UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DENTAL IMAGING TECHNOLOGIES CORPORATION,

Petitioner

v.

3SHAPE A/S,

Patent Owner

U.S. Patent No. 10,695,151 to FISKER *et al.*
Issue Date: June 30, 2020
Title: DETECTING TOOTH SHADE

DECLARATION OF DR. IOANNIS A. KAKADIARIS IN SUPPORT OF INTER PARTES REVIEW OF 10,695,151

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TABLE OF EXHIBITS

Exhibit	Description
1001	U.S. Patent No. 10,695,151 ("'151 patent")
1002	File History for U.S. Patent No. 10,695,151
1003	Declaration of Dr. Ioannis A. Kakadiaris
1004	Patent Office Action
1005	U.S. Patent No. 8,532,355 ("Quadling")
1006	U.S. Patent No. 8,570,530 ("Liang")
1007	DK priority document
1008	Toriwaki *et al.*, Fundamentals of Three-Dimensional Digital Image Processing, Springer, 2009 ("Toriwaki")
1009	Gonzalez *et al.*, Digital Image Processing, Third Edition, Pearson Prentice Hall, 2008 ("Gonzalez")
1010	Richert *et al.*, Intraoral Scanner Technologies: A Review to Make a Successful Impression, Journal of Healthcare Engineering, 2017 ("Richert")
1011	Logozzo *et al.*, Recent advances in dental optics – Part I: 3D intraoral scanners for restorative dentistry, Opt Laser Eng, 2013 ("Logozzo")
1012	Kang, Three-Dimensional Lookup Table with Interpolation, Computational Color Technology, Chapter 9, 2006
1013	Vadher *et al.*, Basics of Color in Dentistry: A Review, IOSR Journal of Dental and Medical Sciences, 13(9):78-85, Sep. 2014 ("Vadher")
1014	Douglas *et al.*, Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade

	mismatch, Journal of Prosthetic Dentistry, 9(4):200-208, April 2007 ("Douglas")
1015	Corcodel *et al.,* Metameric effect between natural teeth and the shade tabs of a shade guide, European Journal of Oral Sciences, 118:311-316, 2010 ("Corcodel")
1016	Borse *et al.*, Tooth shade analysis and selection in prosthodontics: A systematic review and meta-analysis, J Indian Prosthodont Soc, 20:131-40, 2020 ("Borse")
1017	Baltzer *et al.*, The Determination of the Tooth Colors, Quintessenz Zahntechnik, 30(7):726-740, 2004 ("Baltzer")
1018	Declaration of Dr. James L. Mullins ("Mullins Decl.")
1019	*Curriculum Vitae* of Dr. James L. Mullins
1020	*Curriculum Vitae* of Dr. Ioannis A. Kakadiaris
1021	Lagouvardos *et al.*, Repeatability and Interdevice Reliability of Two Portable Color Selection Devices in Matching and Measuring Tooth Color, J. Prosthetic Dentistry (2007) ("Lagouvardos")
1022	Ishikawa-Nagai *et al.*, Reproducibility of Tooth Color Gradation Using A Computer Color-Matching Technique Applied to Ceramic Restorations, J. Prosthetic Dentistry (2005) ("Ishikawa-Nagai")
1023	Tung *et al.*, The Repeatability of an Intraoral Dental Colorimeter, J. Prosthetic Dentistry (2002) ("Tung")
1105	U.S Patent No. 7,698,068 ("Babayoff")
1106	Chu *et al.*, "Dental Color Matching Instruments and Systems. Review of Clinical and Research Aspects," Journal of Dentistry, 38 Supp 2:e2-16, 2010 ("Chu")
1107	U.S. Patent Publication No. 2005/0074718 ("Graham")

1108	WIPO Patent Publication No. 2010/145669 (“Fisker”)
1109	U.S. Patent Application Publication No. 2010/0201986 (“Inglese”)
1110	U.S. Patent No. 6,249,616 (“Hashimoto”)
1111	U.S. Patent Application Publication No. 2011/0188726 (“Nathaniel”)

I. INTRODUCTION

I, Ioannis A. Kakadiaris, Ph.D., resident of Bellaire, Texas, USA, hereby declare as follows:

1. I have been retained by Foley & Lardner, LLP to provide my opinion concerning the validity of U.S. Patent No. 10,695,151 ("the '151 patent," Ex. 1001).

2. I am being compensated for my time by the hour in preparing this declaration, but my compensation is not tied to the outcome of this matter.

II. QUALIFICATIONS

3. In forming the opinions expressed in this Declaration, I have considered and relied upon my education, background, and experience. In addition, I have reviewed and relied upon additional materials in preparation for this Declaration, as described below.

4. My experience and education are detailed in my curriculum vitae ("CV"), a copy of which is provided as Exhibit 1020. My CV also lists publications on which I am a named author.

5. I earned a Bachelor of Science in Physics in 1989 from the University of Athens in Athens, Greece. I earned a Master of Science degree in Computer Science in 1991 from Northeastern University. In 1997, I earned a Doctor of Philosophy degree in Computer Science from the University of Pennsylvania.

6. From 1997 to 2003, I worked for the University of Houston ("UH") as an Assistant Professor in the Department of Computer Science. From 1999 to 2003, I served as an Adjunct Assistant Professor at the School of Biomedical Informatics, University of Texas Health Science Center ("UTHealth"). From 2000 to 2002, I served as an Adjunct Assistant Professor in the Department of Plastic Surgery of the University of Texas M.D. Anderson Cancer Center.

7. From 2003 to 2006, I worked as an Associate Professor in the Department of Computer Science of the University of Houston. I served as an Adjunct Associate Professor of School at the Biomedical Informatics, University of Texas Health Science Center. From 1997 to 2005, I served as the Director of the Visual Computing Lab in the Department of Computer Science, UH.

8. Since 2006, I have served as an Adjunct Professor at the School of Biomedical Informatics, University of Texas Health Science Center. Since 2005, I have served as the Director of the Computational Biomedicine Lab in the Department of Computer Science, University of Houston. In 2008, I served as the Director of Methodist Hospital Research Institute-UH-Weill Cornell Medical College, Institute for Biomedical Imaging Sciences.

9. I have extensive experience teaching the UH Computer Science course 6373 (as detailed in my CV), which teaches principles of imaging/image analysis and from my research publications as described in my CV.

10. I have served and am currently serving an expert witness in four (4) cases involving technology relating to imaging and analysis.

11. I understand that anticipation of a claim requires that every element of a claim is disclosed expressly or inherently in a single prior art reference.

12. I further understand that obviousness must be analyzed from the perspective of a person of ordinary skill in the relevant art (a "POSA") when the invention was made. In analyzing obviousness, I understand that it is important to understand the scope of the claims, the level of skill in the relevant art, the scope and content of the prior art, the differences between the prior art and the claims, and any secondary considerations. I understand that such secondary evidence can include evidence of commercial success caused by an invention, evidence of a long-felt need that was solved by an invention, evidence that others copied an invention, or evidence that an invention achieved a surprising result. I understand that such evidence must have a nexus, or causal relationship to the elements of a claim, to be relevant to the obviousness or non-obviousness of the claim.

13. I also understand that the '151 patent was filed on February 5, 2108, and claims priority to Danish Patent Application No. 2014 70066 ("DK priority document"; Ex. 1007), filed on February 7, 2014 (the "purported Effective Date"). Ex. 1001, '151 patent, Cover. I have analyzed the obviousness in this report as of

the purported Effective Date or somewhat before, understanding that as time passes, the knowledge of a POSA will increase.

14. I understand that under certain circumstances the owner of the '151 patent might try to prove an even earlier date of invention, *i.e.*, earlier than February 7, 2014. If this occurs, I reserve the right to revise my opinion(s). I will refer to the relevant time period as 2014 in this declaration, with the understanding that this does not include the time period on or after the purported Effective Date.

15. I understand claim terms of a patent in IPR shall be construed using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

16. I have reviewed the concepts disclosed in the '151 patent based on the language of the claims, the specification of the '151 patent, and the knowledge of a person of ordinary skill as of the purported Effective Date. I have also reviewed the petition for *inter partes* review.

17. In forming my opinion, I have relied on the '151 patent claims and disclosure, the prosecution history of the '151 patent, the pertinent exhibits to the Petition for *inter partes* review of the '151 patent, my own experience and expertise,

and the knowledge of the person of ordinary skill in the relevant art in the 2014 timeframe.

18. In 2014, I believe that a POSA would have had at least a bachelor's degree in Computer Engineering, Computer Science, Computer Vision, or an equivalent field, as well as at least two years of imaging/image analysis experience, or alternatively, at least six years of comparable industry experience. A POSA would have had experience with and knowledge of 3D imaging systems and 3D modeling techniques.

III. BACKGROUND TO THE '151 PATENT

19. The subject matter of the '151 patent lies primarily in the field of digital image processing and, in particular, digital imaging software. At the time of the invention, the processes claimed in the '151 patent were generally well-known and available for use in image processing applications, including the domain of dentistry, before the filing of the '151 patent.

A. Digital Image Processing

20. We think of images as being either 2-dimensional ("2D") or 3-dimensional ("3D"). 3D images have depth because there is a third coordinate for each image element, typically the object's distance from the sensor. Thus, a digital image can be considered a digital n-dimensional matrix of discrete elements, each of which has a particular value.

21. For any particular digital image, the values associated with a particular element are common values that convey a color value of the location. A color value can be a scalar value, for example 0 to 255, which conveys a grey level in the case of a greyscale image. However, color values can also be conceptualized as an n-dimensional vector of values where each value in the vector indicates the prevalence of a certain color component. Such vectors are commonly implemented as 3-dimensional RGB vectors, where there is a value for the amount of red at the element, a value for the amount of green at the element, and a value for the amount of blue at the element.

22. Digital image processing is a field of study that collects and manipulates digital images and consists of a number of fundamental processes including: image acquisition, image enhancement, image restoration, color image processing, compression, morphological processing, segmentation, representation and description, and recognition. Ex. 1009, Gonzalez, pp. 25-28. These processes are displayed graphically as follows:

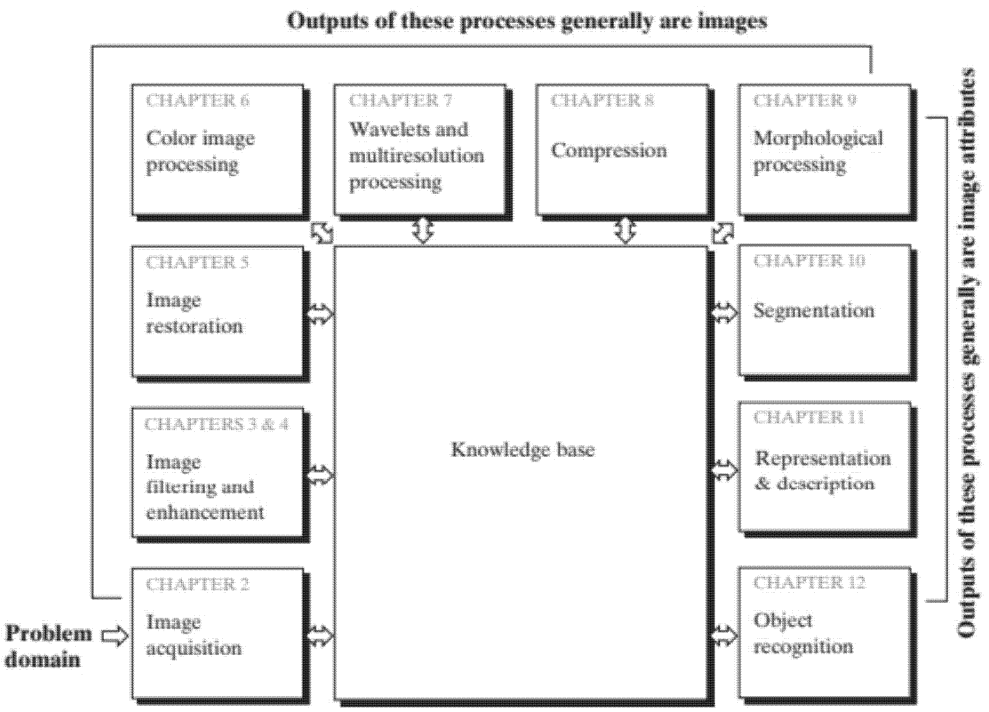


FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

Ex. 1009, Gonzalez, p. 26. The '151 patent involves the steps of image acquisition, image filtering and enhancement, image restoration, color image processing, segmentation, representation and description, and object recognition.

1. Image Acquisition

23. Image acquisition is the acquiring of a digital image. Ex. 1009, Gonzalez, pp. 46-52. In many cases, an image sensor is used to obtain one or more 2D images. *Id.* The process of acquiring images by an image sensor can be thought of as a process for acquiring new images. However, digital images can also be stored and retrieved from a memory device. *Id.*

2. Image Enhancement

24. Image enhancement is the process of making an original image more suitable for a particular application. Ex. 1009, Gonzalez, p. 25. Interpolation, averaging (smoothing), and the general replacement of one value in an image for another value, based on some criteria—usually adjacent or overlapping image values—are examples of image filtering and enhancement.

25. Gonzalez identifies averaging as an example of image enhancement. Gonzalez describes one manner of using averaging to enhance a digital image by determining a location's color value based on the average of a surrounding region of color values, referred to as the location's "neighborhood." This is depicted graphically in Figure 3.1 of Ex. 1009 below:

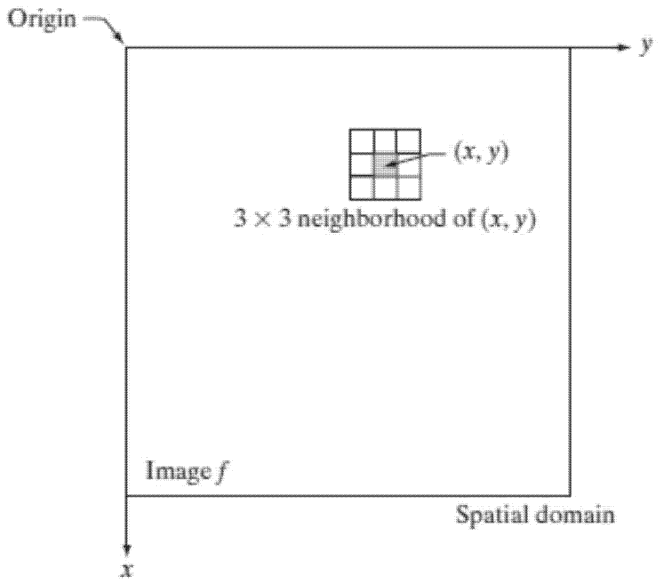


FIGURE 3.1 A 3 × 3 neighborhood about a point (x, y) in an image in the spatial domain. The neighborhood is moved from pixel to pixel in the image to generate an output image.

Gonzalez explains "[t]he process that Fig. 3.1 illustrates consists of moving the origin of the neighborhood from pixel to pixel and applying the operator T to the

pixels in the neighborhood to yield the output at that location. Thus, for any specific location (x, y), the value of the output image g at those coordinates is equal to the result of applying T to the neighborhood with origin at (x, y) in f. For example, suppose that the neighborhood is a square of size and that operator T is defined as 'compute the average intensity of the neighborhood.'" *Id.*, p. 106.

26. In the context of overlapping images, the same basic image processing principles apply, except between two images there is an extra step of determining which pixels or voxels of one image are in the neighborhood of the pixels or voxels of a second image. *See* Ex. 1110, Hashimoto, 6:26-33, 13:1-14; Ex. 1111, Nathaniel, ¶0099.

3. Image Restoration and Reconstruction

27. Image reconstruction is the process of generating a 3D image from two or more 2D images acquired by the image sensor. Ex. 1009, Gonzalez, p. 29; Ex. 1008, Toriwaki, p. 24 (FIG. 2.2). A number of image reconstruction techniques can be used to generate the 3D image. Ex. 1011, Logozzo (surveying and discussing the application of 3D image reconstruction in the field of intraoral scanners); Ex. 1010, Richert (same).

4. Segmentation, Representation and Description, and Recognition

28. In digital image processing it is often necessary to segment different regions of the image based on determined characteristics or attributes. Segmentation,

for example, refers to analyzing attributes of an image to assign a value to each region so one can distinguish between regions. Gonzalez explains, generally, that "[s]egmentation procedures partition an image into its constituent parts or objects." Ex. 1009, Gonzalez, p. 27. Representation and description typically follow segmentation, which usually is raw pixel data constituting either the boundary of a region (i.e., the set of pixels separating one image region from another) or all the points in the region itself. *Id.* Recognition labels a region based on identified properties or attributes of the region. *Id.*

B. Shade Matching in Dentistry

29. 3D image processing is particularly useful in the field of shade matching in dentistry, when the objective is to generate an accurate colorized 3D digital image of a tooth or set of teeth for the purposes of generating a dental restoration or prosthesis. Historically, there are two ways to determine tooth shade: (1) manually, using a visual shade guide, and (2) automatically, using a machine such as an intraoral scanner, typically also using a visual shade guide. Ex. 1016, Borse, pp. 132-33.

30. Determining tooth shade manually involves holding a shade guide having various colored teeth next to a subject tooth to determine which of the teeth the shade guide best matches the subject tooth. *Id.* The VITA 3D-MASTER shade guide system is depicted below.

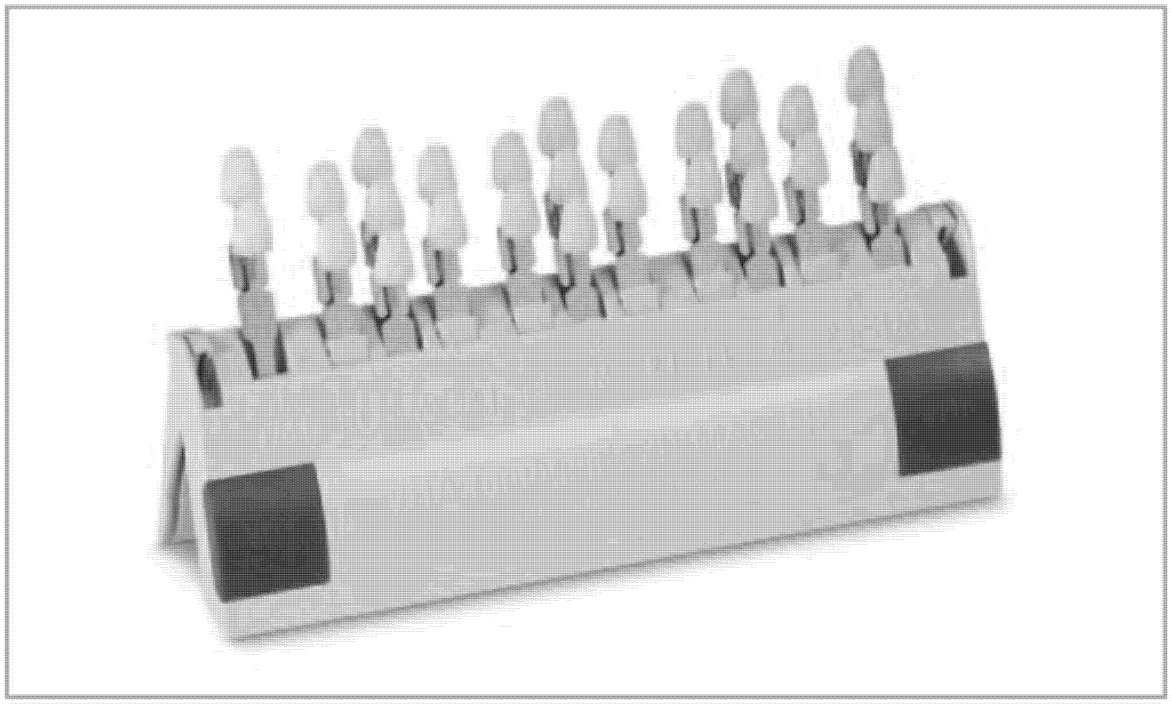


Fig. 14 VITA SYSTEM 3D-MASTER®: The toothguide is divided into five lightness groups. Each lightness group includes a central tooth with six teeth around it for the determination of differences in intensity (chroma) and hue.

Ex. 1017, Baltzer, p. 734.

