ORIGINAL ARTICLE

Dynamic smile visualization and quantification: Part 1. Evolution of the concept and dynamic records for smile capture

David M. Sarver, DMD, MS,[a] and Marc B. Ackerman, DMD[b]
Vestavia Hills, Ala, and Bryn Mawr, Pa

The "art of the smile" lies in the clinician's ability to recognize the positive elements of beauty in each patient and to create a strategy to enhance the attributes that fall outside the parameters of the prevailing esthetic concept. New technologies have enhanced our ability to see our patients more dynamically and facilitated the quantification and communication of newer concepts of function and appearance. In a 2-part article, we present a comprehensive methodology for recording, assessing, and planning treatment of the smile in 4 dimensions. In part 1, we discuss the evolution of smile analysis and review the dynamic records needed. In part 2, we will review smile analysis and treatment strategies and present a brief case report. (Am J Orthod Dentofacial Orthop 2003;124:4-12)

For its 100th anniversary, the American Association of Orthodontists designed a logo that featured the message, "Orthodontics—100 years of smiles." However, a MEDLINE search from 1967 to the present of the keywords "orthodontics" and "smile" yields only 23 articles, whereas a search of the keywords "orthodontics" and "profile" yields 153 articles; perhaps a more appropriate slogan might have been, "Orthodontics—a century of profiles"!

Esthetics in orthodontics has been defined mainly in terms of profile enhancement, but if you ask lay people what an orthodontist does, their answers will usually include something about creating beautiful smiles. The current interest in smile enhancement is overdue. Classification schemes have generally been based on static morphologic features, such as molar relationships and the extent of facial divergence. We focus on the profile because the lateral cephalogram is the lynchpin of orthodontic treatment planning. As a result of our efforts to be as scientific as possible in our diagnosis and treatment planning, we have tended to drift away from clinical examination of the patient and the art of physical diagnosis. The goal of enhancing patient appearance requires us to revisit fundamental concepts of art and beauty that were present during the early development of orthodontic doctrine.

Art played an important role in Angle's orthodontic school. Wuerpel, an art professor and a visiting professor in Angle's school, taught the students about Greco-Roman sculpture and facial proportion. At the memorial meeting of the Eastern Association of the Graduates of the Angle School of Orthodontia in 1931,[1] Wuerpel delivered a tribute to his late friend and summarized his own role in the school. Angle originally told Wuerpel, "I have been forced to conduct this school because I cannot get any college to conduct it [orthodontia] the way it should be conducted. I want to give my students the finest instruction that I can get for them. When I inquired for an artist who might write for me some fundamental rule which might govern the character of the faces that came into the hands of my students so that they and I would have the assurance that all deformity would be corrected, I couldn't find any one to give me the rule." Wuerpel replied, "Only a fool would reason like that!" Thus began a debate between lifelong friends about the need to define individual beauty rather than to set strict rules based on classical norms. Angle never used cephalometric radiography, because it was introduced 1 year after his death.[2]

There is little debate about the many advancements that Angle made in orthodontics, most notably his system of classifying malocclusion. But perhaps more attention should be paid to his inclusion of art in the orthodontic search for quantifying facial beauty. Wuerpel said that if Angle "had imagination and would develop it properly, he would be able to understand my

[a]Adjunct professor, Department of Orthodontics, University of North Carolina, Chapel Hill; and private practice, Vestavia Hills, Ala.
[b]Clinical associate, Department of Orthodontics, University of Pennsylvania School of Dental Medicine, Philadelphia; Director of Orthodontics, Division of Dentistry, Children's Hospital of Philadelphia; and private practice, Bryn Mawr, Pa.
Reprint requests to: David M. Sarver, DMD, MS, 1705 Vestavia Parkway, Vestavia Hills, AL 35216; e-mail, SarverD@aol.com.
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profession as well as I understood it myself, even though he might not be a creator of artistic work. At that time I did not know what beautiful things he could do with his fingers. He was truly an artist; he did all sorts of things in a most artistic way." Art instruction was an integral part of the Angle curriculum, but it has gradually disappeared from the modern residency program.

