Designation: E2545 – 07 (Reapproved 2012)

Standard Test Method for Objective Measurement of Gingival Color Using Digital Still Cameras[1]

This standard is issued under the fixed designation E2545; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The color of gingiva is an important parameter used to ascertain certain medical and esthetic information. RGB color values for gingiva are derived from the native signals generated by a digital still camera, DSC, by broadband measurement of the reflectance of gingiva. This Test Method, E2545, specifies the procedure used for the color measurement of gingival color at 45° relative to the sample plane containing the gingiva under a nearly equal energy illuminating at 45° and viewing at 0°. This method is appropriate for evaluating the color of facial gingiva.

1. Scope

1.1 This test method covers the procedure, instrumental requirements, standardization procedures, material standards, measurement procedures, and parameters necessary to make precise measurements of gingival color. In particular it is meant to measure the color of gingiva in human subjects.

1.2 Digital images are used to evaluate gingival color on the facial labial or buccal surfaces of the gingiva. The marginal gingival tissue adjacent to natural teeth may be of particular interest for analysis. All other non-relevant parts; such as teeth, tongue, spaces, dental restorations or prostheses, etc., must be separated from the measurement and the analysis. All localized discoloration; such as stains, inclusions, pigmentations, etc., may be separated from the measurement and the analysis.

1.2.1 The broadband reflectance factors of gingiva and the surrounding tissue are measured. The colorimetric measurement is performed using an illuminator(s) that provides controlled illumination on the gingiva using a digital still camera to capture the digital image.

1.3 Data acquired using this test method may be used to assess personal gingival color for the purposes of identifying overall health status, health status at specific sites in the mouth, or to track changes in personal health status for individuals over time. Pooled data may be used to assess gingival color, health and disease among populations in epidemiological surveys, evaluation of comparative product efficacy, or safety and treatment response in clinical trials involving gingival health or disease.

1.4 The apparatus, measurement procedure, and data analysis technique are generic, so that a specific apparatus, measurement procedure, or data analysis technique may not be excluded.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials

E284 Terminology of Appearance

E308 Practice for Computing the Colors of Objects by Using the CIE System

E1345 Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements

E1767 Practice for Specifying the Geometries of Observation and Measurement to Characterize the Appearance of Materials

[1] This test method is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.06 on Image Based Color Measurement.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 *ISO Publications:*[3]

ISO 17321–1 Colour characterization of digital still cameras (DSCs) — Part 1: Stimuli, metrology, and test procedures

ISO/IEC 1544–1:2000 – JPEG2000 Information technology – JPEG 2000 image coding system – Part 1: Core coding system, commonly known as JPEG 2000 jp2 file format

2.3 *ISCC Publications:*[4]

Technical Report 2003–1 Guide to Material Standards and Their Use in Color Measurement

2.4 *Other Publications:*[5]

TIFF Tagged Image File Format

3. Terminology

3.1 Terms and definitions in Terminology E284 are applicable to this test method.

3.2 *Definitions:* Terms included in this section are peculiar to this standard.

3.2.1 *angle of incidence, n*—θ_1 and optional θ_2, the polar angle between the central ray of the illuminator(s), I_1 and I_2, and the Z axis which is the optical axis of the camera.

3.2.1.1 *Discussion*—These are shown in Fig. A1.1.

3.2.2 *bit depth, n*—the number of digital bits used to store information contained in each color channel of each pixel.

3.2.2.1 *Discussion*—The bit depth determines the maximum number of colors that may be encoded by the system. For example, a 24 bit system comprising 8 bits per channel can encode 2^8 by 2^8 by 2^8 or about 17 million; colors far more than are distinguishable by the human observer.

3.2.3 *facial surfaces, n*—the surfaces of teeth and gingiva that are oriented outward toward the lips (labial) and cheeks (buccal), and facing away from the tongue or roof of the mouth.

3.2.4 *gingivitis, n*—inflammation of the marginal gingiva in response to dental plaque accumulation on adjacent tooth surfaces.

3.2.5 *in-vivo—adj, or adv*, within a living body.

3.2.5.1 *Discussion*—Used to describe measurements made in a living body.

3.2.6 *polarization, n*—the process by which vibrations of light are given a definite orientation; also the state produced by that process.

3.2.7 *polarizing filter, n*—a component that blocks one of the two planes of vibration of an electromagnetic wave, thus producing linearly polarized light.

4. Summary of Test Method

4.1 This test method describes the procedures for broadband reflectometry of gingival tissue. The standardization of the instrument used to measure the tissue is defined. The images of artifact standards and samples are captured with a DSC. The RGB values of these images are read and stored. The results are reported as RGB values and can be converted to other colorimetric coordinates such as CIELAB. Procedures for converting the RGB camera values to component CIELAB values are also presented.

5. Significance and Use

5.1 The color of gingiva or changes in gingival color can be observed. The light reflected from the facial surfaces of the gingiva can be used to calculate color coordinates. These data reveal information about the efficacy of a product, treatment studied, or epidemiology of anti-gingivitis treatments. For example, clinical studies of gingivitis treatment systems evaluate the efficacy of manufacturers' products.

5.2 The change in color of the facial surface gingiva can be used to determine and optimize the efficacy of anti-gingivitis treatments. For example, the data can provide the answer to the question: "What product or system is the most efficacious in the treatment of gingivitis?"

5.3 Chronic inflammatory disease of the gingiva and periodontium results in destruction of gingival connective tissue, periodontal ligament, and alveolar bone. Clinically, inflammation is seen as redness, swelling, and bleeding observed upon probing.

5.4 This procedure is suitable for use in diagnosis and monitoring, research and development, epidemiological or other surveys, marketing studies, comparative product analysis, and clinical trials.