31. Automatic processes for determining tooth shade use instruments for measuring the color of a tooth and comparing measured results to a standard or reference to determine a match. Ex. 1016, Borse, pp. 132-33; Ex. 1017, Baltzer, pp. 730-32. The results of such a comparison are shown below:

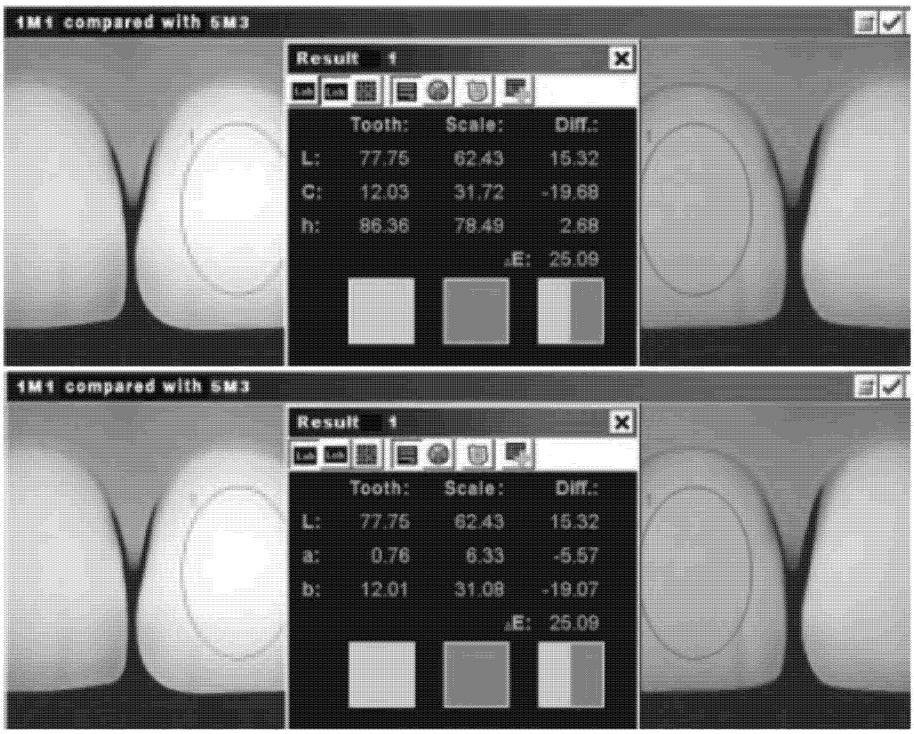


Fig. 9 and 10 L*C*h values resp. L*a*b values of the lightest natural tooth in comparison with the darkest natural tooth. The differences of the L*a*b-values produce the values ΔL = 15.32, Δa = –5.75 and Δb = 19.07. The term ΔE describes the perceived color difference between the two color samples and corresponds to the distance between the two color positions in the color space.

Ex. 1017, Baltzer, p. 732. Ultimately, the goal with either a manual or automatic method of shade matching is to match a patient's tooth to a shade value so that a dental restoration or prosthesis can be made that looks acceptable to a patient.

32. Sometimes, measured color values of a patient's tooth will not have a corresponding shade value in the shade guide being used by the manual or automatic process. In automated processes, the color space of the shade guide can be interpolated. For example, "[c]olor space transformation using a 3D lookup table (LUT) with interpolation [can be] used to correlate the source and destination color values in the lattice points of a 3D table, where non-lattice points are interpolated by using the nearest lattice points." Ex. 1012, Kang, p. 151. In the above, lattice points

correspond to known shade values and non-lattice points correspond to a tooth shade value interpolated from those lattice points.

33. The application of interpolation is well known in the field of dentistry: "if the color characteristics for a patient fall between two shades, some interpolation may be applied to the two shades to produce an additional shade for the patient's tooth that suitably fits the generated color characteristics for that patient." Ex. 1107, Graham, ¶0050.

C. Assessing the Difference in Perception of Shade Match in Dentistry

34. Assessing the difference in perception of a shade match was first a manual process, but it has become automated. The value ΔE is a metric for estimating the perceptual difference of a shade match. The "Δ" symbol represents the difference, and 'E' refers to "Empfindung," which is German for sensation/perception. Ex. 1017, Baltzer, p. 733. ΔE is calculated according to the Pythagorean theorem as discussed further below. *Id.*

35. Computation of perceptual differences is not unique to image processing and more properly falls into the category of general computing and data manipulation. In the field of dentistry, scores can be used to assist dental practitioners in the difficult task of selecting colors for a prosthesis or restoration that a human observer will perceive as natural. *See*, *e.g.*, Ex. 1013, Vadher, p. 78.

36. In summarizing the basics of color in the field of dentistry, Vadher, on a paper on the topic of color in dentistry, explains, "colored restoration or prostheses should impart the translucency and fluorescence of natural dentition, and reproduce the opacity and vitality of natural tooth structure." *Id.* For the purposes of measuring color in dentistry, Vadher explains that the CIELAB (also known as CIE L*a*b* or CIE Lab) color system that was defined in 1976 "supports the accepted theory of color perception based on three separate color receptors in the eye and is currently one of the most popular color spaces." *Id.* at p. 79.

37. Vadher further explains, "[t]he advantage of the CIE Lab system is that color differences can be expressed in units that can be related to visual perception and clinical significance." *Id.*, p. 80. "The tooth color can be represented in many different color spaces, such as the L*C*h* color space representing color in terms of Lightness, Chroma and Hue, or in the L*a*b* color space as described e.g. by Hassel et al. (Hassel 2012) and Dozic et al. (Dozic 2007). The L*a*b* color space has the advantage that it is designed to approximate human vision with the L* component closely matches human perception of lightness." Ex. 1001, '151 patent, 1:32-38; *see generally* Ex. 1021, Lagouvardos, Ex. 1022 Ishikawa-Nagai, Ex. 1023, Tung. The L*C*h* and L*a*b* color spaces use the same diagram, but the L*C*h* space uses cylindrical coordinates rather than rectangular coordinates. *See, e.g.*, https://sensing.konicaminolta.us/us/blog/understanding-the-cie-lch-color-space/. In

the L*a*b* color space, L* indicates lightness (black (0) to white (100)); a* indicates red (+) and green (-); and b* indicates yellow (+) and blue (-). Ex. 1013, Vadher, pp. 79-80; *see generally* Ex. 1021, Lagouvardos, Ex. 1022, Ishikawa-Nagai, Ex. 1023, Tung. In the L*C*h* color space, the letters L*, C*, and h° represent the lightness, chroma, and hue color characteristics. *Cf.*, EX 1023, Tung, pp. 2-3.

38. The question of whether to rely on a machine computed shade values for a dental prosthesis or restoration is complicated because there are differences in the way that humans and machines perceive color, as such "the answer whether to use visual or instrumental method for color matching in dentistry is: whenever if possible, use both, as they complement each other and can lead towards predictable esthetic outcome." Ex. 1106, Chu, p. e7. Nonetheless, as discussed above, there are several metrics by which machines compute the perceptual difference between the measured and the matched values, including ΔE.

39. Douglas, in a paper on the perceptibility of color difference, explains: "The formula used for calculating color differences in this system is: $\Delta E = [(\Delta L^*)^2 + (\Delta a)^2 + (\Delta b^*)^2]^{1/2}$ where ΔL*, Δa*, and Δb* are differences in color parameters for the 2 specimens measured for comparison. Numeric description of color permits precise definition of the magnitude of the color difference between objects—for example, the porcelain color of a metal ceramic crown and the shade tab or tooth to which it is to match." Ex. 1014, Douglas, p. 201 (citations in the paper omitted here).

40. Then, using ΔE to assess perceptual difference, Douglas concluded, "[t]he predicted color difference at which 50% of the dentist observers could perceive a color difference (50/50 perceptibility) was 2.6 ΔE units. The predicted color difference at which 50% of the subjects would remake the restoration due to color mismatch (clinically unacceptable color match) was 5.5 ΔE. Acceptability and perceptibility color tolerances at the 50/50 level were significantly different (P<.05) because their 95% confidence limits did not overlap." *Id.*, pp. 204-05.

41. Similarly, Corcodel in, a paper studying the effects of illuminating light tooth color, implemented a study where, "[p]airs of teeth and tabs for which the colour difference was within a given tolerance were sought. The colour difference was calculated using the Euclidian distance formula for two colour samples: ΔE_{ab} = $((L1^* - L2^*) \times (L1^* - L2^*) + (a1^* - a2^*) \times (a1^* - a2^*) + (b1^* - b2^*) \times (b1^* - b2^*))^{1/2}$. Ex. 1015, Corcodel, p. 312.

IV. THE '151 PATENT

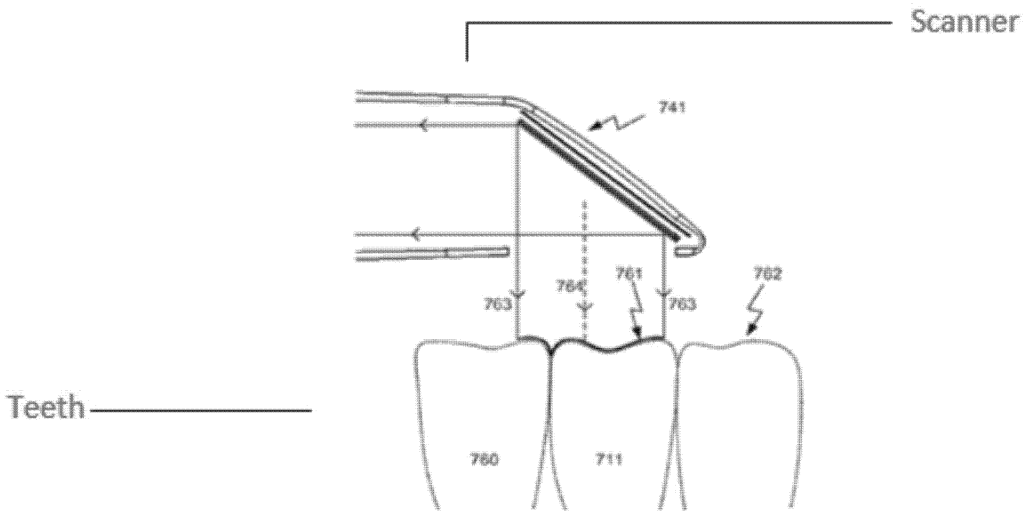
A. Overview

42. The '151 patent discloses methods for automating tooth shade determination by obtaining a 3D representation of the tooth comprising both shape data and texture data.[1] *See, e.g.*, Ex. 1001, '151 patent, 2:6-10. A tooth shade value

[1] According to the '151 patent, tooth shade matching previously had been done manually by a dentist by comparing a shade guide held next to a patient's teeth to determine the appropriate shade for a dental restoration. *Id.*, 1:19-2:2. A technician

is determined for at least one point on the tooth based on the texture data of the corresponding point and known texture values of one or more tooth shade values. *Id.*, 2:11-15. The texture data express the texture of the tooth and can comprise a profile of varying texture across the tooth and is described as at least one of tooth color or surface roughness. *Id.*, 2:32-38. The shape data expresses the shape of the tooth. *Id.*

43. The '151 patent discloses a system where a three-dimensional model of teeth and the texture (*i.e.*, color or shade) of the teeth are determined using an intraoral scanner. *Id.*, 15:52-16:32. Figure 7A illustrates scanning a set of teeth:

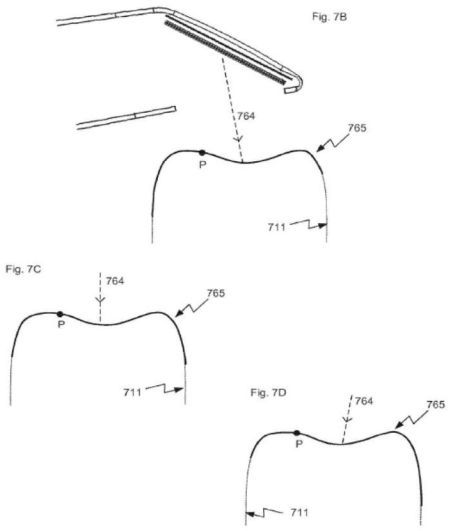


Id., FIG. 7A (annotated), 16:9-13 ("In FIG. 7A the scanner 741 . . . is held in one

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often used pictures of the shade guide comparison taken by the dentist to determine the ceramic to be used to create the dental restoration. *Id.* The '151 patent describes the manual process as "time consuming and inaccurate." *Id.*

position relative to the teeth 711, 760 . . . while recording a sequence of 2D images for one sub-scan."). The field of view or area of the sub-scan is illustrated by line 761 and is bounded at its perimeter by the light rays 763. *Id.*, 16:9-32. As illustrated in Figures 7B-D, sub-scans are a series of scans taken as the scanner is manually moved by the dental practitioner.



Id., FIG. 7B-D, 16:33-51. The line 765 shows the change field of view of the scans (sub-scans). *Id.* The '151 patent further explains that "color information from multiple sub-scans can be interpolated and averaged by methods such as texture weaving, or by simply averaging corresponding color components of the sub scans corresponding to the same point/location on the surface." *Id.*, 16:1-5.

44. When the texture data is tooth color, the texture data may be color data and express a color profile of the tooth. The tooth shade value for a point on the tooth may be derived by comparing the color data of the corresponding point of the digital

3D representation with known color values of one or more reference tooth shade values. *Id.*, 2:39-45, 14:42-67. Describing the process, the '151 patent explains, "the tooth shade values of different points or regions of the teeth are derived from the texture data of the digital 3D representation of the patient's set of teeth . . . the digital restoration design relative to the CAD model of the milling block is then determined . . ., where different criteria can be apply to provide the best fit between the desired shade profile and what actually can be obtained as dictated by the shade profile of the milling block." *Id.*, 14:42-67.

45. Figure 4 below "shows a screen shot 410 where determined tooth shade values are derived for a total of 15 regions on the digital 3D representation of the tooth 411." *Id.*, 14:17-19, FIG. 4.

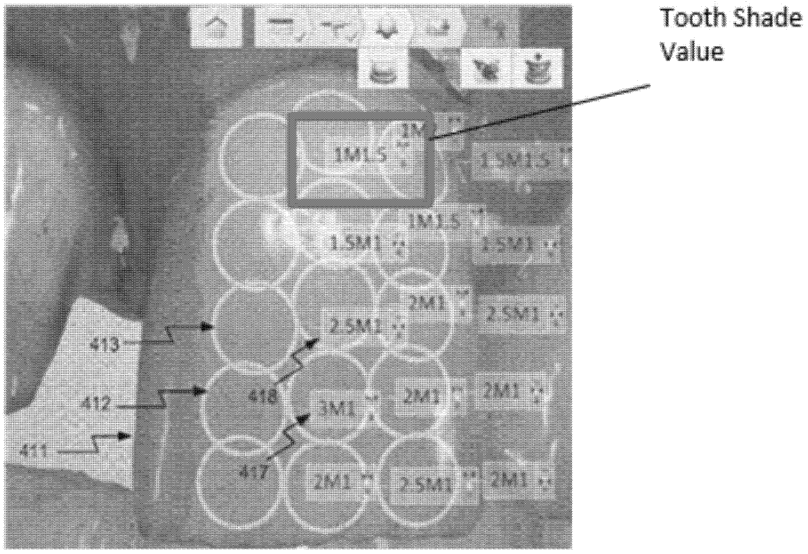


FIG. 4 (annotated).

46. When the texture data comprises color data, the '151 patent explains selecting the tooth shade value of the point can comprise computing the color difference between the determined color data in the point and the color data of the reference tooth shade values. *Id.*, 5:51-54. This difference can, *e.g.*, be calculated as a Euclidian distance in the used color space. *Id.*, 5:54-56. According to the '151 patent, as an example, the Euclidian distance ΔE between two points may be given by the following equation:

$$\Delta E = \sqrt[2]{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

Id., 5:56-64. The '151 patent explains that selecting the tooth shade value can then comprise determining for which of the reference tooth shades the color difference, *i.e.,* the Euclidian distance ΔE is smallest. *Id.*, 5:65-67.

47. The '151 patent explains that a certainty score may be derived by expressing the certainty of the determined shade value. *Id.*, 6:25-27. According to the '151 patent, this provides the advantage that a measure of how accurate the determined value is can be displayed to the operator, preferably when the patient is still at the clinic such that further scanning can be performed if this is required to provide a more precise tooth shade value. *Id.*, 6:28-33.

48. The '151 patent further explains that the Euclidian distance ΔE between the color data to the selected reference tooth shade value can be used in determining

the certainty measure. *Id.*, 7:24-26. If the Euclidian distance ΔE is above a threshold value, the uncertainty is evaluated to be too large. *Id.*, 7:26-28. The patent notes "[t]he color data can here both relate to color data of the point or the average color data for a region surrounding the point." *Id.*, 7:28-30.

49. The '151 patent discloses a user interface for displaying color information to the dentist or operator of a scanner. For example, Figure 3 illustrates regions of a set of teeth labeled with shade values 321 and a certainty score 322. Although the certainty score in this example is graphical (with an indication of high or low certainty), the patent also explains the certainty score can be a mere check mark which indicates that the certainty score is sufficiently good to provide that the derived tooth shade values can be relied on.

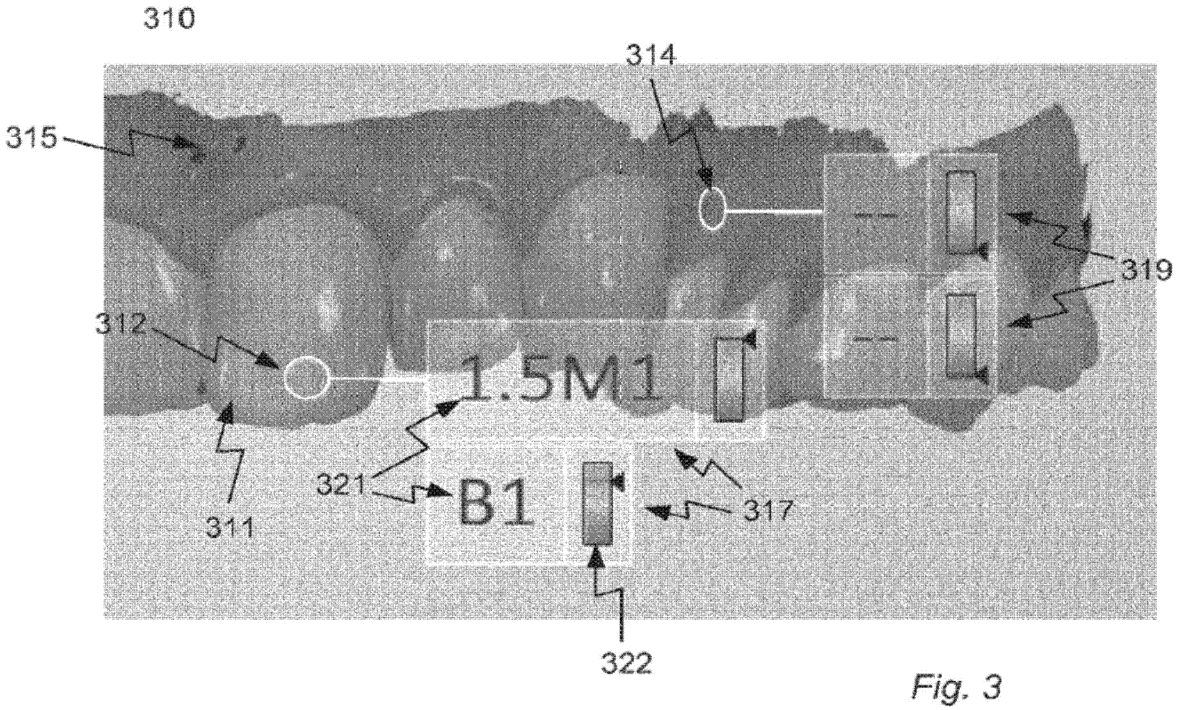


Fig. 3

Id., Fig. 3, 13:51-14:9. The displayed shade values are provided by prior art shade guides. *Id.*, 1:40-50. When the color data is derived for a point on the tooth, the tooth shade value for that point can be determined by comparing the derived color data with the known color data of the reference tooth shade values of a tooth shade guide such as the VITA 3D-Master." *Id.*, 17:13-17.

B. Summary of the Prosecution History of the '151 Patent

50. U.S. Patent Application No. 15/888,764, which was eventually issued as the '151 patent, was filed with 18 original claims. Claim 1 was independent. On September 20, 2019, the examiner issued a non-final Office Action. Ex. 1004, Patent Office Action. Claims 1-18 were rejected under the doctrine of obviousness-type double patenting as being unpatentable over claims 1-18 of U.S. Patent No. 8,998,719 ("the '719 patent") and over claim 1 of the '387 patent. Ex. 1004, Patent Office Action, pp. 2-4. Claims 1-3 and 10-13 were also rejected under 35 U.S.C. §103 as being unpatentable over Quadling (Ex. 1005), and further in view of Liang (Ex. 1006). Ex. 1004, Patent Office Action, p. 4.

51. The examiner asserted that Quadling discloses obtaining a digital 3D representation of the tooth but does not expressly disclose determining a tooth shade value. Ex. 1004, Patent Office Action, pp. 4-5. However, the examiner asserted that Liang is in the same field of endeavor and discloses such a feature. *Id.* Accordingly, the examiner concluded that at the time of the invention, it would have been obvious

to a person of ordinary skill in the art to combine Liang's image data processing system with the Quadling system to achieve a system that determines both color and 3D information of scanned teeth. *Id.* According to the examiner, the suggestion and/or motivation for doing so would have been to obtain tooth shade information. *Id.* Pending claims 4-9 and 14-18 were objected to as being dependent upon a rejected base claim. *Id.*, p. 6.

