lengthening and application of laminate veneers.

(Fig. 23). Staged multidisciplinary care was recommended for this patient. The first phase, in adolescence, consisted of orthodontic treatment to improve the overbite/overjet relationship. The second phase, initiated in young adulthood, involved clinical crown lengthening and placement of laminate veneers.

Conclusion

Smile analysis and smile design generally involve a compromise between two factors that are often contradictory: the esthetic desires of the patient and orthodontist, and the patient's anatomic and physiologic limitations. Using digital video and computer technology, the clinician can evaluate the patient's dynamic anterior tooth display and incorporate smile analysis into routine treatment planning. Esthetic smile design is a multifactorial decision-making process that allows the clinician to treat patients with an individualized, interdisciplinary approach.

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