5.5 Popular methods assess gingival inflammation via repeated clinical examination of the gingival tissues.[6,7] These methods typically quantify gingival color, which are used to assess gingival health or disease, at multiple intraoral sites on the gingiva using a simple non-linear scoring system or index. Assessment of gingival color is an important component of health status for mild-to-severe gingival disease. These techniques are time-consuming, subjective, and often invasive, and for archival purposes, separate intraoral photographs must be collected to document gingival color and appearance. Variation between and among examiners may contribute to appreciable differences in measurement.[8]

6. Interferences

6.1 The interferences identified below may be eliminated and problems avoided by controlling and regulating each factor within the constraints of the allowable experimental error. The values and limits for these factors are typically determined experimentally. If the standard laboratory conditions listed below change during the test or from test to test by an appreciable amount, these conditions may cause interferences,

[3] Available from International Imaging Industry Association (13A), 701 Westchester Avenue, Suite 317W, White Plains NY 10604, www.13a.org.

[4] Available from ISSC, Inter-Society Color Council, 11491 Sunset Hills Rd., Reston, VA 20190, www.iscc.org.

[5] TIFF, Tagged Image File Format, Adobe Systems Incorporated, San Jose, CA, http://www.adobe.com.

[6] Loe H., and Silness, J., "Prevalence and Severity," *Journal Peridontal Disease in Pregnancy*, I, *Acta Odontologica Scand*, 1963, 21:533-551.

[7] Lobene, R. R., Weatherford, T., Ross, N. M., Lamm, R. A., and Menaker, L., "A modified gingival index for use in clinical trials," *Clinical Prevention Dentistry*, 1986, 8:3–6.

[8] McClanahan, S. F., Bartizek, R. D., and Biesbrock, A. R., "Identification and consequences of distinct Loe-Silness gingival index examiner styles for the clinical assessment of gingivitis," *Journal of Periodontology*, 2001, 72:383–92.

and the accuracy and precision requirements of this test method may not be achieved. In some cases these effects may only be observed during the performance of the test.

6.1.1 *Factors Affecting Test Results*—The following environmental factors are known to affect the test results.

6.1.1.1 *Extraneous Radiation*—Light including near infrared from sources other than the illuminator(s) must be shielded from the test apparatus.

6.1.1.2 *Vibrations*—Mechanical oscillations that cause components of the apparatus to move relative to one and another may cause errors in test results.

6.1.1.3 *Thermal Changes*—Temperature changes occurring during a test or differences in temperature between testing locations may affect the reflectance factor of the standardization, calibration, and verification plaques, and the apparatus spectral response function.

6.1.1.4 *Power Input Fluctuations*—Large changes in the line frequency or supply voltage may cause the apparatus to report erroneous results.

6.1.2 *Retractors*—The surface finish of the retractors affects the experimental test results. It has been determined that a glossy finish on the surface of the retractors may introduce a bias into the test results.

6.2 The system must allow for successful standardization. If the system cannot be standardized, a series of checks must be performed (lighting, camera, etc.) to identify the reason. The component of the system in error will be adjusted or replaced to bring the system back into calibration.

7. Apparatus

7.1 *General*—The components described in this section are described generically. The intention is not to exclude any component from being used, or to exclude any type of instrument that may be available commercially. Between 4 and 6 different components or component assemblies are required to accomplish the measurement.

7.2 *Geometry*—The geometry of the system is 45:0 as described in Practice E1767. The DSC System Geometry (Coordinate System) and Angular Convention are shown in Fig. A1.1 included in Annex A1.

7.3 *Components*—A block diagram of these component assemblies is shown diagrammatically in Fig. A1.2, included in Annex A1.

7.3.1 *Source Illumination Assembly*—Contains the source of illumination and associated optics to produce irradiance, E, on the sample over a specified spot area, designated A. The source is broadband and continuous in nature. A diagrammatic representation of the components of a typical source illumination assembly Unit is shown in Fig. A1.3, included in Annex A1.

7.3.2 *Spectral Power Distribution*—The light source should be spatially uniform over the area of interest, and have a spectrum that approximates CIE Illuminant D50 over the spectral range of the DSC, a choice that is customary and achieves the uniformity of practice. Commonly used light sources include incandescent lamps with filters to simulate a standard illuminant, flash xenon with filters, or white-LED lamps to realize the approximate color temperature of 5000K.