52. On December 16, 2019, the Applicant amended claim 1 to incorporate the purported allowable subject matter of claim 4, which was directed to "deriving a certainty score expressing the certainty of the determined tooth shade value." Ex. 1002, File History for U.S. Patent No. 10,695,151, p. 44. The Applicant further amended claims 14 and 15 into independent form, suggesting that the examiner felt the distinct features of claims 14 and 15 (issuing as claims 13 and 14) related to generating a "tooth shade profile comprises a one or more tooth shade regions on the tooth surface where an average tooth shade is derived for each region from tooth shade values determined for a number of points within the region" (*Id.*, p. 47), and "recording a series of sub-scans of the tooth, where at least one of said sub-scans comprises both texture information and geometry information for said tooth, and generating the digital 3D representation of the tooth from the recorded series of sub-scans" (*Id.*, p. 47).

V. CLAIM CONSTRUCTION

53. For purposes of this *inter partes* review, I have considered the claim language, specification, and portions of the prosecution history to determine the meaning of the claim language as it would have been understood by a POSA at the time of the invention. I have been advised by counsel that the "plain and ordinary meaning" or *Philips* standard is applied in *inter partes* review, where a claim term is given its plain and ordinary meaning in view of the specification from the viewpoint of a POSA. I have applied the Philips standard in my analysis. Therefore, unless otherwise stated, I have applied the plain and ordinary meaning to claim terms.

VI. OVERVIEW OF GROUNDS AND PRIOR ART

54. Based on my review and analysis of the materials cited herein, my opinions regarding the understanding of a POSA as of February 7, 2014, and my training and experience, it is my opinion that claims of the '151 patent are invalid based on the following grounds:

Grounds	Claims	Statutory Basis	Prior Art
1	1, 2, 6, 7, and 9-15	103	Babayoff and Chu
2	3	103	Babayoff and Chu and Graham
3	15-17	103	Babayoff and Chu and Nathaniel
4	1, 2, 7, and 9-15	103	Babayoff and Inglese

5	3	103	Babayoff and Inglese and Graham
6	15-17	103	Babayoff and Inglese and Nathaniel

A. Overview of Babayoff

55. In procedures relating to manufacturing a dental prosthesis, Babayoff recognizes that it is important to match the color and texture of the prosthesis with the color and texture of the surrounding teeth. Ex. 1105, Babayoff, 2:24-3:49. Babayoff explains that "[t]raditional methods of color matching are based on visual comparison between a removable tooth-shaped color tab of a shade guide, such as, for example Vita, and the surrounding teeth." *Id.* Babayoff describes certain prior art and concludes that 3D structure and local variations in tooth data have not been considered together in the prior art. *Id.*, 2:34-67.

56. Babayoff discloses systems and methods for obtaining geometric and color data of teeth. For example, Babayoff discloses, "[t]he first step of the method according to the present invention relates to providing at least one numerical entity that is representative of the three-dimensional surface geometry and color of at least part of the intra-oral cavity." *Id.*, 7:53-56. Babayoff illustrates in Figure 1 a block diagram of a scanning device for obtaining the geometry and color of teeth. *Id.*, FIG. 1.

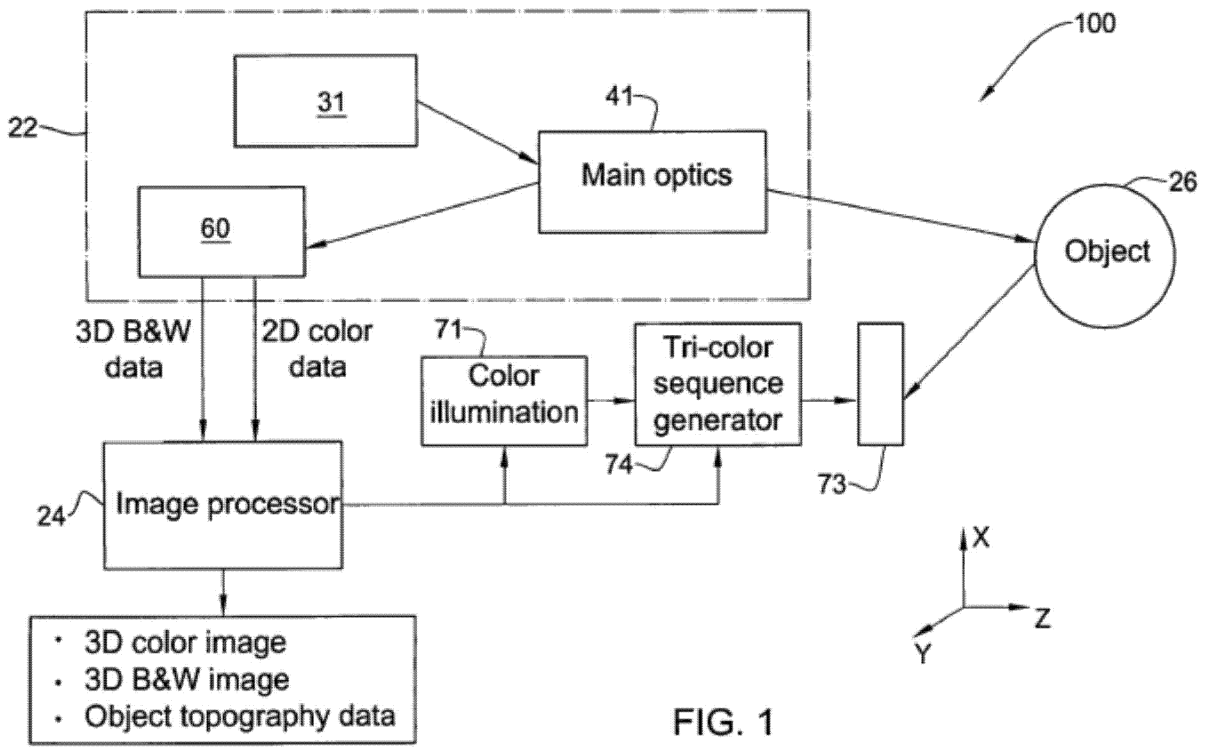


FIG. 1

"Fig. 1 … illustrates the general relationship between the various elements of a device for providing a 3D color numerical entity []". *Id.*, 8:25-28. Babayoff separately explains the acquisition of three-dimensional geometry and color data. *Id.*, 8:30-56.

57. Figure 2C of Babayoff illustrates the algebraic manipulation of geometry and color entities to form a new entity I[X, Y, Z, C] with both color and 3D geometric information. *Id.*, FIG. 2C.

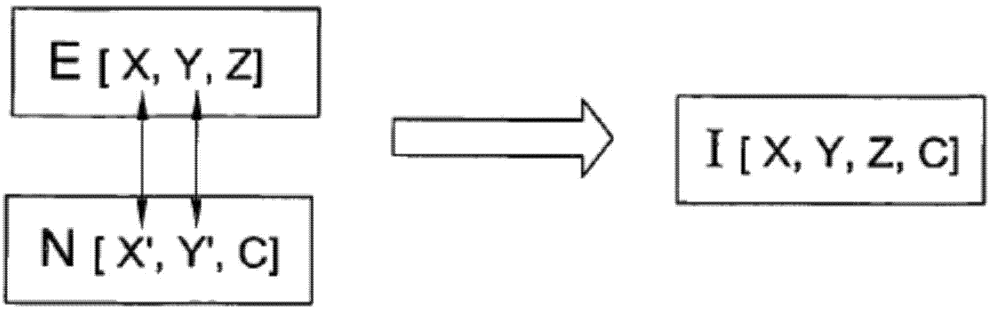


FIG. 2C

58. Babayoff explains, "[t]he 2D color image thus corresponds to another entity N comprised of the location and color value of each pixel forming this image, (X', Y', C). The X-Y coordinates of the pixels are on a plane substantially parallel to the X-Y plane of the entity E . . . [the] similar X-Y and X'-Y' coordinates in the entities E and N, respectively, will substantially represent the same part of the object 26. Accordingly, the color value C of each pixel of entity N can be mapped to the data point of entity E having X-Y coordinates that are the same as the X-Y coordinates of the pixel, whereby to create another entity I comprising surface coordinate and color data (X, Y, Z, C), as illustrated in FIG. 2C." *Id.*, 9:12-32.

59. One objective of Babayoff is to provide a color map for a dental prosthesis. Babayoff summarizes a method to achieve this goal in Figure 17. *Id.*, FIG. 17; *Id.*, 26:8-30.

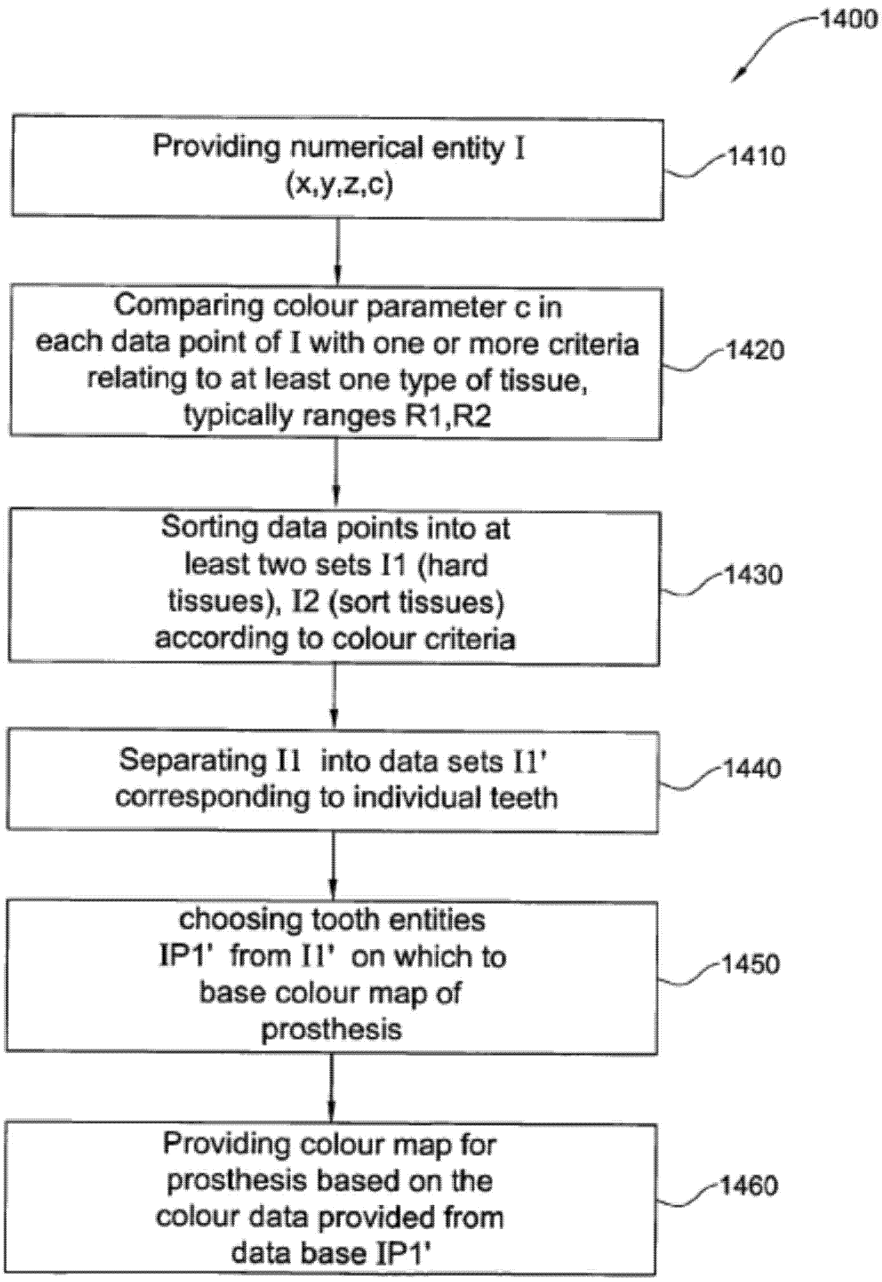


FIG. 17

The determined color map provides shade values for the dental prosthesis based on measured color values and known texture values from other teeth. *Id.*, 21:23-22:33. As illustrated in Figure 19, the shade information is transformed into a model to be sent for the purpose of fabricating a dental prosthesis. *Id.*, FIG. 19.

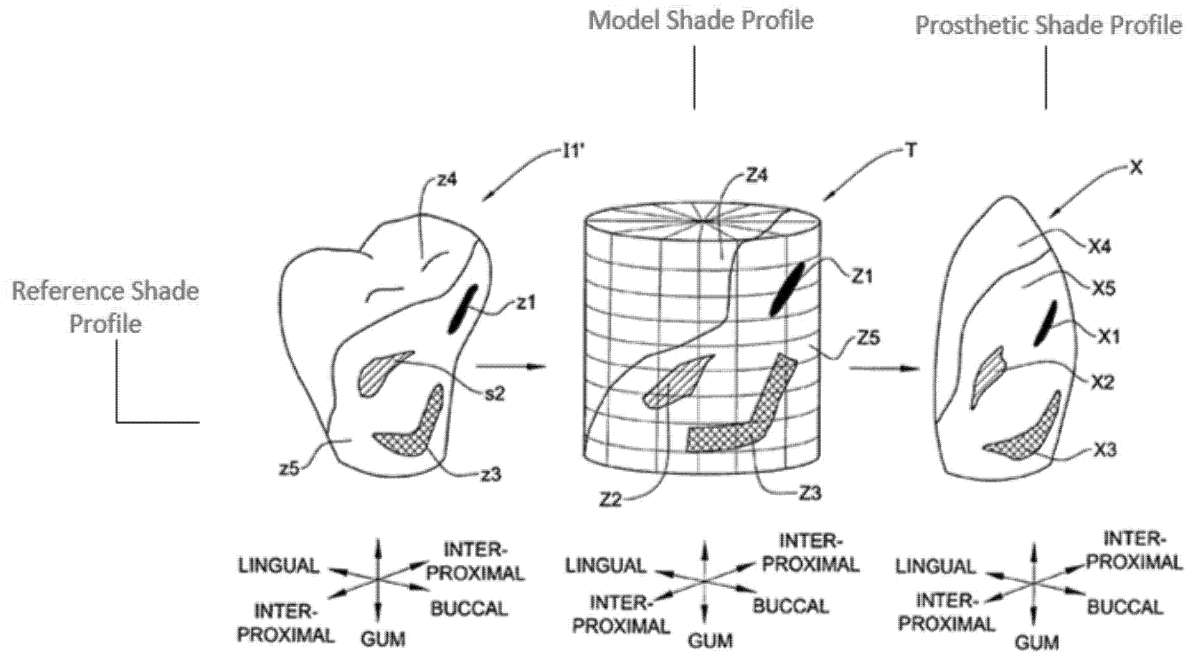


FIG. 19

Id., FIG. 19 (annotated). "The entity X thus comprises the surface geometry of the prosthesis, and the shading information with respect to this geometry, including features x1-x5 transferred from features Z1-Z5 respectively, that will provide a similar appearance to that of the tooth on which the color was modelled." *Id.*, 27:19-25.

60. Babayoff discloses a number of methods for smoothing out the color values of entity X to enhance its appearance. For example, Babayoff discloses, "the tooth may be divided into three general zones: a gingival zone close to the gums, an intermediate body zone, and an incisal zone comprising the cusp of the tooth. The

colors can be mapped into each of the zones independently, and then smoothed out between the zones to avoid sharp discontinuities in color." *Id.*, 27:33-38.

61. Babayoff further discloses that a "weighted average of the colors could be provided, wherein more weight is given to teeth that are closest in location and/or function than to other teeth. Again, when such a combination of the color information is effected, it is important to ensure that the various entities T are aligned with respect to the individual interproximal, buccal and lingual sides." *Id.*, 27:47-53.

B. Overview of Chu

62. Chu, published in 2010, is titled "Dental color matching instruments and systems. Review of clinical and research aspects." Ex. 1106, Chu, p. e2. Chu explains that spectrophotometers, colorimeters, and imaging systems are useful and relevant tools for tooth color measurement and analysis—including indirect restorations, communication for indirect restorations, reproduction and verification of shade, and for quality control of color reproduction. *Id.*, p. e2. Chu explains that "[t]he interest in color research in dentistry has increased significantly over the past several decades." *Id.* Chu "provide a comprehensive review of the current state of shade-matching technologies and instrumentation, and their clinical and research application." *Id.*

63. Chu explains that, at the time of publication, the most common manner of shade-matching was visual, using shade guides, including the empirical-based

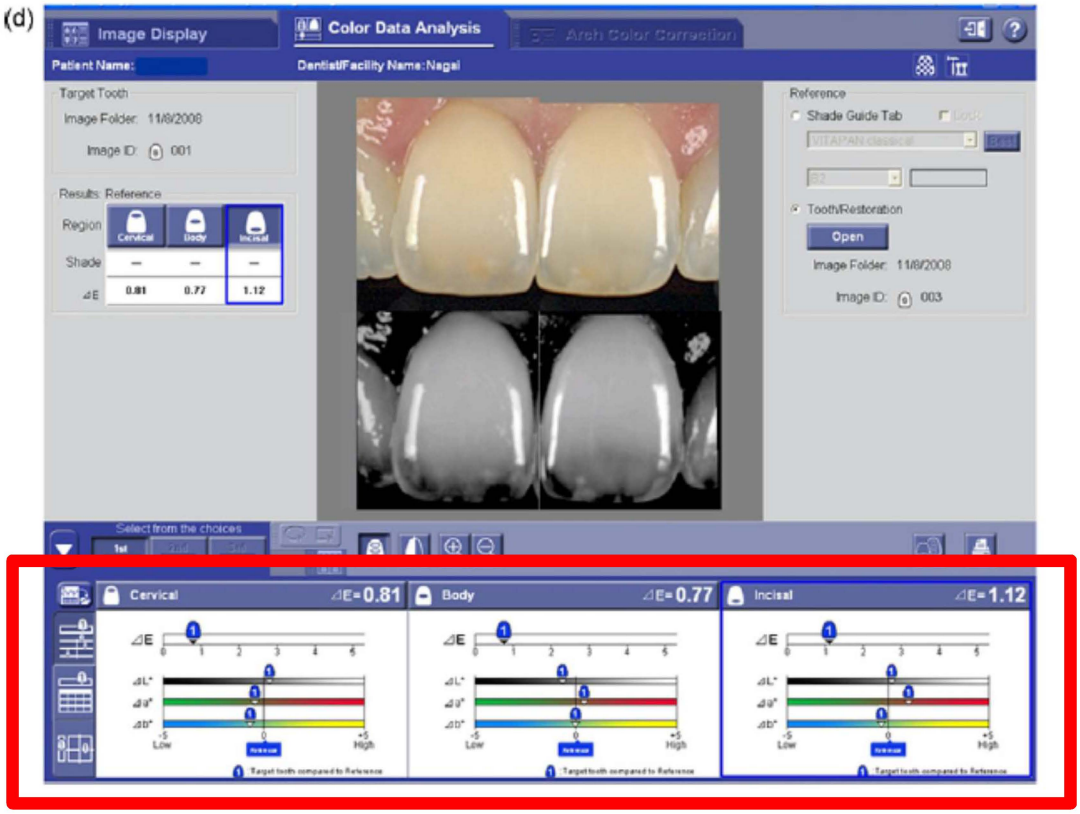
Vita chart. *Id.* Chu explains, however, that instruments for clinical shade-matching also exist, including spectrophotometers, colorimeters, and imaging systems. *Id.*, p. *e3.* Chu further explains that such dental shade-matching instruments have been brought to market to reduce or overcome imperfections and inconsistencies of traditional shade-matching. *Id.*, p. e3.

64. Chu surveys commercially available spectrophotometers, colorimeters, and imaging systems. With respect to spectrophotometers, Chu refers to Olympus' *Crystaleye* product as one example and states that "[t]hrough the development of optical and image processing technology, this product allows the practitioner to match tooth shade and color more accurately and simply," further noting "'virtual shade tabs' in the computer database can be cross-referenced and superimposed visually onto the natural tooth image to be matched giving the technician the ability to visualize the correct shade tabs." *Id.*, p. e4. With respect to colorimeters, Chu refers to X-Rite's *ShadeVision* product and notes that a complete tooth image is provided through the use of three separate gingival, middle, and incisal databases. *Id.* Lastly, with respect to imaging systems, Chu refers to Smart Technology's *ClearMatch* product, and states the system "uses high-resolution digital images and compares shades over the entire tooth with known reference shades," further noting the product "contains the color database of industry-standard shade guides." *Id.*

65. Chu explains that the aforementioned Complete Tooth Surface Measurement [CTSM] devices "give a color map of the gingival, body and incisal shades for the fabrication of direct or indirect restorations." *Id.* Chu notes that spectrophotometers, such as *CrystalEye* "provide shade tab designation and the respective ΔE* values compared to shade tab values in memory." *Id.* Chu explains that a shortcoming of such devices is that they "average out" color data over the complete tooth surface, which can lead to inaccuracies. *Id.* Accordingly, Chu teaches that limited area measurement devices providing 3-5 mm diameter areas should be applied to several areas to obtain a representative evaluation of tooth shade, recommending at least three measurements—one in each of the gingival, body, and incisal areas of the tooth. *Id.*

66. Chu recognizes that dental color measuring instruments are increasingly used in research, frequently associated with the valuation of measurement uncertainties, comparison between visual and instrument findings, visual color thresholds and evaluation of color compatibility, stability, and interactions of human hard and soft oral tissues, head and neck tissues and dental materials. *Id.*, p. e5. In at least this respect, Chu recognized the problem of reliability in automated tooth shade matching, noting, "[p]recision and accuracy of these systems are influenced by the quality of the camera and image processing method." *Id.*

67. Chu explains that "all 'objective' color measuring instruments have been developed based on the 'standard observer' and they are good only if they match that response." *Id.*, p. e7. Chu explains that ΔE* values are used to mathematically determine how well a shade will match a measured tooth color. *Id.* For example, Figure 1 depicts a clinical application of the *CrystalEye* device, with Figure 1(d), in particular, noting "[c]olor difference ΔEs obtained in all 3 areas are considered to be excellent color match." *Id.*, p. e6 (ΔE analysis outlined in red for emphasis).