When did modern orthodontics diverge from art? Advances in orthodontic technology, especially radiographic cephalometry, led to a shift away from the art of orthodontic diagnosis and treatment planning as practitioners increased their reliance on measurements. Clinical examination, once the hallmark of orthodontic diagnosis, became secondary to the information gained from lateral cephalometric radiographs and plaster study models. Today's "art of the smile" is being driven by the orthodontist's ability to clinically examine the patient in 3 dimensions and use the latest technology (computer databasing of the clinical examination and digital videography) to document, define, and communicate the treatment strategy to patients and colleagues involved in interdisciplinary care.

A smile is defined and described differently by different dental specialists.[3-9] In dentistry, we often diagnose in terms of what we do mechanically. For example, the cosmetic restorative dentist has a more standardized approach to the improvement of the smile, which is logical considering he or she is working with a relatively static system in terms of growth and dentofacial development. The cosmetic dental patient is generally a mature adult who presents for restoration or improvement of anterior dental appearance.

Why is there no accepted standard for "smile analysis"? The primary reason is that the orthodontic specialty has only recently focused its attention on the multifactorial nature of the smile, combined with a shift toward patient-driven esthetic diagnosis and treatment planning.[10] A century ago, the orthodontic paradigm was geared toward achieving optimal proximal and occlusal contacts of the teeth within the framework of a balanced profile, along with acceptable stability, all of which were measured statically. The early concepts of esthetics revolved largely around the patient's profile, and we believed that, once the "ideal" tooth–jaw positions were achieved, then the soft tissues would fall in line.[11] When cephalometric-based diagnosis and treatment planning hit full stride in the 1950s and 1960s, esthetics in orthodontics was defined primarily in terms of the profile.

In the contemporary orthodontic paradigm, we examine patients in both resting and dynamic relationships in 3 spatial dimensions and then attempt to harmonize the discrepancy between their anatomic and physiologic lip–tooth–jaw relationships and their esthetic and functional desires.[12] In the art of treating the smile, we orthodontists are faced with a 2-fold task. First, in problem-oriented treatment planning,[13-15] the orthodontist must establish a diagnosis that identifies and quantifies which elements of the smile need correction, improvement, or enhancement. We propose that further evolution of the concept of problem-oriented diagnosis and treatment planning should entail identifying the positive elements of the smile that should be maintained. In other words, we want to identify the positive attributes of a patient's smile to be sure that we protect them as we direct treatment at the more problematic aspects. Second, a visualized treatment strategy must be created to address the patient's chief concerns. The complete treatment effort cannot focus solely on unilateral problems, such as Class II skeletal patterns and open bite, but must include facial balance and smile esthetics. The dramatic increase in interdisciplinary collaboration is a direct result of the recognition that orthodontists and dentists are committed to the same goals—function and esthetics—but neither field can provide all of the necessary treatment alone in many cases.[8,16-19] Computer imaging technology has greatly facilitated recognition of the effect of our orthodontic treatment plans on facial appearance, causing us to step back from seeing the teeth only and helping us to recognize the entirety of facially directed or facially responsive treatment plans. Imaging technology has also greatly enhanced communication between doctors and patients, and among doctors themselves.

The contemporary orthodontist no longer evaluates patients in terms of only the profile, but also frontally and vertically, to complete the 3 spatial dimensions, and statically and dynamically. Our philosophy mandates that the orthodontist now add a fourth dimension: time (Fig 1). Simply stated, orthodontists are the first in line in a decision-making process that ultimately affects a patient's appearance for the rest of his or her life. The burden on the orthodontist is to understand not only dentoskeletal growth and development, but also soft tissue growth, maturation, and aging.

The orthodontist must work with 2 dynamics. The first is that of soft tissue repose and animation assessed at the patient's examination[20-25] and includes how the lips animate on smile, gingival display, crown length, and other attributes of the smile. The second is the facial change throughout a patient's lifetime—the impact of skeletal and soft tissue maturational and aging characteristics, which are well documented. Both can, in a way, be considered moving targets, hence the difficulty in standardization. Think for a moment about