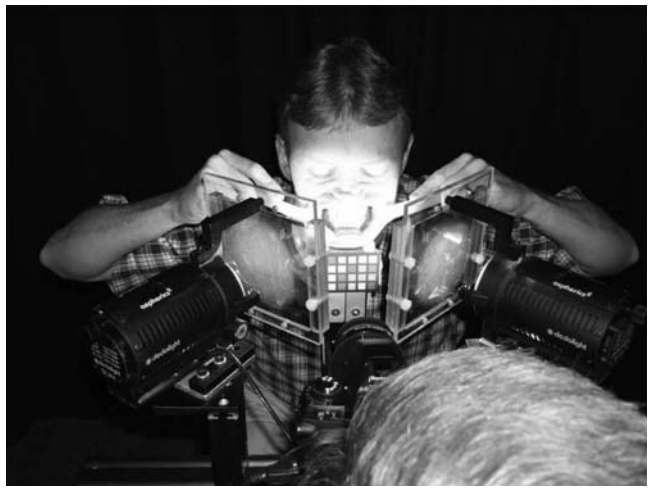

FIG. 1 Subject Positioned in Instrumentation

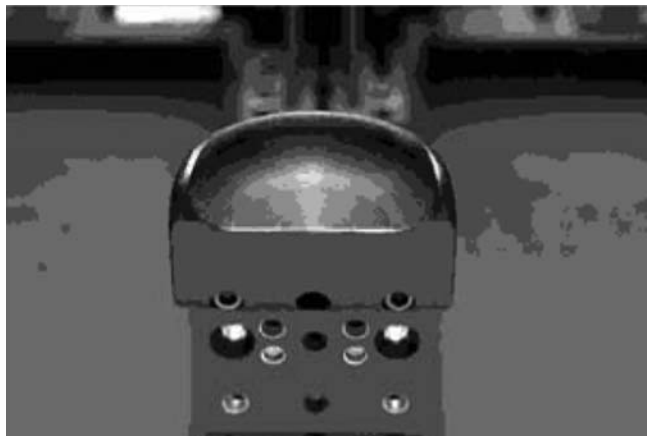

FIG. 2 Chin Rest

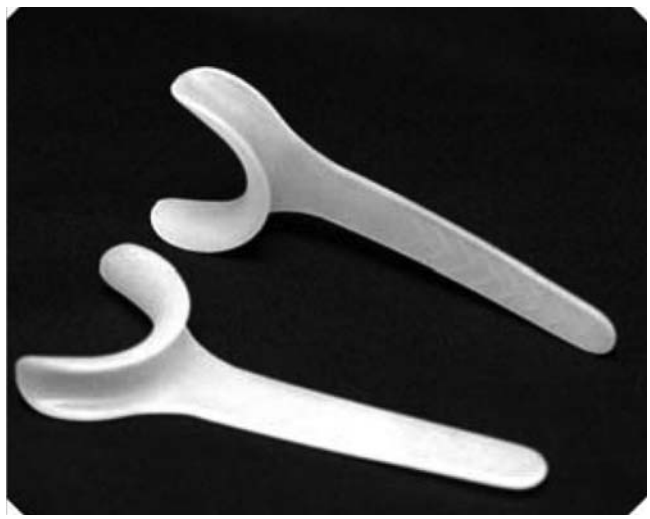

FIG. 3 Picture of Matte Lip Retractor

7.3.3 *Polarizer*—The linear polarizer provides and controls the polarization state of the incident light. This polarizer on the illuminators plus a cross polarizing filter on the lens system of the DSC eliminates glare caused by reflection of the subject's gingiva tissue during imaging. Wavelength range, extinction

ratio, transmittance, and beam deviation are important parameters of the components and must be selected.

7.3.4 *Heat Rejection Filters*—These filters remove undesired near infrared (IR) radiation including heat that adversely affects the subject, and provide spectral shaping of the spectral power distribution of the source illumination

7.3.5 *Selective Blue Filters*—These filters condition the spectral power distribution of the illumination so that the spectral power distribution is similar to Illuminant D50.

7.3.6 *Sample Plane Holder*—The sample plane holder provides a secure mount so that it positions the subject's incisors normal to the Z axis, and centered along the X and Y axes. This must be done so that the gingival tissue is presented to the DSC in a repeatable and reproducible manner. The sample mount must be kept unobtrusive so that it is "friendly" and not intimidating to the subjects. A chin rest is used to precisely position the subjects relative to the instrumentation (Fig. 1). The subjects place their chin on a chin rest which is a quarter-cup shaped rig, as shown in Fig. 2.

7.3.6.1 Lip retractors[9] (Fig. 3) are used to expose the majority of the subject's gingiva to the DSC system. Subjects hold their head straight, join the tips of their upper and lower incisors together and place their tongue against the top of their mouth. The facial surface of the central incisors should be aligned with a line marked on the chin rest indicating the center along the X axis.

7.4 *Detector Optical Elements:*

7.4.1 The typical detector optical elements are shown in Fig. A1.4, included in Annex A1.

7.4.2 The linear cross polarizer provides and controls the plane of polarization, which is the plane spanned by the E-vector and the Poynting vector. The linear cross polarizer must be rotated around the optical axis of the beam to change the plane and state of polarization; therefore eliminating the strong reflection caused by the wetness of the gingival tissue during measurement. This cross polarizer must be oriented rotationally perpendicular, 90°, to the Source Polarizing elements. A linear cross polarizing assembly is diagrammatically shown in Fig. A1.4.

7.5 *Digital Still Camera*—The DSC must have several performance characteristics.

7.5.1 The depth of focus of the camera and lens combination must be sufficient to accommodate the differences in gingiva caused by natural variations between subjects.

7.5.2 *Detectors:*

7.5.2.1 Either a 3 chip RGB DSC or a single chip RGB DSC will perform adequately in this application.

7.5.2.2 *Field of View*—The field of view of the DSC and lens combination must be sufficient to accommodate differences in specimens occurring naturally in subjects, and include the entire " Field of View" as shown in Fig. A1.5. There can be no exception to this requirement.

7.5.3 *Bit Depth*—The bit depth must be 8 bits or greater to accommodate accurate conversion of the digital signals into CIE color spaces. Bit depth of 8 bits is commonly available.

7.5.4 *Acceptance Aperture*—The aperture of the lens system must be sufficient to accommodate the angular subtense of the sample and illuminate the detector chip.

7.6 *Computer Interface:*

7.6.1 The DSC must be interfaced and controlled by a computer.

7.6.1.1 White Balance and Black Balance must be adjustable by the computer through the interface.

7.6.1.2 Exposure control must be settable and reproducible by the computer.

7.6.1.3 Gain control should be selectable and settable by the computer.

7.6.2 It is desirable to have a live video output for validating the positioning of the human subjects and test specimens prior to capturing the image.

7.6.3 For image analysis purposes an uncompressed file format is recommended. Any lossless format may be used. The Tagged Image File Format, TIFF,[5] is a format that allows storage in uncompressed form as well as allowing lossless LZW compression and lossy JPEG compression. Camera RAW is also an acceptable format.

8. Sampling, Test Specimens, and Test Units

8.1 *Selection of Subjects:*

8.1.1 Generally, a clinical trial is conducted to statistically validate the efficacy of a particular treatment method, product, or status of health of an individual or a group.