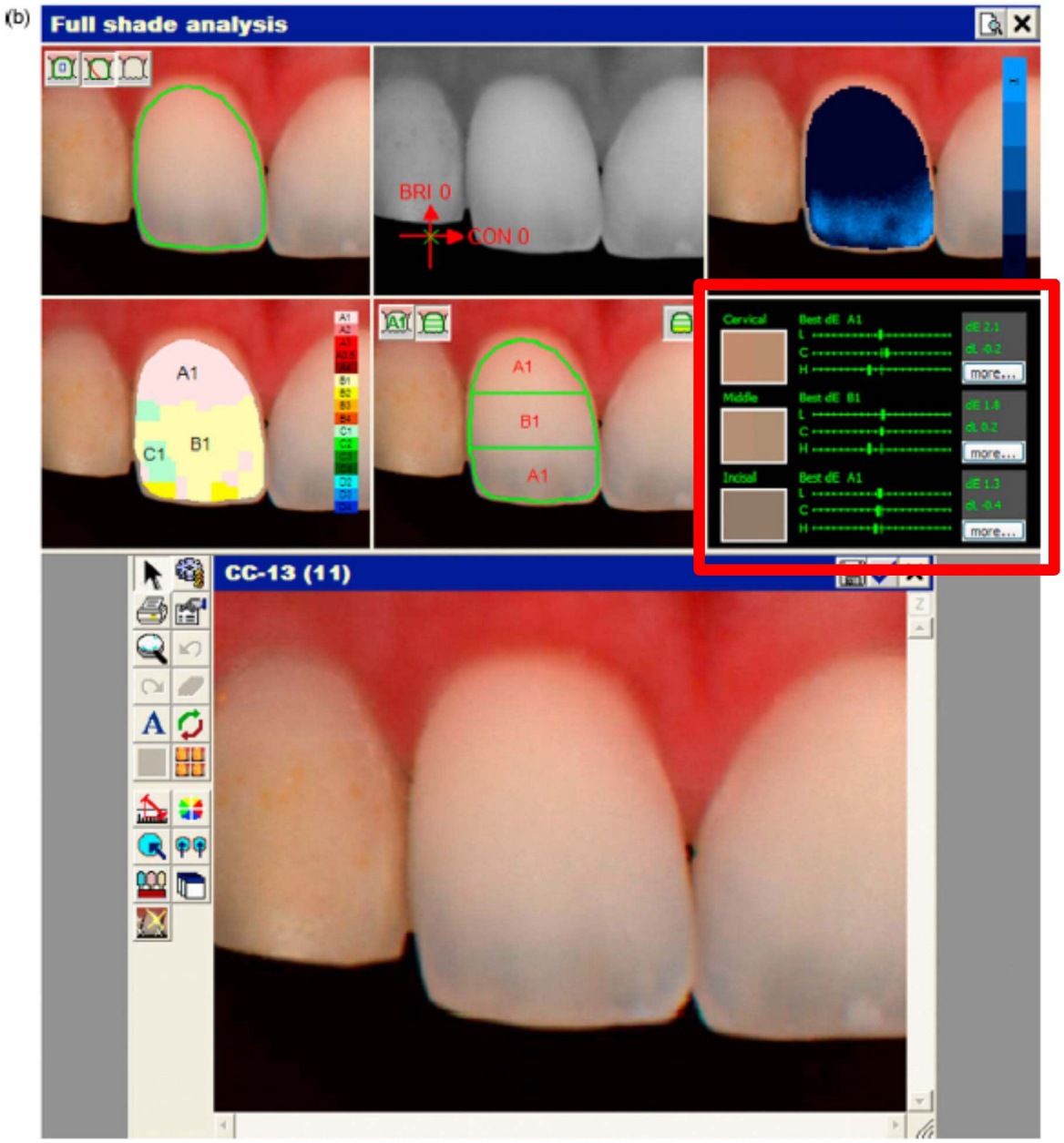


68. Addressing the evaluation of visual color thresholds, Chu explains that "[p]erceptability and acceptability visual thresholds can be quantified only by

combining visual and instrumental color measurement methods." *Id.* With respect to perceptibility thresholds, Chu explains, "[w]hen the color difference between compared objects can be seen by 50% of observers (the other 50% will notice no difference), we are talking about the 50:50% perceptibility threshold." *Id.* With respect to acceptability threshold, Chu explains, ["w]hen the color difference is considered acceptable [to] 50% of observers (the other 50% would consider it unacceptable), this corresponds to 50:50% acceptability threshold." *Id.* Chu concludes that a color match in dentistry is a color difference at or below the 50:50% perceptibility threshold and an acceptable color match is at or below the 50:50% acceptability threshold. *Id.* Chu explains that in dental literature, a ΔE* of 1 is the 50:50 perceptibility threshold under controlled conditions. A ΔE* of 2.7 and 3.3 were found to be 50:50 acceptability thresholds (50% of observers will accept the restoration and 50% will replace it because of color mismatch). *Id.*

69. In addition to providing screenshots from the clinical application of the *CrystalEye* spectrophotometer in shade matching analysis in Figure 1, Chu refers to the clinical application of the *SpectroShade* Micro spectrophotometer used in shade matching analysis. As shown in Figure 5(b) below, Chu explains "[t]he SpectroShade Micro system creates a color map which can be converted to several shade guide systems, this being the Classic Vita Shade Guide. It provides either an overall shade or the shade can be broken down into three distinct areas, cervical,

middle and incisal, and provides detailed shade information in each of these areas and will provide a mathematical analysis resulting in a ΔE* value."



Id., FIG. 5(b), p. e10 (ΔE* analysis outlined in red for emphasis).

C. Overview of Inglese

70. Inglese is titled "Equipment and Method for Measuring Dental Shade" and provides a manner of measuring dental shade by mapping measured color signals in three-dimensional shade space alongside reference tooth shade color values and selecting proximate reference tooth shades for the prosthesis. Figure 5 illustrates Inglese's method, with an accompanying explanation that "[t]he reference 200 designates one point of the shade space. The coordinates of the point in the dimensions of the shade space are symbolized by dotted line projections on the R, G, B dimension axes." Ex. 1109, Inglese, ¶0081.

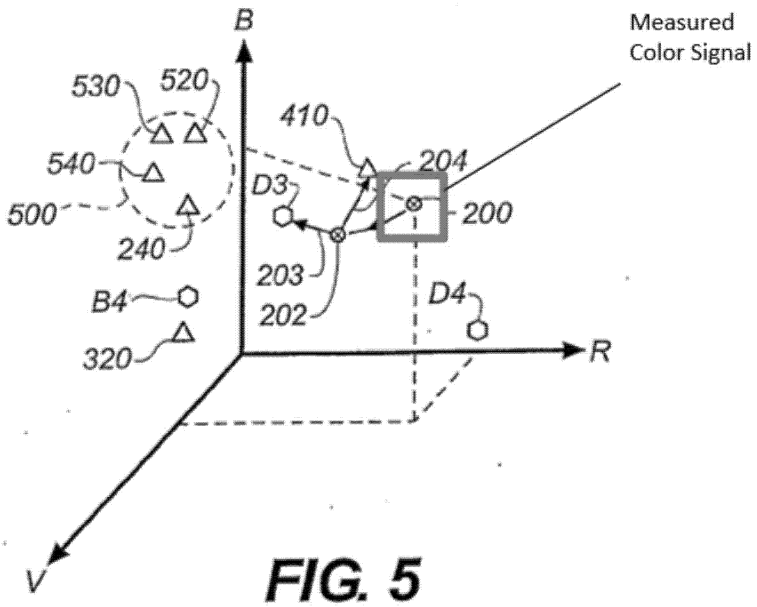


FIG. 5

71. Inglese further explains, "[t]he reference 202 designates a new point of the shade space whose coordinates are established by correcting the coordinates of the initial measurement point 200." *Id,* ¶0082. Inglese continues: "Also shown in the

shade space are the reference points 320, 410, 540. These are shown as small triangles. They correspond to the known values of a first dental shade guide. The coordinates of these points can be acquired by the measuring instrument in a learning phase or be programmed. Another set of reference points B4, D3, D4, shown by small hexagons, corresponds to the shades of a second dental shade guide." *Id.*, ¶0084. Inglese explains that "[t]he reference point closest to the measurement point, possibly corrected, is sought to establish the shade of the relevant tooth part." *Id.*, ¶0085.

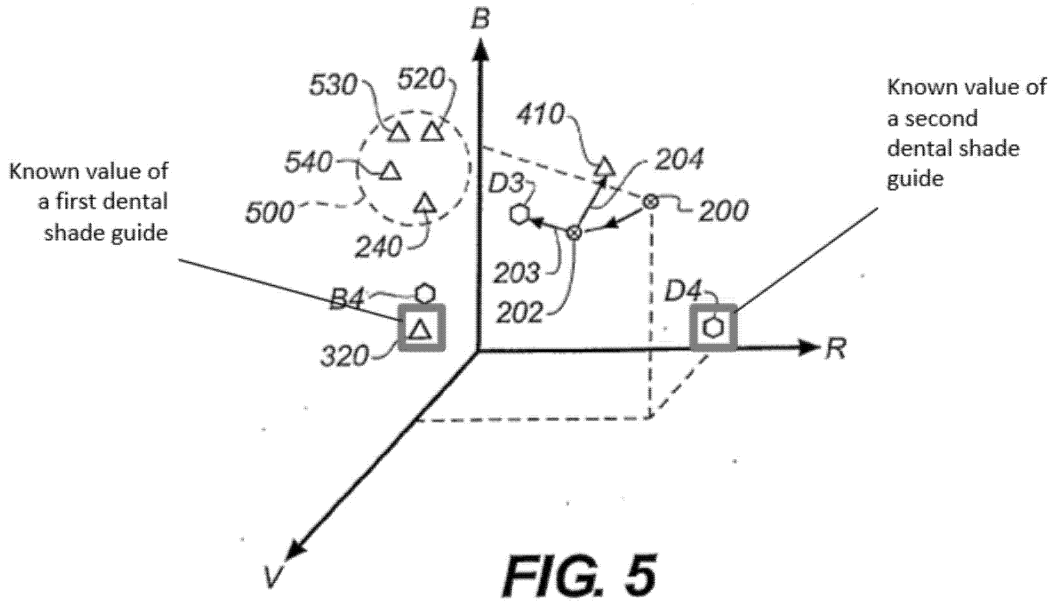


FIG. 5

72. Inglese notes "that the measurement point does not exactly coincide with the reference points. A correction vector 203, 204, of the shade space, pointing from the measurement point to the reference point, indicates the distance and

direction of the gap present between the measurement point and the selected reference point." *Id.*, ¶0086. Inglese explains that, "[d]ata representative of the length and direction of the correction vector can be displayed with the shade, on a control screen or dedicated display." *Id.*

D. Overview of Graham

73. Graham is titled, "Tooth Shade Scan System and Method." Graham summarizes the invention explaining: "a tooth shade scan system is provided that identifies tooth shades for a patient's tooth. An electronic database of tooth shade information for a shade guide may be stored. The database may include shade information based on tooth regions (*e.g.,* the incisal, central, and cervical). . . . An application running on the system may display dividers that the operator can manipulate to divide the image of the patient's tooth into regions. The regions may correspond to regions for which specific tooth shade information is available in the database." Ex. 1107, Graham, Abstract. The tooth shade analysis tool of Graham may identify tooth shades by region, rather than by pixel or by tooth as a whole. *Id.*, ¶0036. For example, the regions may be the cervical, incisal, and central tooth regions, and the color characteristics for each region (*e.g.*, RGB average values for each region) may be generated. *See id.*, FIG. 5, ¶¶0036, 0047.

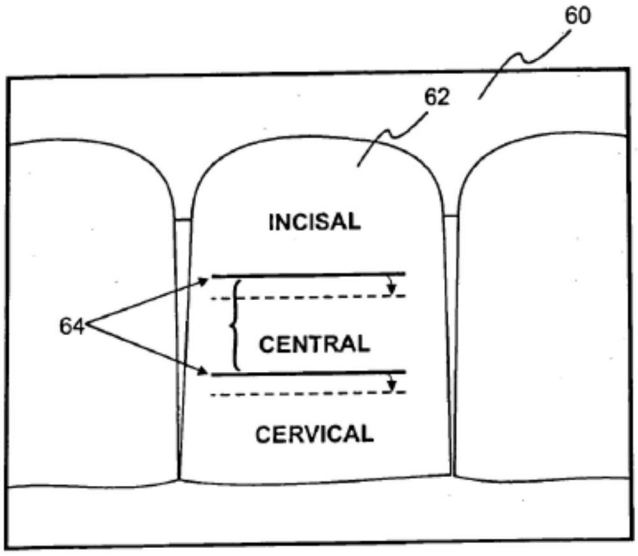


Fig. 5

74. The color characteristic value generated for a tooth (*e.g.*, table 70) may be compared to the database (*e.g.*, table 72) to identify appropriate shades of the region. *See id.*, FIG. 6, ¶¶0047-0051. To improve shade matching, Graham discloses, "if the color characteristics for a patient fall between two shades, some of interpolation may be applied to the two shades to produce an additional shade for the patient's tooth that suitably fits the generated color characteristics for that patient." *Id.*, ¶0050.

E. Overview of Nathaniel

75. Nathaniel discloses a method of combining multiple images into one panoramic image. *See* Ex. 1111, Nathaniel, Abstract. Figures 8A-D illustrate the combination of overlapping images: Ex. 1111, Nathaniel, FIGS. 8A-D.

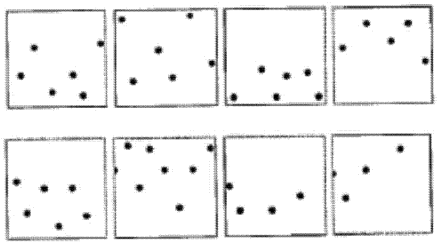


Fig. 8A

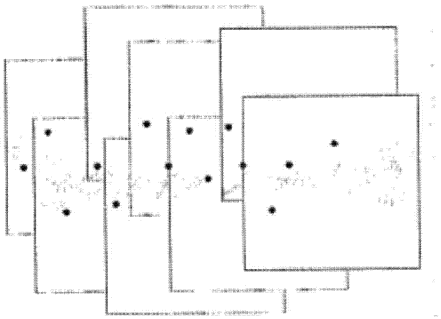


Fig. 8B

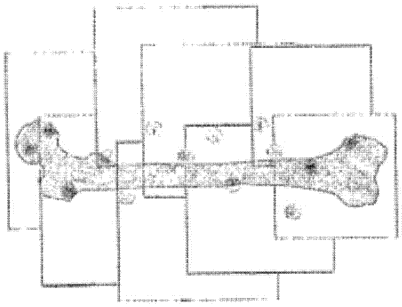


Fig. 8C

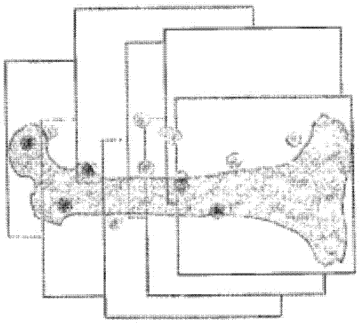


Fig. 8D

76. Nathaniel explains that the "generation of panoramic images requires three distinct steps: 1) correcting the distortion of each single image, generally caused by the optical system, 2) alignment and stitching of the individual images and 3) composing the final panoramic image." *Id.*, ¶0005. Nathaniel further explains the panoramic image reconstruction as follows: "Panoramic image construction: After alignment of the separate X-ray images, and adjusting them for their

magnification ratio, the system constructs the resulting panoramic image by selecting or composing, for each pixel in the resulting image, a value from the appropriate pixels in the appropriate X-ray images. If such appropriate pixel occurs in more than one X-ray image, the preferred embodiment of the invention uses the pixel which is closest to the center in its original X-ray image in order to minimize image distortion. For this pixel, the X-rays are closest to perpendicular to the imaging surface. Other embodiments may use an average value of the original pixels, a weighted average, the maximal or minimal gray level value, or any other decision rule." *Id*., ¶0099.

VII. INVALIDITY OF THE '151 PATENT

A. Ground 1: Claims 1-2, 6, 7, and 9-14 Are Obvious Over Babayoff and Chu

1. Claim 1

[preamble] "1. A method for determining shade of a patient's tooth, wherein the method comprises:"

77. In my opinion, Babayoff discloses "[a] method for determining shade of a patient's tooth." Babayoff discloses, "[a] method for providing data useful in procedures associated with the oral cavity, in which at least one numerical entity representative of the three-dimensional surface geometry and color of at least part of the intra-oral cavity is provided and then manipulated to provide desired data therefrom." Ex. 1105, Babayoff, Abstract. This comprises determination of shade: "For example, the color range R1 for the teeth will include values for c typically

associated with the hard tissues including the teeth, comprising all appropriate shades appropriate for enamel, dentine, pulp and other parts of teeth." *See, e.g.*, *Id.*, 21:28-32.

"obtaining a digital 3D representation of the tooth, where the digital 3D representation comprises shape data and texture data for the tooth;"

78. In my opinion, Babayoff discloses these limitations of claim 1. Babayoff discloses obtaining a digital 3D representation of the tooth. Babayoff explains that the first step of its invention "relates to providing at least one numerical entity that is representative of the three-dimensional surface geometry and color of at least part of the intra-oral cavity." Ex. 1105, Babayoff, 7:54-56. The numerical entity is thus typically at least four-dimensional; three of the independent variables relate to spatial coordinates of a surface (typically defined along orthogonal axes), and the fourth variable refers to a color parameter that is expressed numerically and associated with the spatial coordinates. *Id.*, 7:57-67. Thus, "the numerical entity may comprise a data set of a plurality of 4-dimensional arrays—(x, y, z, c), wherein each array represents the x, y, z geometrical coordinates and the color c of a point on a surface within the intra-oral cavity." *Id.*, 8:9-12. Babayoff further explains that any suitable means may be used to provide the numerical entity, *e.g.*, "a three-dimensional surface scanner with color capabilities may be used." *Id.*, 8:13-22 ("Advantageously, such a scanner makes use of confocal imaging for providing an accurate three-dimensional representation of the target surface within the intra-oral

cavity. Color values are then added to each data point of this data set by obtaining a two-dimensional color image of the target surface, and then mapping the color values of the two-dimensional image onto the three-dimensional 'image.'"); *see also Id.*, 8:30-44, 8:57-9:32, FIGS. 1, 2A, 2B, 2C. Color values may be the independent prime color variables relating to the red, blue, and green (RGB) components associated with the color parameter, or may be expressed, *e.g.*, in terms of hue, saturation and intensity, or any other optical property of teeth including parameters that provide a measure of internal reflectance and translucency. *Id.*, 7:65-8:8.