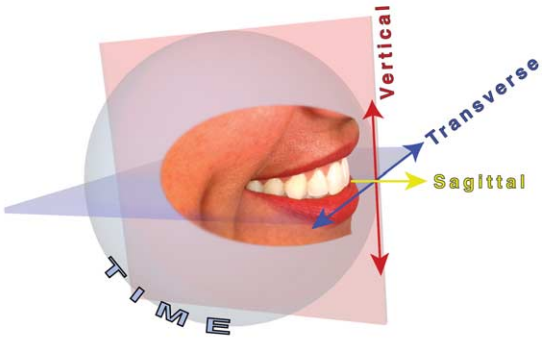

Fig 1. Contemporary orthodontists evaluate smiles in 3 dimensions: transverse, vertical, and sagittal. A fourth dimension, time, should also be considered.

how we document our patients and make diagnostic and treatment decisions. A cephalogram is taken in a fraction of a second. The data generated from measuring the dentoskeletal relationships are a major underpinning of our treatment decisions to be delivered over 2 years; the dentoskeletal relationships are expected to be stable for the rest of the patient's life. Scammon's growth curve is smooth and represents the variable rates and timing of physical growth. In reality, we recognize that this curve represents the averaging of many data sets that fall on either side of that smooth line. When we take the cephalogram in that fraction of a second, on which plot, on which side of the line, have we gathered information? This might validate the popularity of "therapeutic diagnosis,"[26] in which the orthodontist begins treatment with a fairly definite diagnosis but with a flexible treatment plan that allows adjustments for unanticipated growth changes or variable treatment responses during treatment. Brodie[27] cautioned that cephalometrics was never intended as the sole factor in orthodontic treatment plans and said instead that its main strength was in quantification of growth and research.

In this first part of a 2-part article, we offer guidelines by which the orthodontist can record the dynamics of the smile. In the part 2, we will focus on smile analysis and treatment strategies involved in achieving optimal smile esthetics.

RECORDS IN TREATMENT OF THE SMILE

Standard orthodontic records have not changed significantly in many years, but contemporary needs are rapidly evolving. We suggest that, to meet demands of treating all dimensions in orthodontics, our records must provide the information and documentation required in the new soft tissue–dominated treatment-planning regimen. Orthodontic records fall into 3 separate but interdependent categories: static records, dynamic recordings, and direct biometric measurements.

In clinical practice, standard records include film or digital photographs, radiographs, and study models (mounted or unmounted plaster or electronic models). The universal standard for facial images consists of frontal at rest, frontal smile,[28] and profile at rest images. Although these orientations provide an adequate amount of diagnostic information, they do not contain all of the information needed for smile visualization and quantification. To treat smiles, we need to expand our records and databasing of direct clinical examination. The records needed for contemporary smile visualization and quantification can be divided into 2 groups: static and dynamic. We recommend that in addition to the accepted 3 facial image orientations, photographic recordings should also include profile and oblique smile and oblique and frontal smile close-ups (Fig 2).

The dynamic recording of smile and speech is accomplished with digital videography. Digital video and computer technology enables the clinician to record anterior tooth display during speech and smiling at the equivalent of 30 frames per second. We typically take 5 seconds of video for each patient, yielding 150 frames for comparison. The videos are recorded in standardized fashion with the camera at a fixed distance from the subject. One segment of video is taken in the frontal dimension (Fig 3), and another segment of video is taken from the oblique view. These clips, taken before and after treatment for all patients, allow us to use matched frames to analyze changes in smile characteristics. The patient's head is placed in a cephalometric head holder to obtain natural head position, and the patient is asked to rehearse the phrase "Chelsea eats cheesecake on the Chesapeake," and then to smile. The video is downloaded to the computer, and the video clip is compressed. Each clip is approximately 4 MB. The video clip is reviewed, and the frame that best represents the patient's natural unstrained social smile is selected.[29]

Dynamic digital video clips also allow us to ascertain which smile style a patient exhibits. According to the classification of Rubin,[30] there are 3 smile styles. In the *commissure* smile, the corners of the mouth turn upward due to the pull of the zygomaticus major muscles. This is sometimes called "the Mona Lisa smile." In the *cuspid* smile, the upper lip is elevated uniformly without the corners of the mouth turning upward; the entire lip rises like a window shade. In the *complex* smile, the upper lip moves superiorly, as in the cuspid smile, but the lower lip also moves inferiorly in a similar fashion.