8.1.2 A clinical trial usually has entrance criteria. Volunteers who meet clinical trial entrance criteria and provide informed consent are chosen. For example, the clinical trial may require candidates to have gingivitis to some degree.

8.1.3 Candidates may be excluded from participation in a clinical trial due to unique pigmentation, tissue grafts, or other alterations of the gingiva which do not have the reflective properties of natural tissues.

8.2 *Sampling:*

8.2.1 The region of interest is determined from the clinical protocol and may use the gingival margin as a reference. For example, a dental product under evaluation that has target area of action may require a unique sub sampling technique to identify pixels in that area.

8.2.2 Choose the teeth that will have adjoining gingival tissue evaluated; for example, the anterior 12 teeth.

8.2.3 Create a software mask that specifies the coordinates of the gingival margin needed to identify the region of interest. Refer to Fig. 4.

8.2.4 Select the region of interest specified in the clinical protocol. This process may require use of a computer application capable of making the needed geometry or distance calculations.

8.2.5 *Sub Sampling*—The average RGB values for the region of interest can be calculated and reported. Alternatively, the RGB values for each pixel can be reported as a function of position in the image. Each study will have unique sub sampling requirements depending upon the objectives of the study.

[9] Retractors with a matte finish have been found satisfactory for this purpose.

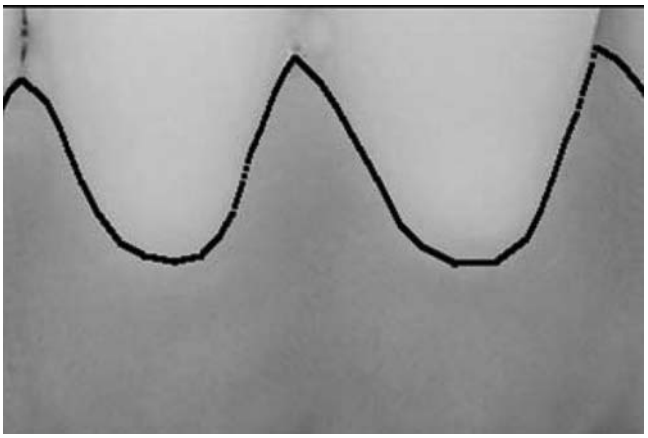

FIG. 4 Illustrative Software Mask

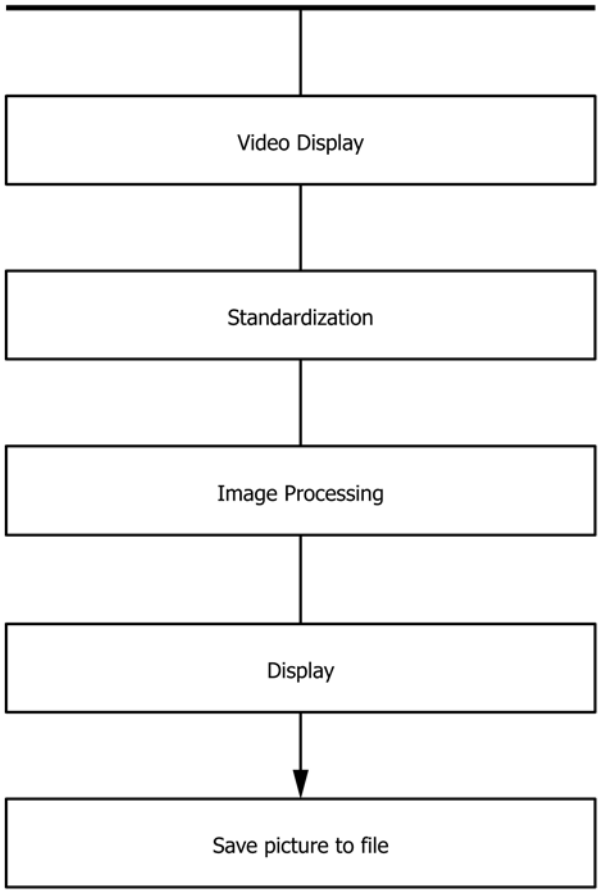

FIG. 5 Typical DSC Application Software Workflow

9. Preparation of Apparatus

9.1 *Warm Up:*

9.1.1 Stabilize the equipment and the facility to a temperature between 20 and 23.9°C (68 and 75°F). Approximately one hour is required for the equipment to reach thermal equilibrium.

9.2 *Software Preparation:*

9.2.1 Turn on the computer and launch the appropriate applications.

9.2.2 The software used to capture the images is custom in nature and developed specifically for the application. The work flow for a typical application is illustrated in Fig. 5.

9.3 *Hardware Preparation:*

9.3.1 Display the live video image. Start the software that provides the "video display."

9.3.2 *Align the Source Illumination Units:*

9.3.2.1 Adjust the illumination on the measurement plane so it is centered and uniform.

9.3.2.2 Using the illumination adjustment screws, adjust the position of the illuminated area so that it is aligned with the center of the sample plane. A centering target is necessary to locate the center of the measurement plane in the horizontal and vertical axes. The horizontal axis of the test target allows the illuminators to be aligned in the vertical axis. The horizontal axis of each illuminator is offset from the geometric axis of the test fixture so that the beams of the illuminators overlap. This minimizes the non-uniformity of the energy distribution in the measurement plane.

9.3.2.3 Adjust the position of the source illumination assembly unit (lighting source element) so that the intensity of each source illumination assembly unit is uniform over the measurement plane.

9.3.2.4 Secure the adjusting screws and verify that the alignments of the source illumination units are correct with the alignment screws secure.

9.3.3 *Aligning the Digital Still Camera Unit:*

9.3.3.1 Adjust the DSC alignment screws to align the optical axis of the digital camera system so that it is perpendicular to the subject (measurement plane).

9.3.3.2 The software should provide an alignment "cross hair" in the exact center of the viewed image to center the DSC precisely.