79. The digital 3D representation of the tooth in Babayoff comprises of shape data and texture data for the tooth, since texture data includes color data. Ex. 1001, '151 patent, 2:37-38. With respect to shape data, Babayoff discloses, "[t]he device 100 comprises a main illumination source 31 for illuminating the object of interest 26, typically a part of the intraoral cavity, and is optically coupled to main optics 41 to provide depth Z values for an arrange range of X-Y points . . . along the surface of the object." Ex. 1105, Babayoff, 8:30-35. Babayoff further discloses detection optics 60, which receives image data from the main optics 41 and the image processor 24 to determine the depth Z values for each X-Y point illuminated on the object 26. *Id.*, 8:35-42. "In this manner, a manipulable three-dimensional numerical entity E comprising the surface coordinates of the object 26" is created. *Id.*, 8:42-44. The entity E thus comprises an array of x, y, z points (shape data). With respect to

texture data, Babayoff discloses that a processor 24 aligns the 2D color image with the previously created 3D entity "and then provides color values to this entity by mapping color values to the entity at aligned X-Y points." Ex. 1105, Babayoff, 8:57-62 ("Such alignment is straightforward because both the 3D data and the 2D color data are referenced to the same X-Y frame of reference."). This process is further explained with reference to Figure 3, where Babayoff explains that concurrently with determining the X, Y, Z points of entity E, as discussed above, a 2D color image of the object is taken using the same detection optics 60, resulting in creation of another entity N comprising X' and Y' points and color C. Ex. 1105, Babayoff, 9:3-15. The entity N thus comprises an array of X' and Y' points and color C (texture data). Because the readings are taken simultaneously, the X' and Y' coordinates of N represent the same part of object 26 as the X and Y coordinates of E. Ex. 1105, Babayoff, 9:15-25. The shape data and texture data in Babayoff are combined to form a numerical entity comprising a plurality of 4-dimensional arrays I (*i.e.*, the digital 3D representation). Referring to Figure 2C, Babayoff explains that the color value c of entity N can be mapped to the data point of entity E having the same X-Y coordinates such that another entity I is created comprising surface coordinates x, y, and z and color data c. Ex. 1105, Babayoff, 9:25-32. Babayoff, in my opinion, thus discloses obtaining a digital 3D representation of the tooth (plurality of 4-dimesional

arrays), where the digital 3D representation comprises shape data (X, Y, and Z coordinates) and texture data (color C) for the tooth.

"determining a tooth shade value for at least one point on the tooth based on the texture data of the corresponding point of the digital 3D representation and on known texture values of one or more reference tooth shade values,"

80. In my opinion, Babayoff in combination with Chu satisfies these limitations of claim 1. Babayoff discloses obtaining a digital 3D representation of the tooth, where the digital 3D representation comprises shape data (X, Y, and Z coordinates) and texture data (color C) for the tooth. Babayoff also discloses a manner of determining the shading of a prosthesis using the color C. Ex. 1105, Babayoff, 26:8-27:62. However, to the extent Babayoff does not disclose determining a tooth shade value for at least one point on the tooth based on the texture data of the corresponding point on the digital 3D representation and on known texture values of one or more reference tooth shade values, Chu discloses these limitations. In particular, Chu discloses determining a tooth shade value from a reference shade guide using measured color data and known color values from one or more reference tooth shade guides.

81. In Babayoff, the manner of determining the shading of the prosthesis is based on the shading characteristics of at least one tooth of the patient. *Id.*, 26:8-30. Babayoff explains that after creation of numerical entity I (including shape data X, Y, Z, and texture data color C), shade information for a prosthesis can be obtained

that makes it compatible with surrounding teeth. *Id.*, 26:20-24. The desired shade for the prosthetic is determined according to a set of rules (algorithmically), or manually by the user, and involves choosing one or more teeth of the patient as a reference, referred to as data sets $I_{P1'}$. *Id.*, 26:37-61. The data from these data sets, $I_{P1'}$ are then analyzed and used to create a color map for the prosthesis or restoration. *Id.*, 26:62-27:29; *see also Id.,* FIG. 19.

82. Thus, although Babayoff discloses a manner of determining color data C for a prosthesis based on the color data C of surrounding teeth, it is not apparent that Babayoff discloses determining a tooth shade value for at least one point on the tooth based on the color data C of the corresponding point of the digital 3D representation and on known color values of one or more reference tooth shade values. Chu, however, discloses these limitations.

83. Chu discloses commercially available imaging systems that compare measured color data with reference color data to determine a tooth shade value. Chu states, "[d]ental color matching instruments also provide the information on best matching tabs from different shade guides." Ex. 1106, Chu, p. e5. Chu further states, "Examples of color matching, interpretation and application of shade analysis data are given in Figs. 1-6." *Id.*

84. Figure 1 of Chu portrays clinical application of a CrystalEye spectrophotometer. *Id.*, pp. e6-e7. The "Reference" tooth shade guide and tooth shade value are depicted in Figure 1(d) as follows:

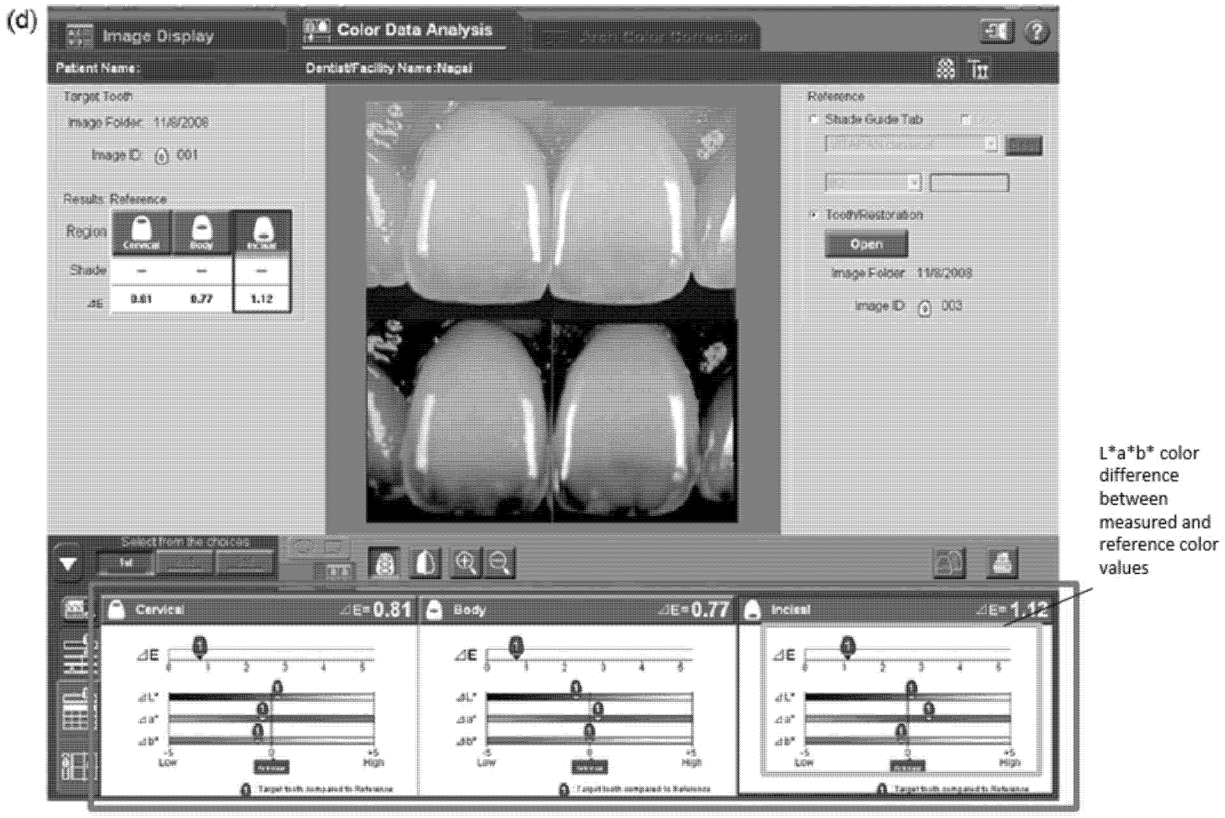


Id., FIG. 1(d) (annotated). In Figure 1(d), the reference shade guide is "VITAPLAN classical" and the reference tooth shade value is "B2." *Id.*

85. Further referring to Figure 1(d), Chu states that "[c]olor difference ΔEs obtained in all 3 areas are considered to be excellent color match." *Id.* The closeness of the match is depicted, in part, by L*a*b* color comparisons between the measured color data and the known color values of the reference tooth shade value. The letters

L*, a*, and b* represent each of the three values of the CIELAB color space used to measure objective color and calculate color differences.

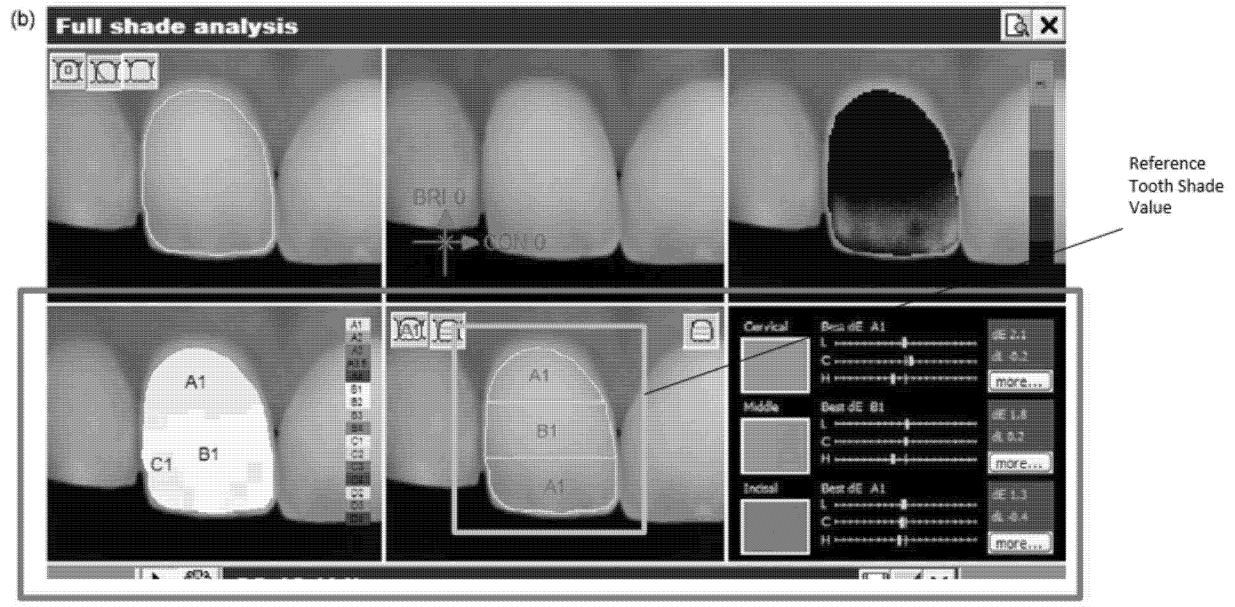
86. This comparison is depicted for cervical, body, and incisal tooth regions in Figure 1(d), as follows:



Ex. 1106, Chu, FIG. 1(d) (annotated).

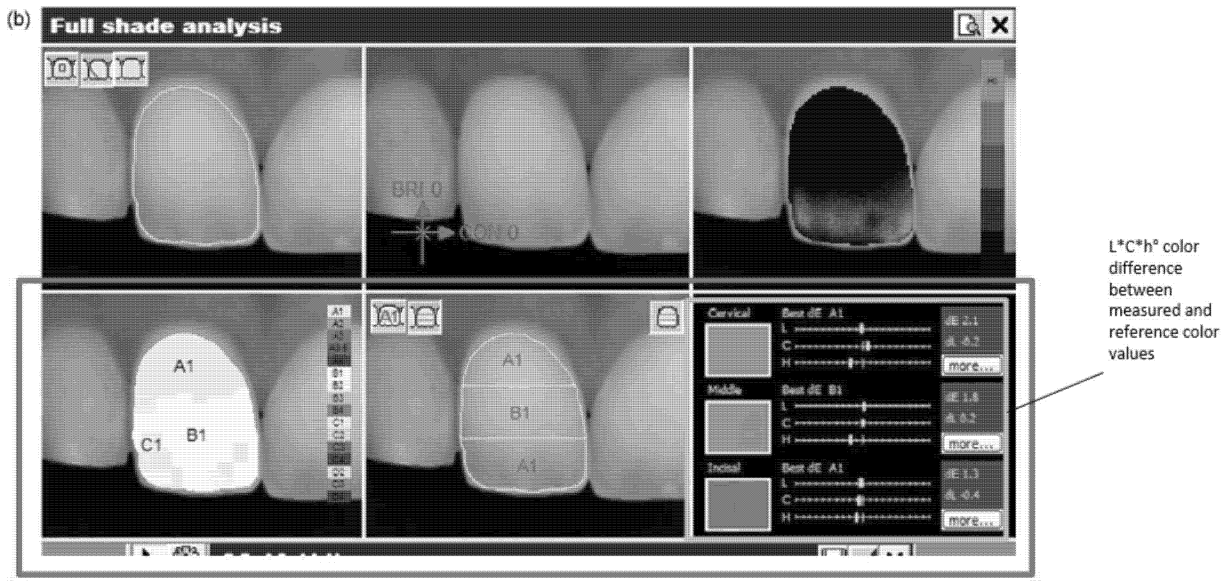
87. Similarly, Figure 5 of Chu portrays clinical application of a SpectroShade Micro spectrophotometer. *Id.*, p. e11. In the figure, a congenitally missing lateral incisor is to be replaced with an implant. *Id.* "The SpectroShade Micro system creates a color map which can be converted to several shade guide systems, this being the Classic Vita Shade Guide. It provides either an overall shade

or the shade can be broken down into three distinct areas, cervical, middle, and incisal . . . ." *Id.* In Figure 5(b), the tooth shade values are depicted as follows:



Id., FIG. 5(b) (annotated).

88. Further referring to Figure 5(b), Chu discloses the "[b]est" ΔE value, which corresponds to the determined tooth shade value. *Id.* In this example, the closeness of the match is depicted by L*C*h° color comparisons between the measured color values and the known color values of the reference tooth shade value. This comparison is depicted for cervical, body, and incisal tooth regions in Figure 5(b), as follows:



Id., FIG. 5(b) (annotated). In Figure 5(b), the reference tooth shade values are A1, and B1, and A1 for the cervical, middle, and incisal regions of the tooth, respectively. *Id.*

89. Because Chu discloses selection of a tooth shade value, *e.g.*, A1, based on a comparison of measured color data with reference color values (expressed in terms of the difference between measured and reference color characteristics L*a*b* or L*C*h°), Chu discloses "determining a tooth shade value for at least one point on the tooth based on the texture data of the corresponding point of the digital 3D representation and on known texture values of one or more reference tooth shade values." *Id.*

90. Chu provides the motivation for determining a tooth shade value for at least one point on the tooth based on the texture data of the corresponding point of

the digital 3D representation and on known texture values of one or more reference tooth shade values by explaining that automated shade matching increases the success of color matching, communication, reproduction, and verification in clinical dentistry, and increases the efficiency of esthetic restorative work. Ex. 1106, Chu, p. e3. Chu further explains that automated shade matching reduces or overcomes imperfections and inconsistencies in traditional shade matching, which is subject to "innate difficulties," including metamerism; suboptimal color matching conditions, tools, and method; as well as the practitioner's age, fatigue, mood, and drugs/medications. *Id.* Chu explains that although the human eye can discern small color differences, the ability to communicate the degree and nature of these differences is lacking in traditional visual comparison. *Id.* Thus, Chu concludes, "[t]he answer whether to use visual or instrumental method for color matching in dentistry is: whenever if possible, use both, as they complement each other and can lead towards predictable esthetic outcome." Ex. 1106, Chu, p. e7.

91. Although Babayoff discloses algorithmically determining tooth color based on surrounding teeth it still requires visual comparison with a reference shade guide to determine a tooth shade value. A POSA, therefore, would have been motivated to replace the shade matching function of Babayoff with the shade matching function of Chu to create an in intraoral scanner that automatically determines a tooth shade value using the color data of the corresponding point of the

digital 3D representation and on known color values of one or more reference tooth shade values. Doing so achieves the improvements described above.

92. A POSA would have expected such a combination to work for its intended purpose because Chu describes prior art imaging systems capable of determining tooth shade values from measured color data and known color values of one or more reference tooth shade values as discussed *supra*. For example, Chu identifies a *Crystaleye* product, and states, "[t]hrough the development of optical and image processing technology, this product allows the practitioner to match tooth shade and color more accurately and simply," further noting "'virtual shade tabs' in the computer database can be cross-referenced and superimposed visually onto the natural tooth image to be matched giving the technician the ability to visualize the correct shade tabs." *Id.*, p. e4. Chu also identifies a *ClearMatch* product and states the system "uses high-resolution digital images and compares shades over the entire tooth with known reference shades," further noting the product "contains the color database of industry-standard shade guides." *Id.*, p. e4. Chu explains that these CTSM devices "give a color map of the gingival, body and incisal shades for the fabrication of direct or indirect restorations." *Id.,* p. e4. Chu notes that spectrophotometers, such as *CrystalEye*, "provide shade tab designation and the respective ΔE values compared to shade tab values in memory." *Id.* Chu thus discloses that the determined tooth shade value could be based on comparison of the

color data determined from the scanned teeth with the color values corresponding to tooth shades available from an "industry-standard shade guide" or "shade tab values in memory." *Id.,* p. e4. Thus, rather than compare the measured texture values to the measured texture values of reference teeth and manually selecting a tooth shade value, as taught by Babayoff, Chu teaches automatically comparing the color data to known color values of reference tooth shade values from a shade guide. A POSA would have understood how to implement the matching function of Chu. As an initial matter, the '151 patent itself is written with the understanding that a POSA would understand how to perform algorithmic matching functions since no specific function is provided in the specification. Indeed, it was well known at the time of the alleged invention of the '151 patent how to calculate tooth color by measuring light reflected on the surface of the tooth and expressing results in the CIE L*a*b* color space and matching those results to shade tabs of a guide system. Moreover, it was known how to express tooth shades in a shade guide system using conversion scales for CIE L*a*b* values based on internally stored data. *Id.* A POSA, therefore, would have been able to replace the shade matching function in Babayoff with the shade matching function as taught by Chu. *Id.*

"wherein the method comprises deriving a certainty score expressing the certainty of the determined tooth shade value."

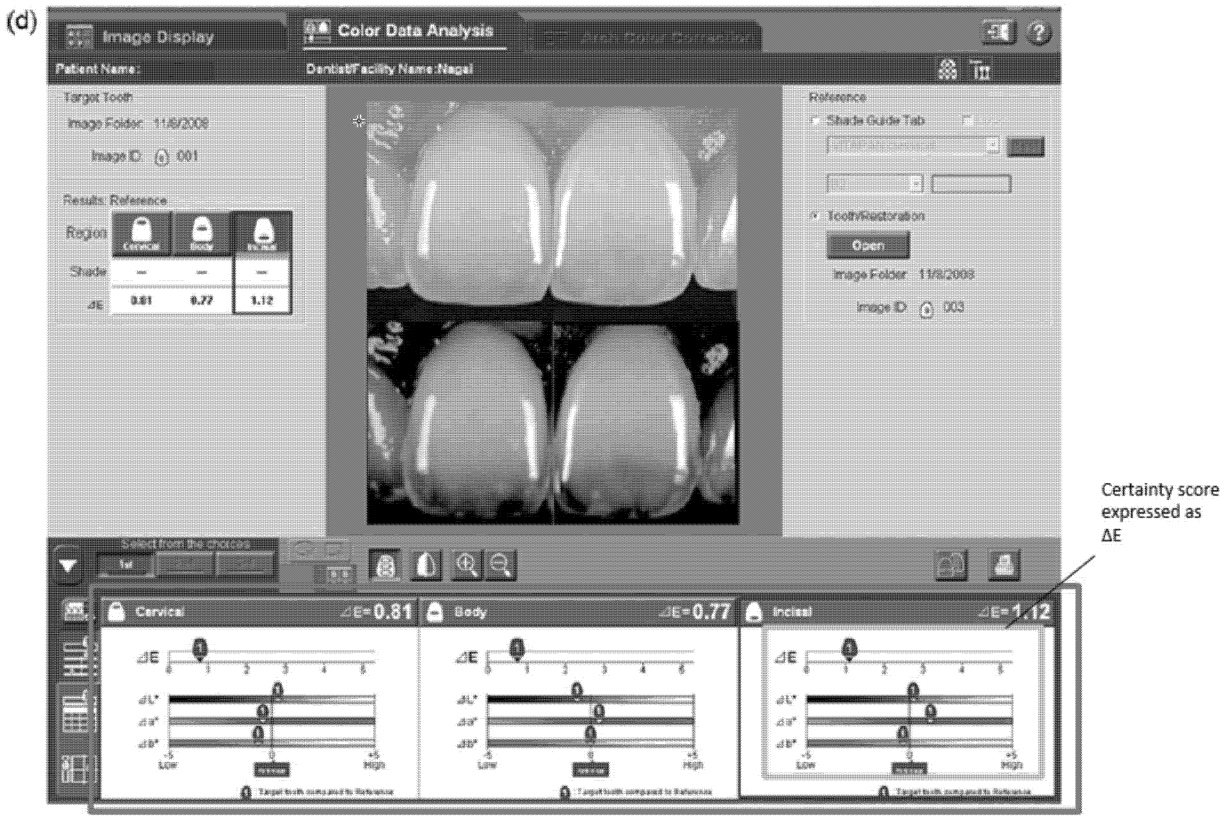
93. In my opinion, Babayoff in combination with Chu satisfies these limitations of claim 1. The '151 patent explains that ΔE is an exemplary certainty

score. Ex. 1001, '151 patent, 7:26-28. In particular, the '151 patent explains that if ΔE is above a threshold value, the uncertainty is too large. *Id.* In this manner, a POSA would understand ΔE to be an example of a certainty score provided by the '151 patent.