Fig 2. Routine patient photos should include several new views, including **A,** profile and oblique (not pictured) facial smile; **B,** oblique smile close-up; and **C,** frontal smile close-up. Profile smile shows nondental characteristics, including position of nasal tip with animation and allows evaluation of upper lip curtain characteristics and proclination or retroclination of maxillary incisors. Oblique smile close-up facilitates evaluation of curvature of molars (when visible), premolars, and anterior teeth in relation to lower lip, enhancing closer evaluation of any anteroposterior cant to palatal and occlusal planes. Frontal smile close-up image permits closer scrutiny of crown height, gingival architecture, relationships of maxillary gingival margins to upper lip and incisal edges and canine tips to lower lip.

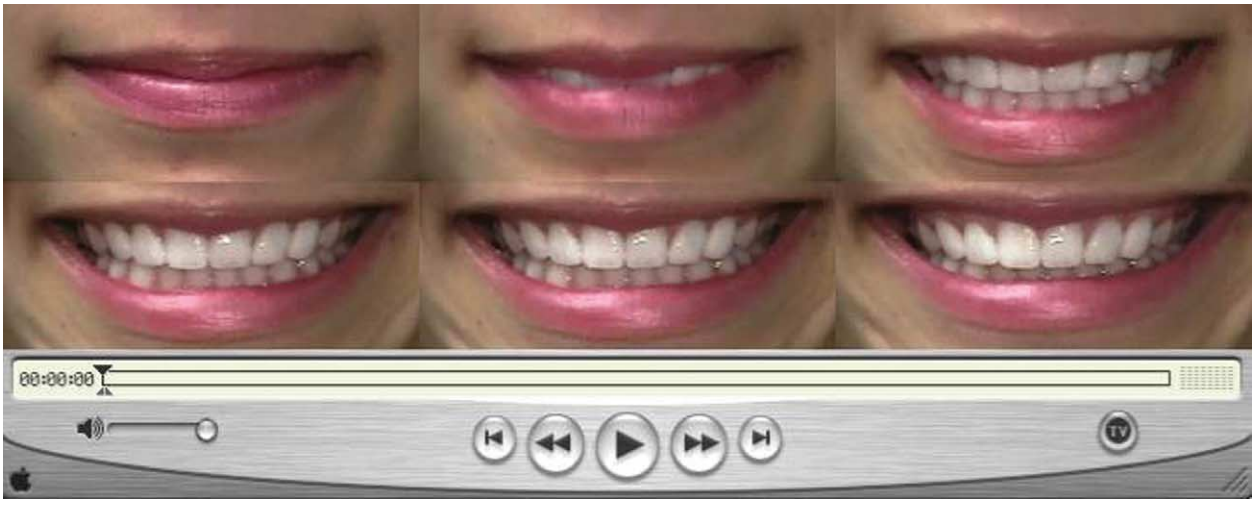

Fig 3. Digital technology enables clinicians to record and evaluate anterior tooth display during speech and smiling.

DIRECT MEASUREMENT AS A BIOMETRIC TOOL

Direct measurement permits the clinician to quantify resting and dynamic lip–tooth relationships. Observation of the smile is a good start, but quantification of resting and dynamic lip–tooth relationships is critical to smile visualization, so that the information gathered from measuring smile characteristics can then be translated into terms meaningful to the treatment plan.