9.3.3.3 Secure the alignment screws.

9.3.3.4 Verify that the alignment of the DSC is correct with the alignment screws secure.

9.3.4 *Adjust the Optical Elements:*

9.3.4.1 Depending upon the actual configuration it may be necessary to align and focus the lens first. See 9.3.6.

9.3.5 *Align the Polarizers:*

9.3.5.1 Adjust the illuminator's polarizers so that they are cross-polarized relative to the DSC. This will minimize the effect of reflections.

9.3.5.2 Install the test fixture that performs the polarization, detection, and alignment. For instance, a chrome sphere,[10] approximately 18 mm (¾ in.) diameter, may be installed in the sample plane. A sphere ensures that reflections from the source illumination units will be seen by the DSC. This reflection component is minimized by adjusting the polarizers to the cross polarizing position so that the refection is extinct.

9.3.5.3 Polarization, detector, and alignment test fixture. See Fig. 6.

[10] Chrome spheres are readily available from ball bearing manufacturers.

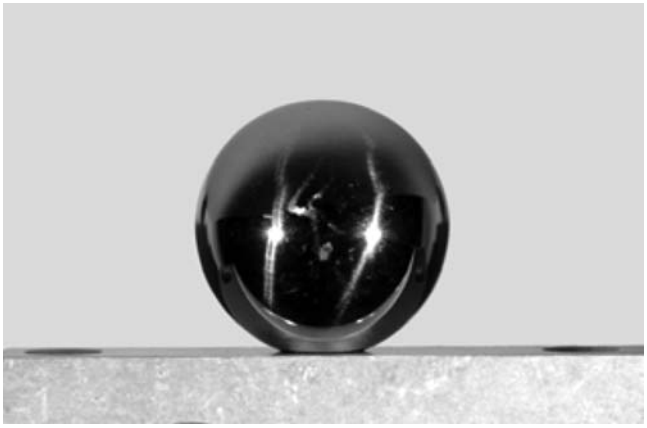

FIG. 6 Polarization (E-Vector) Detection and Alignment Test Fixture

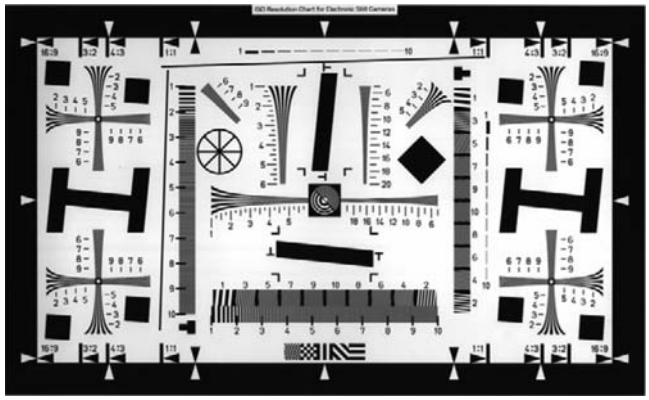

FIG. 7 Resolution Chart

9.3.5.4 Position the polarizers so that the indicator marks are on the top. The indicator marks indicate the nominal polarizing axis of the polarizers. Aligning these filters nominally aligns the polarizing axes of the polarizing filters with the vertical axis of the test fixture. Placing the polarizers in the "pointing up" position is a good starting point.

9.3.5.5 Rotate the polarizer on the DSC, shown as detector optical elements in Fig. A1.4 until the reflection caused by the polarizing test fixture disappears; that is, goes to extinction or a minimum.

9.3.5.6 Secure the polarizing retaining screw on the DSC. Secure the rotational axis of the polarizer.

9.3.5.7 Adjust the polarizing retaining screw and rotate the polarizer on the left source illumination assembly unit until the reflection caused by the gloss of the polarizing test fixture disappears; that is, goes to extinction or a minimum. Secure the polarizing retaining screw on the left source illumination assembly unit.

9.3.5.8 Adjust the polarizing retaining screw and rotate the polarizer on the right source illumination unit until the reflection caused by the gloss of the polarization, detection, and alignment test fixture disappears; that is, goes to extinction or a minimum. Secure the polarizing retaining screw on the right source illumination assembly unit.

9.3.5.9 Adjust the polarizing retaining screw and rotate the polarizer on the DSC until the reflection caused by the gloss of the polarizing detection and alignment test fixture goes to extinction or a minimum. Secure the polarizing retaining screw on the DSC optical element assembly.

9.3.5.10 Secure the polarizing retaining screw on the DSC. The polarizers are correctly aligned.

9.3.6 *Focus the DSC Lens:*

9.3.6.1 Place a focusing target in the sample plane. A resolution chart (Fig. 7) as shown in ISO 17321–1 is adequate for these purposes.

9.3.6.2 Loosen the DSC focusing mechanism and adjust the focusing ring of the lens system until the displayed image is the sharpest.

9.3.6.3 Secure the focusing ring on the camera lens system and validate that the focus of the image did not change. Readjust if necessary.

10. Standardization

10.1 Standardization and its verification are essential steps in ensuring that precise and accurate results are obtained by colorimetric measurements. They require the use of physical standards. Physical standards are supplied by commercial instrument manufacturers[11] and standardizing laboratories. It remains the user's responsibility to obtain and use the physical standards necessary to keep their instrument in optimum working condition.

10.2 Standardization consists of compensating for non-uniformity, white balancing, and color standardization.

10.3 The white balance consists of acquiring an image of an 80 % grey standard.[4] Post image acquisition, the white balance of the camera is set so the RGB channels of the camera are equal. From this same image a position dependant uniformity correction for each color channel is generated.