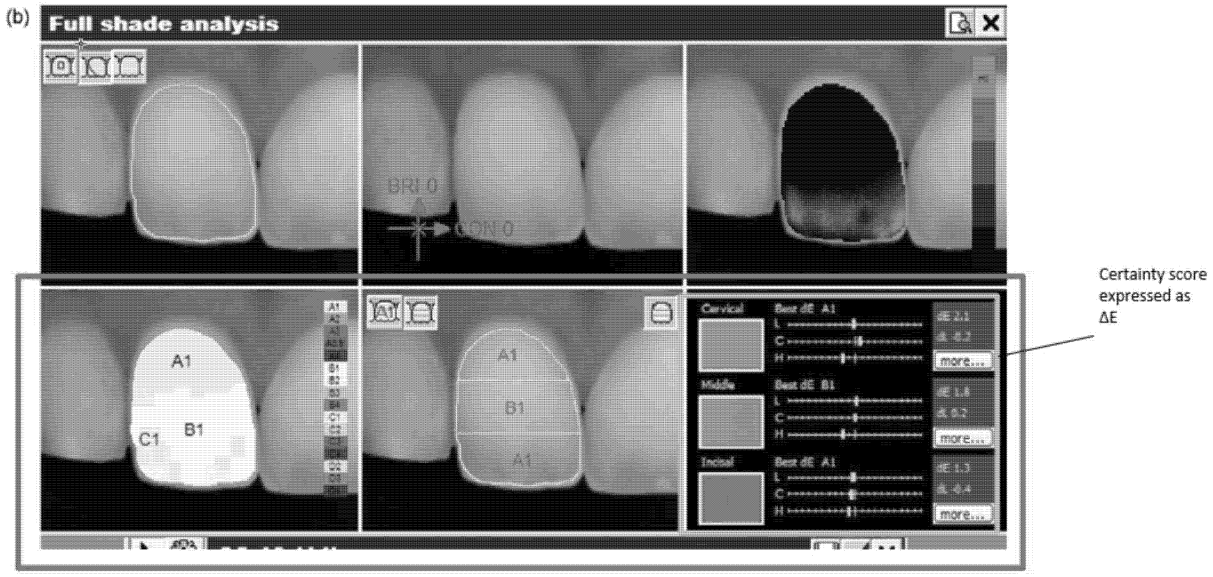
94. Babayoff in combination with Chu discloses determination of a tooth shade value based on comparison of the measured color value with the color value of a reference tooth shade. Both references further disclose the need for the determined tooth shade value to be accurate. For example, Babayoff recognizes that, "[i]n procedures relating to the manufacture of a dental prosthesis such as a crown or bridge, or in other dental restorations, it is important to match the color and texture of the prosthesis with that of the surrounding teeth in the vicinity of the target area in which the prosthesis is to be implanted, to give the prosthesis or restoration a natural appearance." Ex. 1105, Babayoff, 2:24-29. As discussed *supra*, Chu likewise recognizes that, "[t]oday's shade-matching technologies have been developed in an effort to increase the success of color matching, communication, reproduction and verification in clinical dentistry, and, ultimately, to increase the efficiency of esthetic restorative work within any practice." Ex. 1106, Chu, p. e3.

95. Chu describes CTSM devices that provide a measure of the accuracy (*i.e.*, ΔE) of the determined tooth shade value and accordingly a certainty score. As discussed *supra*, Chu discloses a perceptibility threshold in terms of ΔE, where ΔE

values below that threshold are considered a clinical "match" for restoration purposes. Because a POSA would understand Chu's ΔE to be a measure of the accuracy of the determined tooth shade value and accordingly a certainty score, Chu teaches the incorporation of a certainty score by describing CTSM devices that provide tooth shade values and respective ΔE values with respect to those values. Ex. 1106, Chu, p. e4. Examples of Chu's depiction of such certainty scoring are as follows:



Ex. 1106, Chu, FIG. 1(d) (annotated).



Id., FIG 5(b) (annotated).

96. In addition, providing motivation to modify Babayoff to compare texture data with reference texture values of reference tooth shade values to determine tooth shade values, Chu further provides motivation to modify Babayoff to include a certainty score expressing a measure of the accuracy of the determined tooth shade value for the reasons provided above in connection with claim 1.

97. A POSA would have expected such a combination to work for its intended purpose because Chu describes prior art imaging systems capable of deriving a certainty score expressing the certainty of the determined tooth shade value as discussed *supra*. Further, the modification of Babayoff to include a certainty score as taught by Chu would have been straightforward for a POSA to implement because it would require nothing more than the use of simple mathematic

calculations - *e.g.*, the prior art ΔE calculation disclosed by the '151 patent (Ex. 1001, '151 patent, 5:56-64), and the use of known reference guide datasets such as Vitapan classic. Indeed, Chu surveys a variety of intraoral scanner devices that provide tooth shade values and respective ΔE values with respect to those tooth shade values. A POSA would have understood how to derive a certainty score from the measured color values and reference color values because the ΔE calculation was known in the prior art and would require nothing more than implementing a simple algebraic equation. A POSA, therefore, would have been able to add the certainty score to Babayoff as taught by Chu.

2. Claim 2

"2. The method according to claim 1, wherein determining the tooth shade value for the point comprises selecting the reference tooth shade value with the known texture value closest to the texture data of the point."

98. In my opinion, Babayoff in combination with Chu discloses, "wherein determining the tooth shade value for the point comprises selecting the reference tooth shade value with the known texture value closest to the texture data of the point." Babayoff discloses that in procedures relating to the manufacture of a dental prosthesis or other dental restoration "it is important to match the color and texture of the prosthesis with that of the surrounding teeth in the vicinity of the target area . . ., to give the prosthesis or restoration a natural appearance." Ex. 1105, Babayoff, 2:26-29. Babayoff identifies prior art methods of matching tooth shade, referencing

U.S. Patent No. 6,007,332 as an example of calorimetric of spectrophotometric analysis "to achieve the final selection of the closest match." *Id.*, 3:18-19.

99. Chu also describes the importance shade matching, referencing multiple CTSM devices designed to select "best matching tabs from different shade guides." Ex. 1106, Chu, p. e5. Based on the degree of color match, determined based on ΔE*, Chu explains that the color may be further adjusted in certain areas to obtain excellent color match. *See id.*, FIG. 1(c) ("Excellent color match was confirmed in the cervical and body areas. Minor modification may be required in the incisal area to increase the value and yellowness.").

100. Thus, in my opinion, it would be obvious to design the algorithm discussed above in connection with claim 1 to select a reference tooth shade value that is closest to the measured tooth shade value. That is what selection of the best ΔE value, as taught by Chu, accomplishes—*e.g.*, it determines the tooth shade value closest to the measured color value in, *e.g.*, L*a*b* color space. A POSA would have expected such a combination to work for its intended purpose because Chu already described selecting the reference tooth shade value with the known texture value closest to the texture data of the point. A POSA would have understood how to implement such a matching function because algorithmic matching was well known and taught to undergraduate students in computer science/engineering.

3. Claim 6

"6. The method according to claim 1, wherein the method comprises comparing the derived certainty score with a range of acceptable certainty score values."

101. In my opinion, Babayoff in combination with Chu discloses, "wherein the method comprises comparing the derived certainty score with a range of acceptable certainty score values." As discussed *supra* in connection with claim 1, Chu discloses a perceptibility threshold in terms of ΔE. Ex. 1106, p. e7. In particular, Chu discloses that a ΔE of 1 met the perceptibility threshold such that the color difference between compared object (*e.g.*, a tooth and a reference shade tab) can be seen by 50% of observers (the other 50% will notice no difference). *Id.* Chu explains "[a] color match in dentistry is a color difference at or below the perceptibility threshold. *Id.* It would have been obvious to automate this manual process by using the ΔE value thresholds suggested by Chu to output a certainty score in terms of a measure of the accuracy of the determined tooth shade value. For example, it would have been obvious to designate a range of ΔE values between 0 and 1 as a range of acceptable certainty scores and compare a derived ΔE value to that range. Chu provides the motivation for comparing the derived certainty score with a range of acceptable certainty score values by explaining that a score between 0 and 1 would indicate a color difference at or below the perceptibility threshold. A POSA would expect such a combination to work for its intended purpose because Chu already

explains determining color match can be done by comparing ΔE to the perceptibility threshold. A POSA would have understood how implement a range of acceptable certainty score values because doing so would require nothing more than simple modification of the matching function to perform a final comparison of the calculated ΔE to the range 0 to 1.

4. Claim 7

"7. The method according to claim 1, wherein the certainty measure relates to how uniform the sub-scan texture information is at the point, and/or to how close the texture data is to the known texture value of the determined tooth shade value, and/or to the amount of texture information used to derive the texture data at the point."

102. In my opinion, Babayoff in combination with Chu discloses, "wherein the certainty measure relates to how uniform the sub-scan texture information is at the point, and/or to how close the texture data is to the known texture value of the determined tooth shade value, and/or to the amount of texture information used to derive the texture data at the point." The combination meets the limitation "wherein the certainty measure relates . . . to how close the texture data is to the known texture value of the determined tooth shade value." As already discussed in connection with claim 2, the Babayoff-Chu combination involves calculation of a certainty score in terms of ΔE, which is a measure of how similar the texture data are to the known texture value of the determined tooth shade value. Claim 7 is accordingly obvious for the reasons discussed in claim 2.

5. Claim 9

"9. The method according to claim 1, wherein the one or more reference tooth shade values relate to shade values for natural teeth with intact surface and/or to shade values for teeth prepared for a dental restoration."

103. In my opinion, Babayoff in combination with Chu discloses, "wherein the one or more reference tooth shade values relate to shade values for natural teeth with intact surface and/or to shade values for teeth prepared for a dental restoration." As discussed above, in Chu, the reference tooth shade values are, for example, the color tab values of Vitapan classic or other commonly used shade guides, which are described as corresponding to the color of human teeth. Ex. 1106, pp. e3-4. Because they correspond to the color of human teeth, they relate to shade values for natural teeth with intact surface and/or to shade values for teeth prepared for a dental restoration. Claim 9 is obvious for the reasons discussed in claim 1.

6. Claim 10

"10. The method according to claim 1, wherein the method comprises comparing the texture data with known texture values for soft oral tissue, such as gum tissue and gingiva."

104. In my opinion, Babayoff discloses, "wherein the method comprises comparing the texture data with known texture values for soft oral tissue, such as gum tissue and gingiva." Babayoff discloses a method of generating color data in order to distinguish between different regions of the intraoral cavity, for example between soft tissue, such as gum and gingiva, and teeth. Ex. 1105, Babayoff, 20:65-

23:7; FIG. 15. In the described embodiment, the measured color values c are compared to known color range R_1 and R_2, corresponding to two different tissues, *e.g.*, teeth and gums, respectively.

105. Based on comparison of the color values c to these ranges, Babayoff explains, "data points for entity I are sorted into at least two sub-data sets, I_1, I_2, according to the color criteria, that is, for example, whether the value of the color parameter of each data point is within R_1 or R_2, respectively. . . . I_2 should contain all data points in which the color parameter thereof corresponds to the color of the soft tissues, and thus should comprise the coordinates relating to the soft tissues only within the original entity I." *Id.*, 22:22-33. Babayoff uses the comparison to determine the finish line of the tooth, which is useful in preparation of dental prosthetics. *Id.*, 22:62-23:47. In at least this manner, Babayoff describes comparing the texture data with known texture values for soft oral tissue, such as gum tissue and gingiva.

7. Claim 11

"11. The method according to claim 1, wherein the texture information comprises at least one of tooth color or surface roughness."

106. In my opinion, Babayoff in combination with Chu discloses, "wherein the texture information comprises at least one of tooth color or surface roughness." As discussed in claim 1, the texture information in Babayoff is the "color parameter c," which is tooth color. *See*, *e.g.*, *id.*, 21:23-60, 26:30-36.

8. Claim 12

"12. The method according to claim 1, wherein the method comprises creating a shade profile for the tooth from shade values determined one or more points on the tooth."

107. In my opinion, Babayoff discloses, "wherein the method comprises creating a shade profile for the tooth from shade values determined one or more points on the tooth." Babayoff discloses using the 3D data (Cartesian x, y, z) and texture value (color c) to generate a shade profile of the tooth. In particular, sub-data set I_1 (distinguished from set I_2 corresponding to gums and gingiva) contains a color value c for each cartesian coordinate x, y, and z. "Thus, I_1 will contain all data points in which the color parameter thereof corresponds to the color of teeth []" *Id.*, 22:26-27. These coordinates and color c values are used to create a shade profile for the tooth, depicted graphically in Figure 19, where the color data of I_1 are used to create a dental prosthesis X having a shade profile based on I_1. *Id.*, 26:8-27:38, FIG. 19.

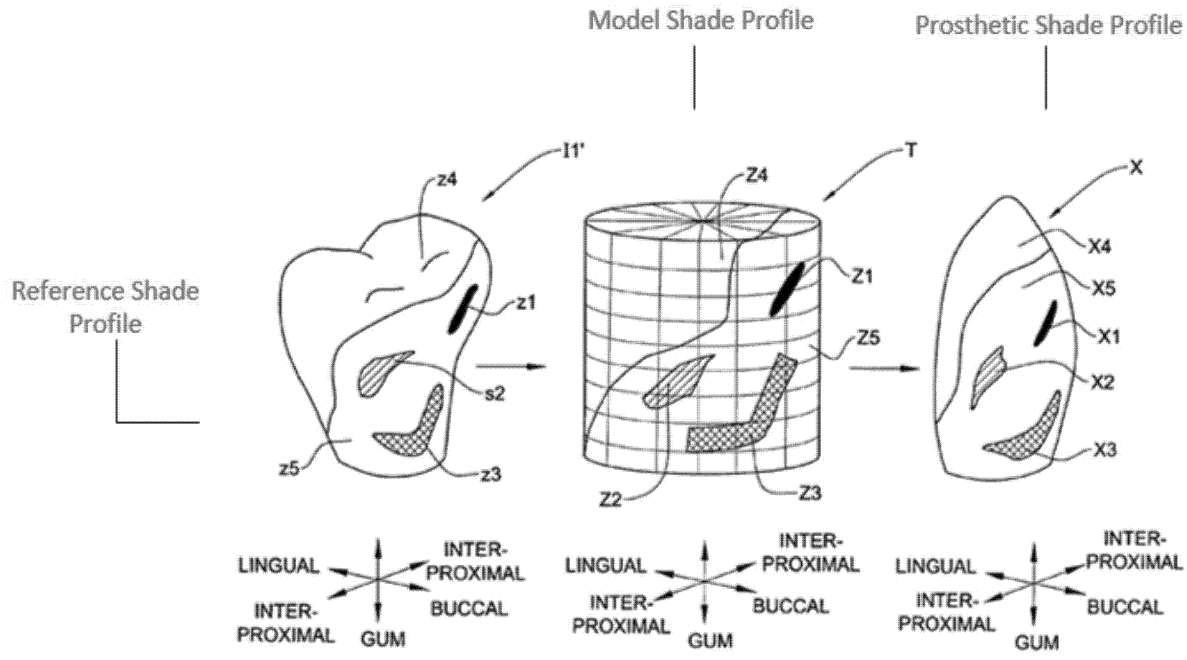


FIG. 19

Ex. 1105, Babayoff, FIG. 19 (annotated). Babayoff accordingly discloses creating a shade profile for the tooth from shade values determined one or more points on the tooth.

9. Claim 13

108. Independent claim 13 is substantially identical to claim 12 except it omits the certainty score limitation and adds the following:

> **"[13] wherein the tooth shade profile comprises a one or more tooth shade regions on the tooth surface where an average tooth shade is derived for each region from tooth shade values determined for a number of points within the region."**

109. In my opinion, Babayoff in combination with Chu discloses the claim 13 limitations, with the limitations shared with claims 1 and 12 disclosed by

Babayoff and Chu for the reasons I describe above in connection with those claims. In addition to the shade profile discussed above in claim 12, which uses directly measured color c values to determine a shade profile, in my opinion, Babayoff also discloses a manner of generating a shade profile from average shade values determined from a number of points within the region.

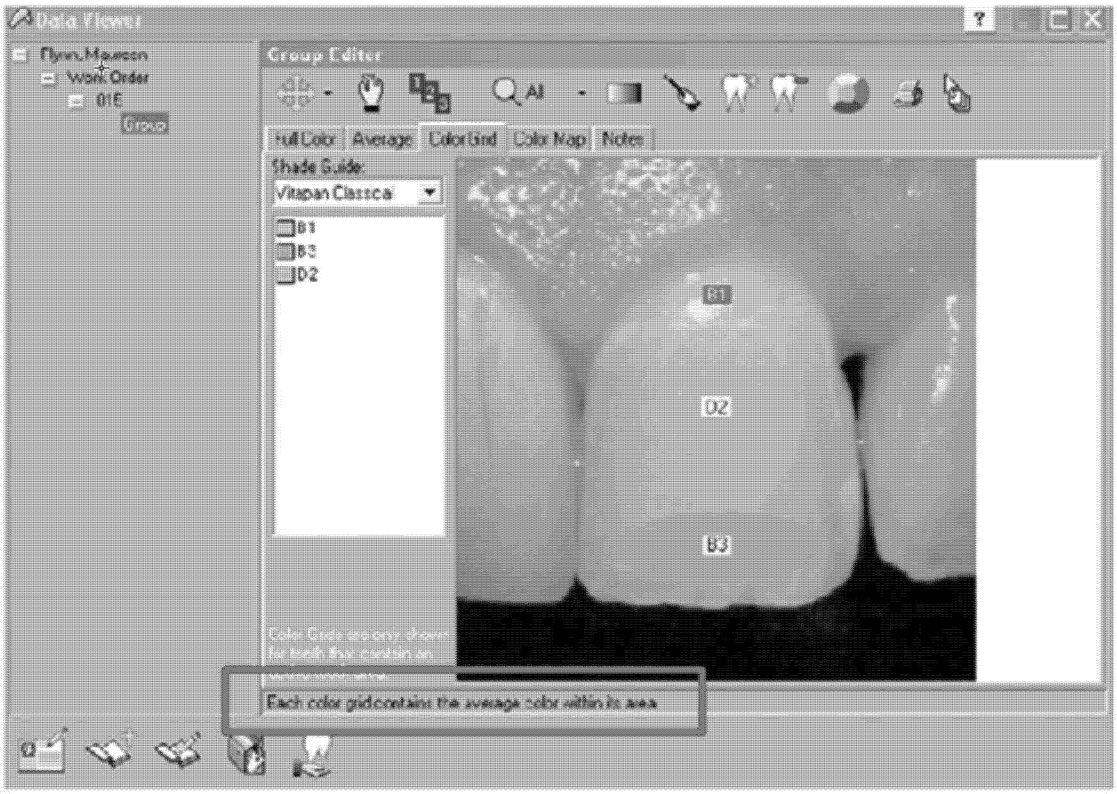
110. Babayoff states that rather than matching the shade of an entire tooth, "the tooth may be divided into three general zones: a gingival zone close to the gums, an intermediate body zone, and an incisal zone comprising the cusp of the tooth." Ex. 1105, Babayoff, 27:33-36. Babayoff explains that the colors can be mapped into each of the zones independently, and then smoothed out between the zones to avoid sharp discontinuities in color. *Id.*, 27:36-38. A POSA would understand that averaging is a manner of smoothing out differently colored zones.

111. Babayoff also describes a manner of averaging tooth shade values and using those average values to determine a tooth shade value. *Id.*, 27:39-57. Babayoff teaches that rather than selecting a reference color c from one tooth, the color c from a set of teeth can be averaged and used as a tooth shade value. *Id.* In this respect, Babayoff teaches a tooth shade profile comprising a region of tooth shade determined from the average of tooth shades within the region.