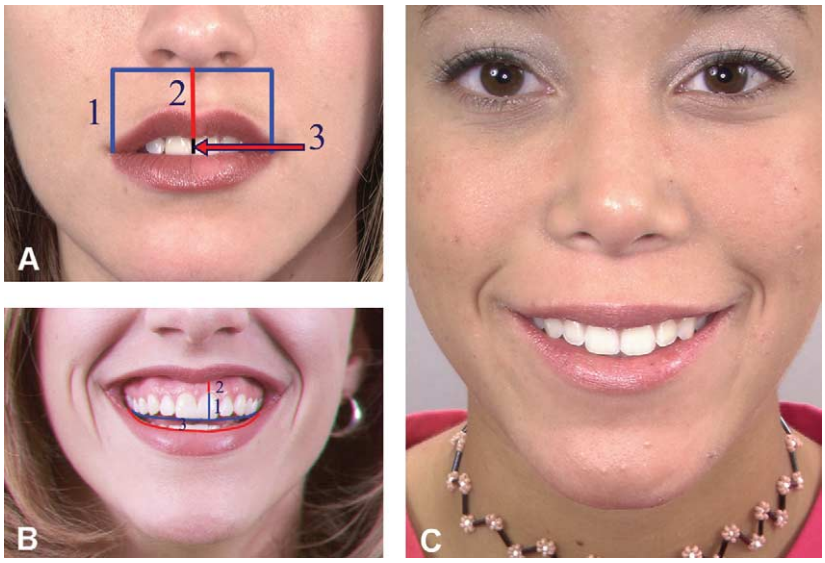

Fig 4. A, Systematic measurements of resting relationships include *1*, commissure height; *2*, philtrum height; and *3*, interlabial gap and incisor show at rest. **B,** Systematic measurements of dynamic relationships include *1*, crown height; *2* gingival display; and *3*, smile arc relationships. In low smile relationships, percentage of incisor display on smile is measured. **C,** Ideal smile arc has maxillary incisal edge curvature parallel to curvature of lower lip upon smile; term *consonant* is used to describe this parallel relationship.

Direct measurement also has application in research efforts relative to time-related changes and the repeatability of the social smile. The dynamics of the smile also interact with the maxillary teeth and affect the appearance of the smile. Systematic measurement of resting tooth–lip relationships virtually leads the clinician to a quantified treatment plan. We suggest that the following frontal measurements should be performed systematically (Fig 4): philtrum and commissure height, interlabial gap, incisor show at rest and smile, crown height, gingival displace, and smile arc.

The philtrum height is measured in millimeters from subspinale (the base of the nose at the midline) to the most inferior portion of the upper lip on the vermilion tip beneath the philtral columns. The absolute linear measurement is not particularly important, but its relationship to the upper incisor and the commissures of the mouth is significant. In the adolescent, the philtrum height is often shorter than the commissure height, and the difference can be explained in the differential in lip growth with maturation.[31-34]

Commissure height is measured from a line constructed from the alar bases through subspinale, and then from the commissures perpendicular to this line.

The interlabial gap is the distance in millimeters between the upper and lower lips when lip incompetence is present.

The amount of maxillary incisor show at rest is a critical parameter esthetically, because that is an inevitable characteristic of aging.[31] Thus, an adult patient with 3 mm of gingival display on smile and 3 mm of maxillary incisor display at rest should consider maxillary incisor intrusion or maxillary impaction to reduce gingival display only with great care, because reducing gingival display also diminishes incisor show at rest and during conversation (a characteristic of the aging face).

When smiling, a person shows all or part of the maxillary incisors. The lower the *smile index* (defined in part 2 of this article), the less youthful the smile appears. The percentage of incisor display, when combined with crown height, helps the clinician decide how much tooth movement is required to improve the smile index.

Crown height is the vertical height of the maxillary central incisors; in adults, crown height is normally between 9 and 12 mm, with an average of 10.6 mm in men and 9.6 mm in women.[35] The age of the patient is a factor in crown height because of the rate of apical migration in the adolescent.

The amount of gingival display on smile that is

Fig 5. Direct measurement of static and dynamic relationships is facilitated by computerized database programs.

acceptable esthetically can vary widely, but the relationship between gingival display and incisor show at rest is important. In broad terms, it is better to treat a gummy smile less aggressively, because aging will naturally diminish this characteristic. A gummy smile is often more esthetic than a smile with less tooth display.

The smile arc from the frontal view (the oblique view will be discussed in part 2 of this article) is the relationship of the curvature of the incisal edges of the maxillary incisors and canines to the curvature of the lower lip in the posed social smile.[18,29] In an ideal smile arc, the curvature of the maxillary incisal edge is parallel to the curvature of the lower lip upon smile; the term *consonant* describes this parallel relationship (Fig 4, *C*). In a *nonconsonant* or flat smile, the maxillary incisal curvature is flatter than the curvature of the lower lip on smile. The smile arc relationship is not as quantitatively measurable as the other attributes, so the observation of consonant, flat, or reverse smile arcs is generally cited.