10.4 *Localized Color Standardization*—Standardization is accomplished by regressing DSC raw data of the color standards to determined colorimetric values. The selected color standards surround the area in color space of the specimens being examined. The determined colorimetric values of the color standards are established after a validated system has reached operational equilibrium. When several different systems are deployed, the average data from multiple systems is one of the best methods for establishing these determined colorimetric values. The parameters for the regression equations are generated by capturing digital images of the color standards and extracting the average DSC RGB values.

10.4.1 Absolute artifact standards are collected that represent the colorimetric range of CIELAB color space to be examined. Color atlases such as the Munsell Book of Color[12] have been found useful for constructing a standard set.

10.4.2 Define two k x 3 matrices A and B such that matrix A contains the raw RGB values obtained from the camera of the k absolute artifact standards, and matrix B contains the standard tristimulus values for the CIE 1931 Standard Observer

[11] ISCC Publications, Technical Report 2003–1, *Guide to Material Standards and Their Use in Color Measurement.*

[12] Munsell Color Atlases are available from GretagMacbeth at www.gretagmacbeth.com.

and Standard Illuminant D50 of the same set of absolute artifact standards in the same order.

10.4.3 If the standard tristimulus values of the artifact standard are given in terms of the CIELAB values for the 1931 Standard Observer and Illuminant D50 notation, transform them to tristimulus values by the following:

$$X = X_n\left(\frac{L^*+16}{116}+\frac{a^*}{500}\right)^3 \quad (1)$$

$$Y = Y_n\left(\frac{L^*+16}{116}\right)^3 \quad (2)$$

$$Z = Z_n\left(\frac{L^*+16}{116}-\frac{b^*}{200}\right)^3 \quad (3)$$

where X_n, Y_n, and Z_n are the 1931 2° Standard Observer under Illuminant D50 tristimulus values for the perfect reflecting diffuser.

10.4.4 Calculate the 3 × 3 transformation matrix *t* from:

$$t = (A'A)^{-1}A'B \quad (4)$$

where:

′ = the transpose of the matrix
-1 = the inverse of the matrix.

White Point Tristimulus Values[A] for the 1931 2° Standard Observer under Illuminant D50	
X_n	96.422
Y_n	100.000
Z_n	82.521

[A] These tristimulus values are taken from Practice E308.

10.4.5 *Verification*—After full-scale and color standardization are performed the linearity of the scale should be verified by measuring one or more calibrated standards having intermediate reflectance factors. A linearity verification test should be made using different material standards than those used to calibrate the DSC.

11. Conditioning

11.1 *Apparatus:*

11.1.1 The system is ready for standardization after all electronic components are turned "on" and allowed to stabilize after one hour of warm up at the beginning of each study day.

11.2 *Human Subjects:*

11.2.1 The human subjects prepare themselves by avoiding anything that irritates the gingiva tissue before beginning the measurement sequence. This may include avoidance of unnecessarily hot beverages, irritating foods or spices, or certain oral hygiene activities (such as use of toothpicks) immediately prior to measurement. The human subjects may rinse with water or undergo other routine oral hygiene necessary to remove food debris or other particles in the field of measurement.

12. Procedure

12.1 The procedure detailed below contains steps required to acquire data. All operations are required in the order presented. Other systems may require additional steps.

12.2 Initialize the system.

12.3 Turn on the lights at least 1 hour before taking measurements.

12.4 Allow the system and the environment to thermally stabilize.

12.5 Turn on the computer system.

12.6 Launch the image capture application.

12.7 Display the live video image.

12.8 Validate the equipment is set up correctly.

12.9 Standardize the system.

12.10 *Color Standardization:*

12.10.1 Place the color target in the measurement plane and capture the image.

12.11 *Prepare the Human Subjects:*

12.11.1 Use a set of retractors to expose the measurement area of the gingiva. Have the subject place retractors in their mouth, then position themselves in the measurement plane.

12.11.2 Ensure that the subject is at the correct height, that their chin is on the chinrest, their forehead against the registration bar, and that they are oriented perpendicular to the camera.

12.11.3 *Capture the image:*

12.11.3.1 The image of the subject's gingiva must be captured within 2 minutes from the moment the subject is positioned to minimize the effects of dehydration.

12.11.3.2 Actuate the software to capture the image.

12.11.4 *Validate the Quality of the Image:*

12.11.4.1 Visually examine the image and ensure that the subjects' teeth are centered, fully exposed, the image in focus, and there are no unexpected shadows in the image. Additionally, the tooth area must be exposed for analysis by digital imaging processing.

13. Calculation or Interpretation of Results

13.1 *Color Coordinates:*

13.1.1 *Data Calculation*—Average the camera RGB values obtained from the gingival tissue. Perform any desired calculations of color coordinates that are not made automatically by the software

13.1.1.1 Calculate the tristimulus values using the 1931 CIE 2° Standard Observer and Illuminant D50 of the gingival tissue from:

$$B = A\,t \quad (5)$$

where:

Matrix A = contains in its rows the average camera RGB values of one or more measured tissues
Matrix B = will contain the tristimulus values of the tissue in an identical row.

13.1.1.2 Transform the tristimulus values by:

$$L^* = 116\,f(Q_Y) - 16 \quad (6)$$

$$a^* = 500\,[f(Q_X) - f(Q_y)] \quad (7)$$

$$b^* = 200\,[f(Q_Y) - f(Q_Z)] \quad (8)$$

where:

$$Q_X = (X/X_n);\ Q_Y = (Y\ /\ Y_n);\ Q_Z = (Z/Z_n) \quad (9)$$

and

$$f(Q_i) = Q_i^{1/3} \quad \text{if } Q_i > (6/29)^3$$

else

$$f(Q_i) = (841/108)\, Q_i + 4/29. \qquad (10)$$

Here, i varies as X, Y, and Z.

13.1.2 *Interpretation of Results:*

13.1.3 Evaluate the change in color in terms of component CIELAB values with respect to their position in the band of interest as a function of time, treatment or both. The magnitude and location of the color changes is evaluated against the protocol.