112. Chu likewise describes use of averages to determine a tooth shade value. Chu notes that a drawback of certain CTSM devices is that they "average out"

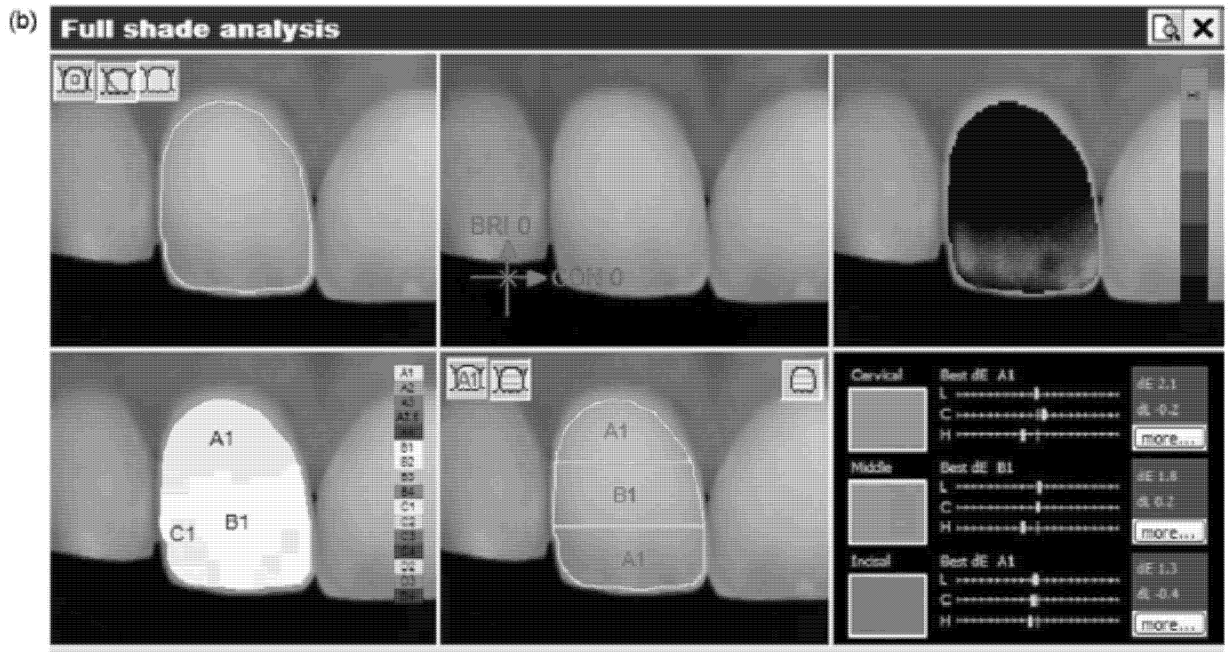
color data over the complete tooth surface or larger defined areas. Ex. 1106, Chu, p. e4. Chu further discloses that several areas of the tooth should be considered to obtain a representative evaluation of tooth shade. *Id.* ("At a minimum, a limited area measurement of the gingival, body, and incisal areas of the tooth should be assed and recorded . . . "). Chu summarizes, "[d]ifferent measurement devices either measure the complete tooth surface providing a 'color map' or an 'average' color of the limited area [3-5 mm] on the tooth surface." *Id.*, p. e2. Chu portrays clinical application of a ShadeVision colorimeter and expressly notes that "[e]ach color grid contains the average color within its area." *Id.*, p. e7.

(b)



Id., FIG 5 (b) (annotated).

113. Thus, in my opinion, it would be obvious, based on the teachings of Babayoff and Chu, to generate a tooth shade profile that averages values, *e.g.*, within the gingival, body, and incisal areas of the tooth. The concept of averaging within discrete measurement areas was contemplated in both Babayoff (smoothing between regions, generating a shade profile of a region using average value within the region) and Chu (averaging within limited areas). Modifying the algorithm in Babayoff to generate the profile in this manner would be straightforward and routine in the field of image processing. As shown in Figure 5(b) of Chu, a POSA would have understood based on the teachings of Babayoff and Chu that averaging the A1 (gingival), B1 (body), and C1 (incisal) regions would avoid sharp discontinuities in color between adjacent regions. Ex. 1106, Chu, FIG. 5(b).



10. Claim 14

114. Independent claim 14 is substantially identical to claim 1 except it omits the certainty score limitation and adds the following:

> **"[14] wherein obtaining the digital 3D representation of the tooth comprises recording a series of sub-scans of the tooth, where at least one of said sub-scans comprises both texture information and geometry information for said tooth, and generating the digital 3D representation of the tooth from the recorded series of sub-scans."**

115. In my opinion, Babayoff discloses the claim 14 limitations. The limitations shared with claim 1 are disclosed by Babayoff modified by the teachings of Chu for the reasons discussed above in connection with claim 1. Babayoff also discloses "obtaining a digital 3D representation of a tooth by recording a series of sub-scans of the tooth, where at least one of the sub-scans comprises both texture information and geometry information for said tooth and generating the digital 3D representation of the tooth from the recorded series of sub-scans.

116. In particular, Babayoff discloses an embodiment where data sets of overlapping areas are stitched together to form an accurate scan of the intra-oral cavity. Ex. 1105, Babayoff, 23:48-51. A scanner is used in the manner described above, but high-resolution numerical sub-entities are formed that represent surface topography and the color of zones. *Id.*, 23:51-56. The scanned zones fully span the target of interest and overlap one another such that certain sub-entities, "shall have

a portion of their data identical to one another within the overlap zone." *Id.*, 23:56-61.

117. Babayoff explains that "by identifying the overlap zone within the entities, the spatial relationship between the entities may be established, and the various entities stitched together or combined to form a global numerical entity that comprises the full geometry and color representation of the target zone. The larger the overlap zone, the greater the accuracy with which the different zones may be synchronized together spatially." *Id.*, 23:65-24:5. This is akin to the '151 patent's explanation of sub-scans, "[d]eriving the texture data based on texture information from two or more sub-scan can provide a more accurate measurement of the texture data." Ex. 1001, '151 patent, 4:33-35.

118. To the extent that Patent Owner argues that the second embodiment of Babayoff (*e.g.*, Ex. 1105, Babayoff, 23:48-25:3) is separate from the fourth embodiment of Babayoff (*e.g.*, Ex. 1105, Babayoff, 26:8-28:7), it would have been obvious to implement the stitching described in the second embodiment to form the entity of the fourth embodiment at least because the resulting overlap zone increases the accuracy of the scan. Ex. 1105, Babayoff, 26:31-36.

119. A POSA would have understood that the stitching of the second embodiment of Babayoff could have been used to obtain the claimed digital 3D representation within the context of the fourth embodiment because stitching to form

a digital 3D representation of the scanned area is well-known and expected in the art. A POSA would have a reasonable expectation of implementing stitching, according to Babayoff in the fourth embodiment of Babayoff because stitching is a well-known and expected way to obtain a digital 3D representation. Further, it would have been obvious to try to implement the stitching of Babayoff's second embodiment in Babayoff's fourth embodiment because such techniques were readily available to Babayoff and could save unneeded experimentation with other ways to form a digital 3D representation.

11. Claim 15

"15. The method according to claim 14, wherein the texture data at least partly are derived by combining the texture information from corresponding parts of a number of the sub-scans."

120. In my opinion, Babayoff in combination with Chu discloses, "wherein the texture data at least partly are derived by combining the texture information from corresponding parts of a number of the sub-scans" for the reasons discussed above in connection with claim 14. In particular, Babayoff explains that "by identifying the overlap zone within the entities, the spatial relationship between the entities may be established, and the various entities stitched together or combined to form a global numerical entity that comprises the full geometry and color representation of the target zone. The larger the overlap zone, the greater the accuracy with which the different zones may be synchronized together spatially." Ex. 1105, Babayoff, 23:65-

24:5. In this manner, Babayoff in combination with Chu discloses, "wherein the texture data at least partly are derived by combining the texture information from corresponding parts of a number of the sub-scans."

B. Ground 2: Claim 3 Is Obvious Over Babayoff and Chu and Graham

"3. The method according to claim 1, wherein determining the tooth shade value for the point comprises an interpolation of the two or more reference tooth shade values having known texture values close to the texture data of the point."

121. In my opinion, Babayoff in combination with Chu and Graham discloses the claim 3 limitations. It would have been obvious to combine Babayoff and Chu for the reasons described above in connection with claim 1 and the requirements of claim 1 are satisfied for that reason. The remaining limitations are added by Grahahm. Graham discloses, "if the color characteristics for a patient fall between two shades, . . . interpolation may be applied to the two shades to produce an additional shade for the patient's tooth that suitably fits the generated color characteristics for that patient." Ex. 1107, Graham, ¶0050.

122. As discussed above, Babayoff in combination with Chu uses measured color values compared with reference tooth shade vales to determine tooth shade values for dental prosthetics and restorations. A POSA would have been motivated to modify the tooth shade values determined by Babayoff and Chu using the teachings of Graham in order to generate a more accurate tooth shade value. A POSA

would have been motivated to increase the accuracy in this fashion because both Babayoff and Chu discuss, at length, efforts to obtain accurate and natural-looking tooth shade and Graham provides a straightforward solution using interpolation.

123. Moreover, Babayoff, Chu, and Graham are all in the field of determining appropriate shade values for dental restorations. *See*, *e.g.*, Ex. 1105, Babayoff, 27:59-62; Ex. 1107, Graham, ¶0036. The addition of the interpolation of shade values to Babayoff and Chu would have required nothing more than the addition of a database of known shade values as disclosed by Chu (Ex. 1106, Chu, p. e4) and Graham (Ex. 1107, Graham, ¶¶0049-50) and a simple code to perform the interpolation when a measured color falls between two reference tooth shade values. Both of these things are well-known, and their implementation into the Babayoff device would have been straightforward.

124. Thus, in my opinion, it would have been obvious to a POSA to combine Babayoff and Chu with Graham to arrive at the claim 3 limitations.

C. Ground 3: Claims 15-17 Are Obvious Over Babayoff and Chu and Nathaniel

1. Claim 15

"15. The method according to claim 14, wherein the texture data at least partly are derived by combining the texture information from corresponding parts of a number of the sub-scans."

125. Babayoff in combination with Chu and Nathaniel discloses, "wherein the texture data at least partly are derived by combining the texture information from

corresponding parts of a number of the sub-scans." The limitations of claim 14 are met by Babayoff and Chu for the reasons discussed above in connection with claim 14 of Ground 1. Further, as discussed above in connection with claim 15 of Ground 1, Babayoff in combination with Chu discloses using the texture data of overlapping scans to build a 3D representation of a tooth, which includes "combining the texture information from corresponding parts of a number of the sub-scans." Ex. 1105, Babayoff, 23:48-25:3. However, to the extent that Patent Owner argues Babayoff in combination with Chu does not disclose this limitation, in my opinion, it is also disclosed by Babayoff combined with Chu and Nathaniel.

126. Babayoff recognizes that "theoretically the corresponding entities should have a portion of their data identical to one another within the overlap zone. However, since the scanner itself moves in orientation and position from scan to scan, the coordinates relating to these overlap zones will usually vary between adjacent scans, even though they relate to the same spatial feature." *Id.*, 23:59-65. Babayoff also recognizes that, "ambiguity may occur . . . if a part of the intra-oral cavity (corresponding to part of the overlapping scanned data in some of the entities) moves in relation to other parts." *Id.*, 24:14-18. A POSA reading Babayoff may recognize that for values of the same tissue type (*e.g.*, teeth) Babayoff does not address ambiguity arising from the variance between adjacent scans. Thus,

confronting this ambiguity, a POSA would look elsewhere to improve the determination of color values in overlapping scan regions.

127. Nathaniel is similarly directed to the creation of 3D models from a series of scan images and is analogous art. Nathaniel addresses the problem of determining an appropriate value of a pixel in overlapping images. Ex. 1111, Nathaniel, ¶¶0024, 0043. To determine the appropriate value for a given pixel, Nathaniel computes an "average" or "weighted average" of the pixels in each of the overlapping images. "If such appropriate pixel occurs in more than one X-ray image, the preferred embodiment of the invention uses the pixel which is closest to the center in its original X-ray image in order to minimize image distortion. For this pixel, the X-rays are closest to perpendicular to the imaging Surface. Other embodiments may use an average value of the original pixels, a weighted average, the maximal or minimal gray level value, or any other decision rule." *Id.*, ¶0099.

128. A POSA would have recognized that methods of combining appropriate pixel data from the overlapping images might result in a more accurate determination of color data when combining the sub-entities of Babayoff. Thus, a POSA would have been motivated to try to improve the color determinations of Babayoff and Chu using the "average" and "weighted average" of Nathaniel. A POSA would have encountered no technical hurdles when implementing the methods of Nathaniel in the context of Babayoff in combination with Chu. A POSA

would have simply written and executed simple computer code to take the average or weighted average of the datasets rather than combining datasets or disregarding one data set in view of the other. An undergraduate student of computer science could write and execute such code.

129. Thus, in my opinion, it would have been obvious to a POSA to combine Babayoff with Chu and Nathaniel to achieve the limitations of claim 15.

2. Claim 16

"16. The method according to claim 15, wherein combining the texture information from the sub-scans comprises interpolating the texture information and/or calculating an average value of the texture information."

130. Babayoff in combination with Chu and Nathaniel discloses, "wherein combining the texture information from the sub-scans comprises interpolating the texture information and/or calculating an average value of the texture information." As discussed in claim 15 of this Ground, Babayoff in combination with Chu and Nathaniel calculates the average value of the texture information. Claim 16 is accordingly obvious for the same reasons.

3. Claim 17

"17. The method according to claim 16, wherein the calculated average value is a weighted average of the texture information."

131. Babayoff in combination with Chu and Nathaniel discloses, "wherein the calculated average value is a weighted average of the texture information." As discussed in claim 15 of this Ground, Babayoff in combination with Chu and

Nathaniel calculates the weighted average value of the texture information. Claim 17 is accordingly obvious for the same reasons.

D. Ground 4: Claims 1, 2, 7, and 9-15 Are Obvious Over Babayoff and Inglese

1. Claim 1

132. In my opinion, Babayoff discloses "[a] method for determining shade of a patient's tooth" and "obtaining a digital 3D representation of the tooth, where the digital 3D representation comprises shape data and texture data for the tooth" for the reasons discussed above in connection with Ground 1. In my opinion, the remaining limitations are met by Babayoff in combination with Inglese as set forth below.

[b] "determining a tooth shade value for at least one point on the tooth based on the texture data of the corresponding point of the digital 3D representation and on known texture values of one or more reference tooth shade values"

133. In my opinion, Babayoff modified by the teaching of Inglese discloses, "determining a tooth shade value for at least one point on the tooth based on the texture data of the corresponding point of the digital 3D representation and on known texture values of one or more reference tooth shade values." As discussed above, Babayoff determines a color c for each Cartesian point on a 3D representation of a tooth and, further, a method determining the shade of a prosthesis or restoration using this information. Ex. 1105, Babayoff, 21:9-13, 26:8-65. Babayoff explains that after creating numerical entity I (including x, y, z, and color c), shade information

for a prosthesis can be obtained to provide a natural-looking appearance compatible with the patient's other teeth. *Id.*, 26:20-24.

134. Inglese describes an intra-oral scanning device and method for determining tooth shade. Ex. 1109, Inglese, ¶0001. In particular, Inglese describes a manner of measuring tooth shade where a sensor receives a measurement signal from the illuminated tooth and that signal is converted into Cartesian x, y, z coordinates in three-dimensional shade space where reference points are also defined. *Id.*, ¶¶0011-14. This is depicted graphically below:

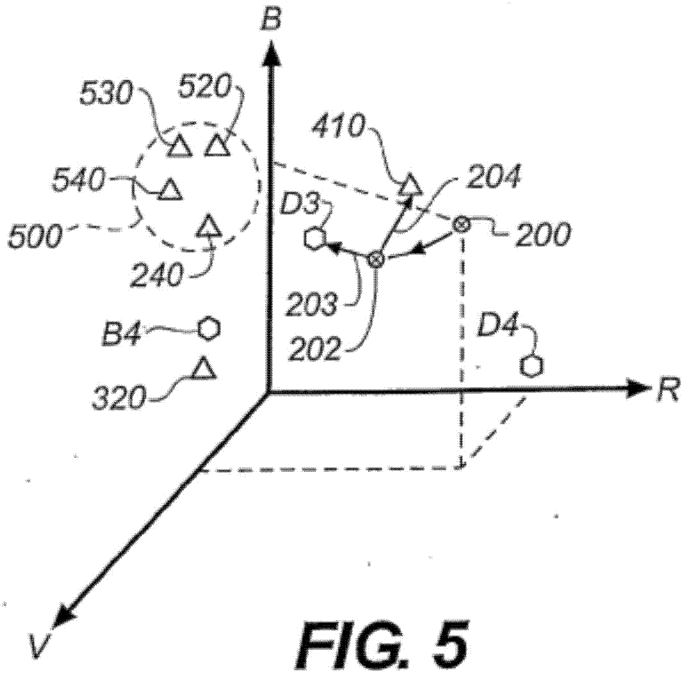


FIG. 5

Id., FIG. 5.

135. Inglese further discloses that an automatic search is performed where the shade corresponding to the reference point close to the measurement point is

established. *Id.*, ¶0015, ¶¶0031-35. "The reference 200 designates one point of the shade space. The coordinates of the point in the dimensions of the shade space are symbolized by dotted line projections on the R, G, B dimension axes." *Id.*, ¶¶0081-0091. Inglese continues: "Also shown in the shade space are the reference points 320, 410, 540. These are shown as small triangles. They correspond to known values of a first dental shade guide. Another set of reference points B4, D3, D4, shown by small hexagons, corresponds to the shades of a second dental shade guide." *Id.* Inglese explains that "[t]he reference point closest to the measurement point, possibly corrected, is sought to establish the shade of the relevant tooth part." *Id.*

136. Inglese provides the motivation for using known texture values of reference tooth shade values with Babayoff's process of generating a 3D representation of a tooth using shape data and texture data by Explaining that the aim in measuring dental shade is to establish the appearance of the tooth as faithfully as possible and providing a means of doing so "freed from the subjectivity part related to the practitioner." *Id.*, ¶¶0001, 0006. It would have been obvious to a POSA, therefore, to replace the manual or algorithmic process of shading a restoration using texture data from surrounding teeth with the automated process of shading a restoration using texture data from reference tooth shade values of a shade guide as taught by Inglese. Indeed, in Babayoff, at the conclusion of the process the user is still left to fabricate the prosthetic from a mold having a certain color. Ex.

1105, Babayoff, 2:47-49. Inglese provides an automated manner of determining that color and expressly suggests automating that otherwise manual process is advantageous.

137. A POSA would have a reasonable expectation of success modifying Babayoff to compare tooth shade with tooth shade guide values rather than tooth shade values from the patient's teeth. The modification would require nothing more than modifying Babayoff's algorithm to compare measured texture values with known texture values of reference tooth shade values and select the closest match. The teachings of Inglese are thus similar in all relevant respects to the teachings of Chu, discussed above in connection with claim 1. Accordingly, it would have been obvious to combine Babayoff with Inglese for the same reasons it would have been obvious to combine Babayoff with Chu.

[c] "wherein the method comprises deriving a certainty score expressing the certainty of the determined tooth shade value."

138. In my opinion, Babayoff in combination with Inglese discloses, "wherein the method comprises deriving a certainty score expressing the certainty of the determined tooth shade value." As discussed above, a POSA would understand ΔE to be an example of a certainty score provided by the '151 patent. Inglese describes a manner of deriving a measure of the accuracy of the determined tooth shade value and thus discloses the required "certainty score." It would have

been obvious to modify Babayoff with Inglese to incorporate Inglese's certainty score in the determination of tooth shade.

139. As discussed above, Babayoff in combination with Inglese discloses determination of a tooth shade value based on comparison of the measured texture value with the texture value of a reference tooth shade to determine the shade. As discussed above, Babayoff recognized the need for the determined tooth shade to be accurate, and so did Inglese, explaining that the aim of measuring dental shade is to establish the appearance of the tooth as faithfully as possible. Ex. 1109, Inglese, ¶0001.

140. As discussed above, Inglese describes a process whereby the measured color signal is modeled in three-dimensional shade space alongside reference tooth shade values. In particular, reference points 320, 410, 540 are shown in Figure 5 as small triangles and correspond to reference shades of shade guide acquired by the measuring instrument in a learning phase or are preprogrammed. *Id.*, ¶0084. Similarly, reference points B4, D3, D4, shown as small hexagons, correspond to shades of a second dental shade guide. *Id.*

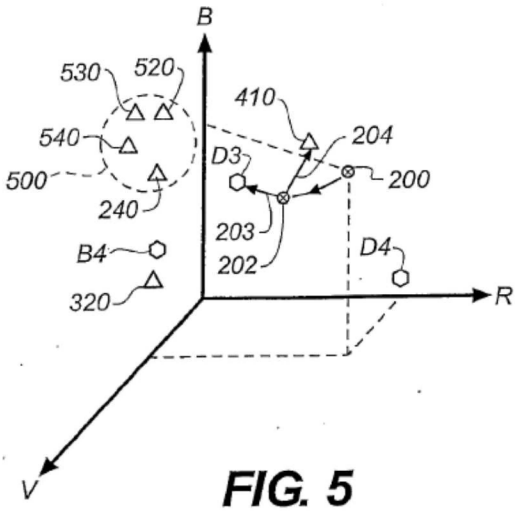


FIG. 5

Inglese explains that the reference point closest to the measurement point, possibly corrected, is sought to establish the shade of the relevant tooth part. "This point is sought for a given dental shade guide." *Id.*, ¶0085

141. The certainty score of Inglese is the algebraic distance between the measured tooth shade and the reference tooth shade. Inglese notes "that the measurement point does not exactly coincide with the reference points. A correction vector 203, 204, of the shade space, pointing from the measurement point to the reference point, indicates the distance and direction of the gap present between the measurement point and the selected reference point." *Id.*, ¶0086. Inglese explains, "[d]ata representative of the length and direction of the correction vector can be displayed with the shade, on a control screen or dedicated display." *Id.* A POSA would understand that the vector between 200 and 202 represents a measure of the

accuracy of the determined tooth shade value, and thus discloses the required "certainty score."