The direct measurement of these static and dynamic relationships is greatly facilitated by the use of computerized databasing programs, which allow the clinician to complete the examination quickly and efficiently; usually, a staff person enters the information as the orthodontist performs the examination. The information is then stored for recall and analysis, and it can even have predefined parameters to identify problematic measurements automatically[16] (Fig 5).

Fig 6. Patient referred for anterior open bite treatment. **A,** Resting relationships characterized by extremely short philtrum relative to commissure. Note reverse resting lip line with short philtrum, resembling frown. **B,** 8-mm gingival display on smile, with thin vermilion and deepening of nasal groove. **C,** Correcting 3-mm anterior open bite might require LeFort I osteotomy. **D, E,** Improved final resting relationships, with lip competence, attractive Cupid's bow, and, most remarkably, an increase in philtrum length relative to commissures. **F,** Posttreatment, patient has 100% incisor show; gummy smile has been eliminated.

CASE ILLUSTRATION

This case demonstrates how important it is to assess soft tissue resting and dynamic relationships in achieving superior esthetic results in orthognathic and orthodontic cases. This patient was referred for treatment of anterior open bite and vertical maxillary excess through combined orthodontic therapy and orthognathic surgery. At rest, she clearly had a short philtrum height relative to the commissures (Fig 6, *A*) with a reverse resting lip posture, resembling a frown. The short philtrum also contributed to her excessive gingival display of 8 mm on smile (Fig 6, *B*). A previous orthognathic procedure had fallen short of the desired result, and she sought further consultation. An anterior open bite of 3 mm was present (Fig 6, *C*), so a LeFort I osteotomy was recommended to achieve bite closure. The systematic evaluations of the upper lip–tooth resting and dynamic relationships were as follows:

Table. Direct biometric data

Procedure	*Expected change*	*Resulting gingival display*
Original		8 mm
Periodontal crown lengthening	−3 mm	5 mm
Philtrum lengthening	−3 mm	2 mm
Maxillary impaction	−2 mm	0 mm

1. Philtrum height (25 mm) was 7 mm shorter than commissure height (32 mm);
2. Incisor crown height was 8 mm;
3. At rest, 8 mm of incisor showed;
4. On smile, 100% of the incisors showed;
5. Gingival display was 8 mm.

The excessive gingival display on smile was therefore attributed to short philtrum height, excessive curtain on smile, short incisor crown height, and mild vertical maxillary excess.

Evaluating the relationship of the maxillary incisor to the upper lip at rest and on smile resulted in the following treatment plan (summarized in the Table):

1. Periodontal crown lengthening to improve crown height and dimensional proportionality and to reduce the amount of gingival display on smile (3 mm additional crown height was achieved).
2. Orthognathic surgery with combined and simultaneous maxillary impaction, rhinoplasty, and V-Y cheiloplasty to lengthen the upper lip. V-Y cheiloplasty and rhinoplasty lengthen the philtrum (3 mm) and provide some lip immobilization due to the orientation of the incisions and lip repositioning. Maxillary impaction of 3 mm posteriorly and only 2 mm anteriorly would close the bite. The soft tissue procedures would dramatically decrease the amount of maxillary impaction needed to achieve ideal smile esthetics; this was highly desirable because of the patient's round face proportionality. The differential impaction of the maxilla, with the posterior maxilla more superior than the anterior, also improved the tilt of the occlusal plane as it relates to smile arc.

Our patient's final resting relationships were greatly improved (Fig 6, *E*), with lip competence, an attractive cupid's bow, improvement in the philtrum length relative to the commissures, and more ideal vermilion show of the upper lip relative to the lower lip. All the desired attributes of an improved smile were also attained (Fig 6, *F*).

CONCLUSIONS

Visualization and quantification of the dynamics of the smile is a 2-stage process. The first crucial step is the clinical examination. The key element in this evaluation is the direct measurement of lip–tooth relationships both dynamically and in repose. Record taking is the second step in this process. We use digital photography, digital videography, radiography, and plaster study casts to accurately record the dynamic and static attributes of a patient's smile. These records are taken frontally and obliquely to allow for a 3-dimensional description of smile characteristics. From this database, one can then perform a smile analysis.

Part 2 of this article will focus on smile analysis and treatment strategies involved in achieving optimal smile esthetics.

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