14. Report

14.1 Include the following information in the report. Mandatory and Recommended information are so indicated. These metadata are to be included in every image.

Number	Section	Mandatory	Desired
14.1	**Format**		
14.1.1	Compression Scheme	X	
14.2	**Photometric interpretation**		
14.2.1	Color Space		X
14.2.3	Reference White	X	
14.2.4	Reference Black		X
14.3	**Segments**		
14.3.1	Number of Rows		X
14.3.2	Number of Cells		X
14.3.3	Number of Columns		X
14.3.4	Pattern		X
14.4	**File**		
14.4.1	File Size	X	
14.4.2	Check Sum		X
14.4.3	Image Identifier		X
14.4.4	Orientation		X
14.4.5	Display Orientation		X
14.5	**Computer**		
14.5.1	Host Computer	X	
14.5.2	OS		X
14.5.3	Capture Software	X	
14.5.4	Capture Software Version		X
14.6	**Digital Camera**		
14.6.1	Manufacturer		X
14.6.2	Manufacturer Model Number		X
14.6.3	Manufacturer Serial Number	X	
14.6.4	F# (number)		X
14.6.5	Resolution		X
14.6.6	Exposure Setting		X
14.6.7	Focal Length		X
14.7	**Image Capture**		
14.7.1	Date	X	
14.7.2	Time	X	
14.7.3	Operator	X	
14.7.4	Location	X	
14.8	**Calibration**		
14.8.1	R, G, B		X
14.8.2	White Point	X	
14.9	**Calibration Target**		
14.9.1	Target ID		X
14.9.2	Target Serial Number	X	
14.10	**System**		
14.10.1	Last Calibration	X	
14.10.2	Last Standardization	X	
14.11	**Image Processing**		
14.11.1	Date Processed	X	
14.11.2	Time Processed	X	
14.11.3	Who processed		X
14.11.4	Software Name		X
14.11.5	Software Version		X
14.11.6	Processing Actions		X

14.2 The information presented above may be recorded in the technical metadata part of an image file. JPEG2000, as defined by ISO/IEC 15444–1, is the normative reference for metadata. Metadata is information about data. Typically, metadata is structured and encoded data that describes the conditions and parameters of a captured image. In concept this information should permit an identical image to be re-captured.

15. Precision and Bias

15.1 The repeatability data were obtained during the month of October 2006 using a glossy white tile as the test specimen. 43 consecutive measurements were gathered in the shortest possible period of time.

15.2 The reproducibility data were obtained over a period of October 2006. The specimens tested are a subset of the BCRA Standards. The instrument population consisted of three DSC colorimeters in multiple laboratories.

15.3 *Repeatability*—Two test results obtained under repeatability conditions, which are defined as measurements made in the same laboratory using the same test method by the same operator using the same equipment in the shortest possible period of time using specimens taken from one lot of homogeneous material, should be considered suspect to a 95 % repeatability limit if their values differ by more than 0.15 unit, ΔE^*_{ab}.

15.4 *Reproducibility*—Two test results made under reproducibility conditions, which are defined as measurements made in different laboratories using different equipment using the same test method, each by a different operator using specimens taken from one lot of homogeneous material, should be considered suspect to a 95 % reproducibility limit if their values differ by more than the values given in Table 1 under the column headed "95 % Reproducibility Limits." Table 1 contains specimen names, RGB values, and 95 % reproducibility limits for the specimens used in the test method.

TABLE 1 Reproducibility Limits

	Specimen Name	Average CIELAB Values			95 % Reproducibility Limits ΔE^*_{ab}
		L*	a*	b*	
1	Pale Gray	82.6	0.2	0.8	1.1
2	Mid Gray	63.9	1.2	0.7	1.3
3	Diff Gray	64.8	-0.7	2.0	1.1
4	Deep Gray	30.0	2.4	-0.3	1.1
5	Deep Pink	48.8	37.5	15.0	1.1
6	Red	48.1	61.5	35.6	1.7
7	Glossy White	90.3	0.9	1.3	0.9
8	Black Glass	20.8	3.9	-1.7	1.6
9	Matte White	89.7	0.9	2.0	0.7
10	Orange	70.3	23.6	75.7	3.6
			Average	=	1.4

15.5 *Context Statement*—The precision statistics cited for this test method must not be treated as exact mathematical quantities that are applicable to all DSC colorimeters, uses, and materials. There will be times when differences occur that are greater than those predicted by the interlaboratory study leading to these results would imply. Sometimes these instances occur with greater or smaller frequency than the 95 % probability limit would imply. If more precise information is required in specific circumstances, those laboratories directly involved in a material comparison must conduct interlaboratory studies specifically aimed at the material of interest.

15.6 *Improving Precision*—Practice E1345 may be useful for improving measurement precision.

15.7 *Bias*—It is not possible to determine the bias, if any, because no accepted reference values are available for the specimens tested. There are no known sources of bias in this test method.

16. Keywords

16.1 colorimetry; digital camera; digital colorimetry; DSC; gingival color; gingivitis

ANNEX

(Mandatory Information)

A1. DIGITAL CAMERA SYSTEM COMPONENTS AND GEOMETRY ILLUSTRATIONS

A1.1 DSC System Geometry (Coordinate System) and Angular Convention

A1.1.1 It is common practice to define the geometry of an optical system (Fig. A1.1) as follows:

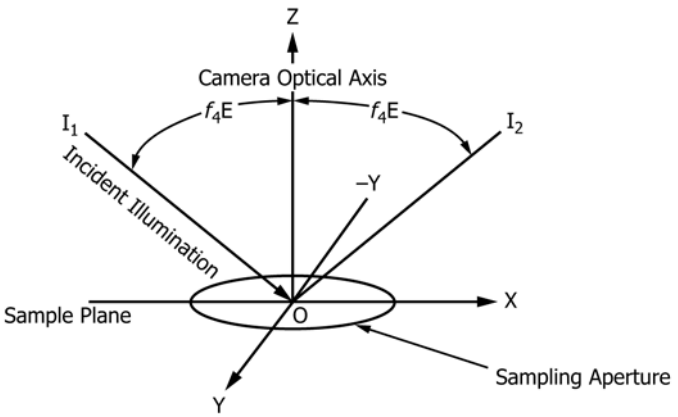

FIG. A1.1 Angular Coordinate Conventions

A1.1.1.1 The camera optical axis is perpendicular to the sample plane.