142. A POSA would have been motivated to combine Babayoff with Inglese for the reasons discussed above and would be motivated to further modify the combination to include a certainty score at least because Inglese teaches ways to correct measurement errors in tooth shade measurement occurring due to transparency, ambient light, and incident light. For example, Inglese explains that visual evaluation generates errors resulting from faulty color perception or the practitioner's visual fatigue. *Id.*, ¶0004. Inglese explains that a more objective evaluation can be performed using a colorimeter, which analyzes the spectral response of the tooth and can be linked to suitable visualization software to prepare a shade map of the tooth displayed on a control screen. *Id.*, ¶0005. Inglese describes a manner of selecting a tooth shade from a set of reference tooth shade values to generate the shade map and eliminate errors from faulty color perception. *Id.*, ¶¶0006-49.

143. Further, it would have been obvious to a POSA to incorporate the correction vectors into Babayoff in the manner disclosed by Inglese to improve the certainty of shade match, as Inglese suggests. A POSA would have had a reasonable Expectation of success when incorporating these vector computations into Babayoff because it would require nothing more than the use of simple mathematic

computations, including the prior art computation disclosed by the '151 patent (Ex. 1001, '151 patent, 5:56-64), and the use of known datasets such as Cromascop and Vita Lumin Classic (Ex. 1109, Inglese, ¶0085).

144. A POSA could have implemented the correction and shade determination methods of Inglese on the N[X', Y', C] space of Babayoff with a reasonable expectation of success. Inglese explains its algebraic operations for shade determination can be performed on a 2D space such as N[X', Y', C]. Implementing Inglese in Babayoff would require nothing more than the straightforward addition of known and well-understood software.

145. Therefore, it would have been obvious to a POSA to improve Babayoff by using the shade determination methods of Inglese to obtain more accurate shade values in the presence of ambient/reflected/refracted light interference and deriving a certainty score expressing the certainty of the determined tooth shade value in the form of a measurement of the accuracy of the determined tooth shade value.

2. Claim 2

"2. The method according to claim 1, wherein determining the tooth shade value for the point comprises selecting the reference tooth shade value with the known texture value closest to the texture data of the point."

146. In my opinion, Babayoff in combination with Inglese discloses, "wherein determining the tooth shade value for the point comprises selecting the reference tooth shade value with the known texture value closest to the texture data

of the point." In Inglese, the known shade values are, for example, 320, 410, 540, B4, D3, and D5 of Figure 5 shown above. "Also shown in the shade space are the reference points 320, 410, 540. These are shown as small triangles. They correspond to known values of a first dental shade guide." Ex. 1109, Inglese, ¶0084. As explained in more detail above in connection with claim 1 of this Ground, Inglese further explains, "[t]he reference point closest to the measurement point, possibly corrected, is sought to establish the shade of the relevant tooth part." *Id.*, ¶0085. The combination of Babayoff and Inglese thus discloses, "wherein determining the tooth shade value for the point comprises selecting the reference tooth shade value with the known texture value closest to the texture data of the point."

3. Claim 7

"7. The method according to claim 1, wherein the certainty measure relates to how uniform the sub-scan texture information is at the point, and/or to how close the texture data is to the known texture value of the determined tooth shade value, and/or to the amount of texture information used to derive the texture data at the point."

147. In my opinion, Babayoff in combination with Inglese discloses, "wherein the certainty measure relates to how uniform the sub-scan texture information is at the point, and/or to how close the texture data is to the known texture value of the determined tooth shade value, and/or to the amount of texture information used to derive the texture data at the point." In particular, Babayoff in combination with Inglese discloses a certainty measure relating to "how

[perceptually] close the texture data is to the known texture value of the determined tooth shade value." As explained in more detail above in connection with claim 1 of this Ground, Inglese discloses, "[t]he reference point closest to the measurement point, possibly corrected, is sought to establish the shade of the relevant tooth part," and involves computation of a correction vector, which "indicates the distance and direction of the gap present between the measurement point and the selected reference point." Ex. 1109, Inglese, ¶0085. The combination of Babayoff with Inglese thus discloses "wherein the certainty measure relates . . . to how close the texture data is to the known texture value of the determined tooth shade value."

4. Claim 9

"9. The method according to claim 1, wherein the one or more reference tooth shade values relate to shade values for natural teeth with intact surface and/or to shade values for teeth prepared for a dental restoration."

148. In my opinion, Babayoff in combination with Inglese discloses, "wherein the one or more reference tooth shade values relate to shade values for natural teeth with intact surface and/or to shade values for teeth prepared for a dental restoration." Babayoff in combination with Inglese discloses shade values for teeth prepared for a dental restoration. Inglese discloses, "shade 410 [is] of the 'Cromascop' dental shade guide. The selected shade can also be that corresponding to point D3 of the second dental shade guide. For example, this is shade D3 of the 'Vita Lumin Classic' dental shade guide." Ex. 1109, Inglese, ¶0085. Accordingly,

the combination of Babayoff with Inglese discloses, "wherein the one or more reference tooth shade values relate to shade values for natural teeth with intact surface and/or to shade values for teeth prepared for a dental restoration."

5. Claim 10

"10. The method according to claim 1, wherein the method comprises comparing the texture data with known texture values for soft oral tissue, such as gum tissue and gingiva."

149. In my opinion, Babayoff in combination with Inglese discloses, "wherein the method comprises comparing the texture data with known texture values for soft oral tissue, such as gum tissue and gingiva." As discussed above in connection with claim 10 of Ground 1, Babayoff discloses a method of generating color data in order to distinguish between different regions of the intraoral cavity, for example between soft tissue, such as gum and gingiva, and teeth, involving comparison of texture data with known texture values for soft oral tissue, such as gum tissue and gingiva. Ex. 1105, Babayoff, 20:65-23:7; FIG. 15. Thus, Babayoff discloses, "comparing the texture data with known texture values for soft oral tissue, such as gum tissue and gingiva."

6. Claim 11

"11. The method according to claim 1, wherein the texture information comprises at least one of tooth color or surface roughness."

150. In my opinion, Babayoff discloses, "wherein the texture information comprises at least one of tooth color or surface roughness." As explained above in

connection with claim 1 of Ground 1, Babayoff obtains a digital 3D representation of a tooth using an intraoral scanning device 100, where the 3D representation comprises shape data and color data for the tooth. Ex. 1105, Babayoff, 8:30-44, 8:57-9:32, FIGS. 1, 4. Babayoff explains, "[a]dvantageously, such a scanner makes use of confocal imaging for providing an accurate three-dimensional representation of the target surface within the intra-oral cavity. Color values are then added to each data point of this data set by obtaining a two-dimensional color image of the target surface, and then mapping the color values of the two-dimensional image onto the three-dimensional 'image.'" *Id.*, 8:15-22. The combination with Inglese adds a manner of plotting the derived color values relative to known reference color values from shade guides in three-dimensional shade space. Ex. 1109, Inglese, ¶¶0001, 0011-14, 0031-35. The combination of Babayoff with Inglese thus discloses, "wherein the texture information comprises at least one of tooth color or surface roughness."

7. Claim 12

"12. The method according to claim 1, wherein the method comprises creating a shade profile for the tooth from shade values determined one or more points on the tooth."

151. In my opinion, Babayoff in combination with Inglese discloses, "wherein the method comprises creating a shade profile for the tooth from shade values determined one or more points on the tooth." As explained above in

connection with claim 12 of Ground 1, a POSA would understand the sub-data set I_1 in Babayoff to be a shade profile for a tooth. Babayoff explains: "Thus, I_1 will contain all data points in which the color parameter thereof corresponds to the color of teeth . . . ." Ex. 1105, Babayoff, 22:26-27. Babayoff further explains that the color data of I_1 are used to create a dental prosthesis X having a shade profile based on I1. *Id.*, 26:8-27:38. Babayoff also discloses various shade profiles for a tooth, including measured N[X', Y', C], base I[X, Y, Z, C] (I_1 for extracted tooth values), transform T[X, Y, Z, C] and model X[X, Y, Z, C], as depicted in Figure 19:

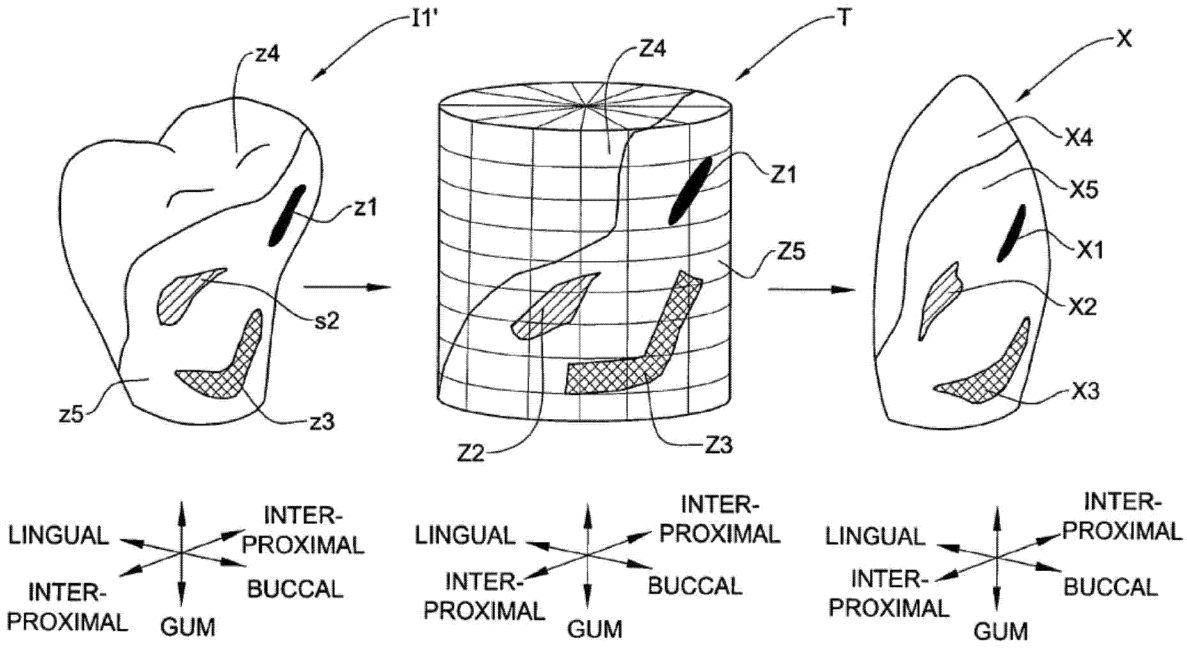


FIG. 19

Further, Inglese discloses a shade map 100, and explains that the shade map is prepared from shade measurements taken from separate parts of the tooth. Ex. 1109, Inglese, ¶0070, FIG. 1. The combination of Babayoff and Inglese thus discloses,

"wherein the method comprises creating a shade profile for the tooth from shade values determined one or more points on the tooth."

8. Claim 13

152. Independent claim 13 is substantially identical to claim 12 except it omits the certainty score limitation and adds the following:

> **[13] "wherein the tooth shade profile comprises a one or more tooth shade regions on the tooth surface where an average tooth shade is derived for each region from tooth shade values determined for a number of points within the region."**

153. In my opinion, Babayoff in combination with Inglese discloses, "wherein the tooth shade profile comprises a one or more tooth shade regions on the tooth surface where an average tooth shade is derived for each region from tooth shade values determined for a number of points within the region," with the limitations shared with claims 1 and 12 disclosed by Babayoff and Inglese for the reasons set forth above in connection with those claims. In addition to the shade profile discussed above in claim 12, which uses directly measured color c values to determine a shade profile, Babayoff also discloses a manner of generating a shade profile from average shade values determined from a number of points within the region as discussed in connection with claim 13 of Ground 1.

154. Inglese likewise discloses this limitation. Inglese discloses that a shade profile is prepared from shade measurements taken from separate parts of the tooth. Ex. 1109, Inglese, ¶0070, FIG. 1. Inglese further discloses that the shade of relevant

tooth part can be compensated for averaging the shades based on the shades of other neighboring tooth parts. *Id.* Inglese also discloses establishing a tooth's shade based on measurements of individual pixels, where averages can then be performed on pixel groups. *See id.*, ¶0077; *see also* claim 26.

155. Thus, in my opinion, it would be obvious based on the teachings of Babayoff and Inglese, to generate a tooth shade profile that averages values between neighboring tooth parts. The concept of averaging within discrete measurement areas was contemplated in both Babayoff (smoothing between regions, generating a shade profile of a region using average value within the region) and Inglese (averaging within pixel groups). Modifying the algorithm in Babayoff to generate the profile in this manner would be straightforward and routine in the field of image processing. It would have been obvious to implement the tooth shade averaging of Inglese in Babayoff.

9. Claim 14

156. Independent claim 14 is substantially identical to claim 1, except it omits the certainty score limitation and adds the following:

> **[14] "wherein obtaining the digital 3D representation of the tooth comprises recording a series of sub-scans of the tooth, where at least one of said sub-scans comprises both texture information and geometry information for said tooth, and generating the digital 3D representation of the tooth from the recorded series of sub-scans."**

157. In my opinion, Babayoff in combination with Inglese discloses, "wherein obtaining the digital 3D representation of the tooth comprises recording a series of sub-scans of the tooth, where at least one of said sub-scans comprises both texture information and geometry information for said tooth, and generating the digital 3D representation of the tooth from the recorded series of sub-scans." The limitations shared with claim 1 are disclosed by Babayoff in combination with Inglese for the reasons discussed above in connection with claim 1 of this Ground. The added limitation of claim 14 is disclosed by Babayoff for the reasons provided in connection with claim 14 of Ground 1.

10. Claim 15

"15. The method according to claim 14, wherein the texture data at least partly are derived by combining the texture information from corresponding parts of a number of the sub-scans."

158. In my opinion, Babayoff in combination with Inglese, discloses, "wherein the texture data at least partly are derived by combining the texture information from corresponding parts of a number of the sub-scans." Babayoff, modified by the teachings of Inglese, discloses the claim 14 limitations for the reasons discussed above in connection with claim 14. The added limitation of claim 15 is disclosed by Babayoff for the reasons provided in connection with claim 15 of Ground 1.

E. Ground 5: Claim 3 Is Obvious Over Babayoff and Inglese and Graham

"3. The method according to claim 1, wherein determining the tooth shade value for the point comprises an interpolation of the two or more reference tooth shade values having known texture values close to the texture data of the point."

159. In my opinion, Babayoff in combination with Inglese and Graham, discloses, "wherein determining the tooth shade value for the point comprises an interpolation of the two or more reference tooth shade values having known texture values close to the texture data of the point." It would have been obvious to combine Babayoff and Inglese for the reasons described in connection with claim 1 and the requirements of claim 1 are satisfied for that reason. Combination with Graham discloses the remaining limitations. Graham discloses, "if the color characteristics for a patient fall between two shades, some of interpolation may be applied to the two shades to produce an additional shade for the patient's tooth that suitably fits the generated color characteristics for that patient." Ex. 1107, Graham, ¶0050.

160. As discussed in claim 1, Babayoff modified by the teachings of Inglese uses measured color values compared with reference tooth shade vales to determine tooth shade values for dental prosthetics and restorations. A POSA would have been motivated to modify the tooth shade values determined by Babayoff and Inglese using the teachings of Graham to generate a more accurate tooth shade value. A POSA would have been motivated to increase the accuracy in this fashion because

both Babayoff and Inglese discuss, at length, efforts to obtain accurate and natural-looking tooth shade, and Graham provides a straightforward solution using interpolation.

161. Moreover, Babayoff, Inglese, and Graham are all in the field of determining appropriate shade values for dental prosthetics and restorations. *See*, *e.g.*, Ex. 1105, Babayoff, 27:59-62; Ex. 1107, Graham, ¶0036. The addition of the interpolation of shade values to Babayoff and Inglese would have required nothing more than the addition of a database of known shade values as disclosed by Inglese (Ex. 1109, Inglese, ¶0085) and Graham (Ex. 1107, Graham, ¶¶0049-50) and a simple code to perform the interpolation when a measured color falls between two reference tooth shade values. Both of these things were well-known and could have been implemented by a POSA.

162. Thus, it would have been obvious to a POSA to combine Babayof and Inglese with Graham to arrive at the claim 3 limitations.

F. Ground 6: Claims 16 and 17 Are Obvious Over Babayoff and Inglese and Nathaniel

1. Claim 15

"16. The method according to claim 15, wherein combining the texture information from the sub-scans comprises interpolating the texture information and/or calculating an average value of the texture information."

163. In my opinion, Babayoff in combination with Inglese and Nathaniel, discloses, "wherein combining the texture information from the sub-scans comprises

interpolating the texture information and/or calculating an average value of the texture information." The limitations of claim 14 are met by Babayoff and Inglese for the reasons discussed above in connection with claim 14 of Ground 4. Further, as discussed above in connection with claim 15 of Ground 4, Babayoff in combination with Inglese discloses using the texture data of overlapping scans to build a 3D representation of a tooth, which includes "combining the texture information from corresponding parts of a number of the sub-scans." Ex. 1105, Babayoff, 23:48-25:3. However, to the extent that Patent Owner argues Babayoff in combination with Inglese does not disclose this limitation, it is disclosed by Babayoff combined with Inglese and Nathaniel.

164. As discussed above, Babayoff recognizes that "theoretically the corresponding entities should have a portion of their data identical to one another within the overlap zone. However, since the scanner itself moves in orientation and position from scan to scan, the coordinates relating to these overlap zones will usually vary between adjacent scans, even though they relate to the same spatial feature." *Id.*, 23:59-65. Babayoff also recognizes that, "ambiguity may occur . . . if a part of the intra-oral cavity (corresponding to part of the overlapping scanned data in some of the entities) moves in relation to other parts." *Id.*, 24:14-18. A POSA reading Babayoff may recognize that for values of the same tissue type (*e.g.*, teeth) Babayoff does not address ambiguity arising from the variance between adjacent

scans. Thus, confronting this ambiguity, a POSA would look elsewhere to improve the determination of color values in overlapping scan regions.

165. Nathaniel is similarly directed to the creation of 3D models from a series of scan images and is analogous art. Nathaniel addresses the problem of determining an appropriate value of a pixel in overlapping images. Ex. 1111, Nathaniel, ¶¶0024, 0043. To determine the appropriate value for a given pixel, Nathaniel computes an "average" or "weighted average" of the pixels in each of the overlapping images. "If such appropriate pixel occurs in more than one X-ray image, the preferred embodiment of the invention uses the pixel which is closest to the center in its original X-ray image in order to minimize image distortion. For this pixel, the X-rays are closest to perpendicular to the imaging Surface. Other embodiments may use an average value of the original pixels, a weighted average, the maximal or minimal gray level value, or any other decision rule." *Id.*, ¶0099.

166. A POSA would have recognized that methods of combining appropriate pixel data from the overlapping images might result in a more accurate determination of color data when combining the sub-entities of Babayoff. Thus, a POSA would have been motivated to try to improve the color determinations of Babayoff and Inglese using the "average" and "weighted average" of Nathaniel. A POSA would have encountered no technical hurdles when testing the methods of Nathaniel in the context of Babayoff in combination with Inglese. A POSA would

have merely needed to write and execute simple computer code to take the average or weighted average of the datasets rather than combining datasets or disregarding one data set in view of the other. An undergraduate student of computer science could write and execute such code.

167. Thus, it would have been obvious to a POSA to combine Babayoff with Inglese and Nathaniel to achieve the limitations of claim 15.

2. Claim 16

"16. The method according to claim 15, wherein combining the texture information from the sub-scans comprises interpolating the texture information and/or calculating an average value of the texture information."

168. In my opinion, Babayoff in combination with Inglese and Nathaniel discloses, "wherein combining the texture information from the sub-scans comprises interpolating the texture information and/or calculating an average value of the texture information." As discussed in claim 15 of this Ground, Babayoff in combination with Inglese and Nathaniel determines the average value of the texture information. Claim 16 is obvious for the same reasons.

3. Claim 17

"17. The method according to claim 16, wherein the calculated average value is a weighted average of the texture information."

169. In my opinion, Babayoff in combination with Inglese and Nathaniel discloses, "wherein the calculated average value is a weighted average of the texture information." As discussed in claim 15 of this Ground, Babayoff in combination

with Inglese and Nathaniel determines the weighted average value of the texture information. Claim 17 is obvious for the same reasons.

VIII. CONCLUSION

I am of the opinion that Claims 1-3, 6, 7, and 9-17 of the '151 patent are invalid for at least the reasons given above.

I hereby declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct, and that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. § 1001).

Executed on _____, 2022

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