A1.1.1.2 The incident radiation is offset about the Y axis by 45 degrees. See Practice E179.

A1.2 Typical Block Diagram for a Digital Still Camera Based Colorimeter

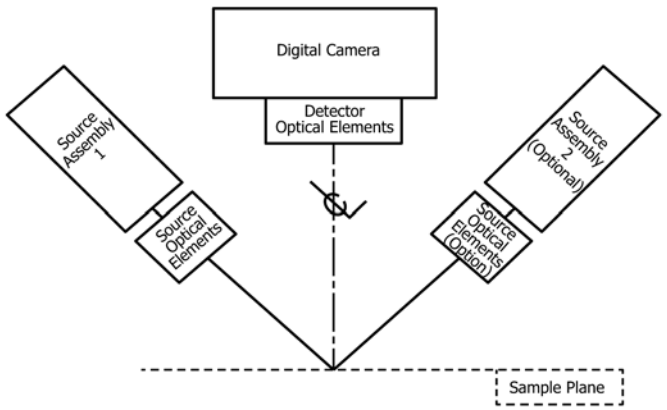

FIG. A1.2 Digital Still Camera Based Colorimeter Block Diagram

NOTE A1.1—The illumination angle may have to be changed from the nominal 45 degrees when examining the posterior teeth.

A1.3 Typical Block Diagram for Source Illumination Unit

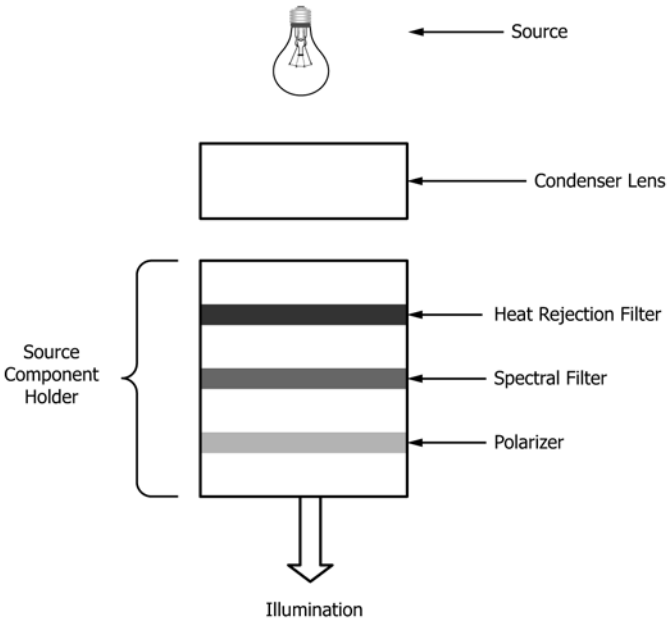

FIG. A1.3 Typical Source Illumination Assembly Unit

A1.4 Typical Block Diagram for Detector Optical Elements

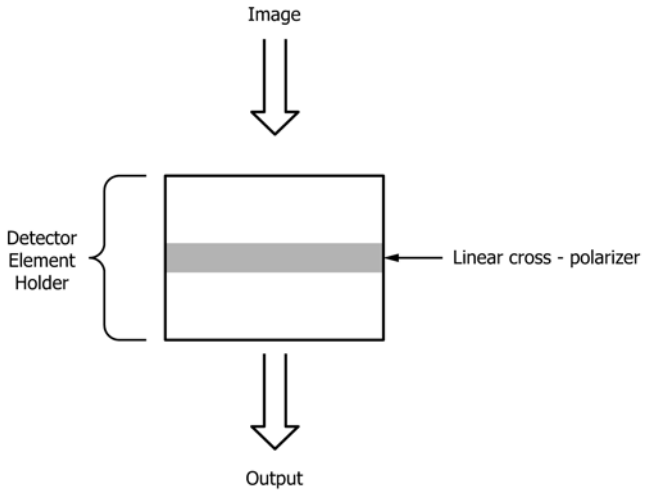

FIG. A1.4 Typical Detector Optical Elements

A1.5 Typical Digital Still Camera System Geometry

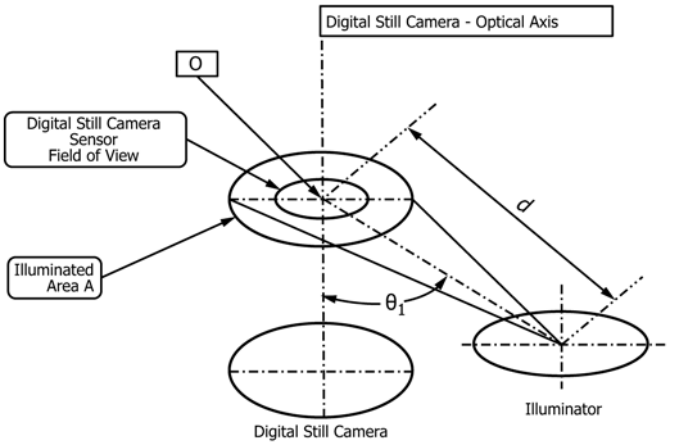

FIG. A1.5 Digital Still Camera System Geometry