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3D e-Shade dental color matching intelligent system

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***Abstract*-**Shade matching is a much complicated task then it may look like. Variability of the factors which influence the shade matching procedure should be minimized. There is a need for a new, better, logically and scientifically arranged shade guide which would cover the complete color range of natural teeth. The project proposes to accomplish a color prosthetical establishing performing system through image processing methods by using cumulative informations concerning chromatic analysis and also the transparency variation depending on work's 3D geometry. By realizing a bidirectional communication routine on a cable support dentist office- dental technician laboratory it is facilitated the establishing of the acquired information volume and quality sufficiency, on the one hand, and on the other hand the prosthetical work delivery programming depending on the material and human resources available in the dental technician laboratory.

I. Introduction

The color of teeth probably constitutes one of the most important parts of our first impression of someone. One of the most important steps in dental restoration (dental prosthesis) is represented by the perfect determination of the dental color. The difficulties associated with dental color matching have led to the development of a number of systems that attempt to replace visual assessment with instrumentation-based assessment using various types of spectrophotometric and calorimetric instruments.

Although the idea of basing shade matching on objective measurements rather than on subjective visual color assessments seems appealing, such measurements are extremely difficult to perform in practice. As a result, reports from dentists and dental laboratory personal indicate that the level of performance of currently available instrument-based shade matching systems is not entirely acceptable. Uncertainties resulting from available instrument-based systems generally require that traditional visual assessments must still be performed for verification.

Thus, much of the values of such systems are largely negated. Color matching is complicated by individual differences in color perception and different ability of color discrimination. Culipepper has found differences among dentist concerning shade matching for the same tooth. It happens that the same dentist matches different shade for the same tooth in two days. Dentists, dental technicians and dental students should go through some of the color vision tests having in mind that about 8% of males and about 0.5% of females have color deficiency.

The most popular color vision tests are Ishihara Charts and 100 Hue Farnsworth Munsell test. If one has color deficiency it certainly does not mean that he can not study dentistry or be a dentist, that is dental technician – it only means that he needs help in shade matching [1].

The failures and limitations of currently available shade-matching systems, both instrument-based and visual-based, can best be understood by examining the difficulties involved in matching the appearance of human teeth. First, tooth color is a complex interaction of reflection, transmission, refraction, fluorescence and scattering by a variety of organic and inorganic components. It is influenced by variations in the composition, structure and thickness of the dental tissues. One result of this complexity is that color appearance and color measurement are greatly influenced by lighting geometry, surrounding colors and other environmental factors [2].

In our days are used two identification methods to prescribe the color's shade, which supposes:

- the manual comparison of the color's resident formations in oral cavity with the existing shades in a color key;
- the automatic comparison through image's numerical processing, image acquired with a video camera.

After identification, the color's code is transmitted to the dental technician, situated, in the most of the cases, in a laboratory with a different geographic location against the dentist. The ensemble of the automatic identification procedure of the dental color and chromatic implementation of the prosthetic restoration contains two errors generators elements referring to the chromatic shade matching:

1. The color's code identification is realized based on the chromatic analyze of the formations residents in the oral cavity. The physical implementation of the prosthesis, after shade code, doesn't lead to a perfect matching with the resident dental formation's shade because the execution material (the composite or the porcelain) has a specific degree of transparency, so that there is a dependency between materials' chromatic and the prosthesis's 3D geometry.
2. The dental technician's materials case has only a limited number of chromatic shades, and many times the cases are incomplete. The chromatic combinations implementing possibility with the elements existing in the case are limited because of the inexistence of a receipt to combine elements.

This paper's proposal is to develop an advanced computer based system capable to minimize the dental prosthesis matching errors.

In this moment, at national and international level, two dental color identification methods are used. The most knew is the color key and it has to do with the dentist's objective ability to determinate the color of the new dental prosthesis through comparison [3]. The method consists in successive application of the key's elements next to the dental formations whose color is searched. The comparison and the right decision of the dentist must take into account the shade, the saturation, and the brightness of the dental formations. The votive color keys and the most used are produced by Vita Company [4].

Another method is video analyze, which is a modern solution of automatic identification of dental color.

A. Video 3D color establishing system's architecture

The 3D e-Shade system is based on virtual instrumentation vision techniques and it is implemental on hardware structures that already exist in dentists' office, as intraoral cameras. The proposed procedure, in obtaining the dental prosthesis chromatic, will be developed on 2 levels: the dentist's level and the dental technician's level, as it is presented in figure 1:

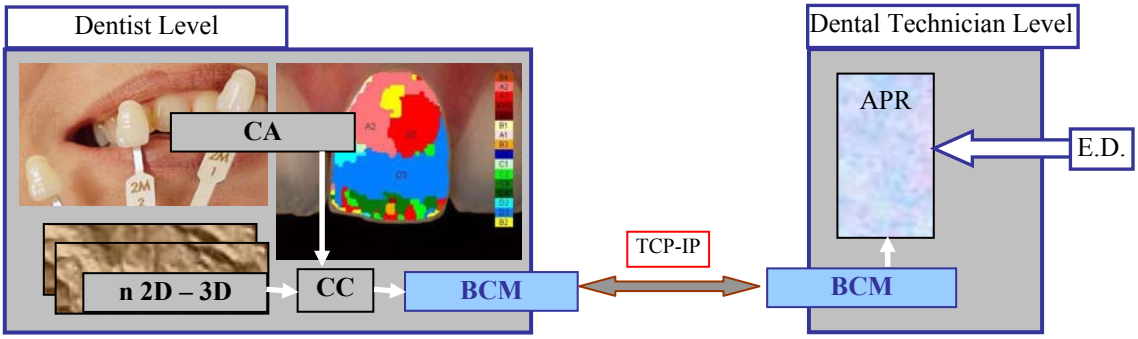

Figure 1. The prosthetical work chromatic prescription algorithm

At the dentist's level, the dental color prescription implies the placement in the neighborhood of the patient' teeth intervention zone of the color reference element (realized from the same material as the future dental work) and the acquisition of the images: resident dental formation – color reference. The chromatic analysis (CA) algorithm in HSL space (hue, saturation and luminance) realizes a comparative investigation between the reference and the investigated formations.

The 3D geometrical synthesizing of the prosthetical cavity is realized by the n2D- 3D algorithm, which uses as entrance data the 2D images, acquired from different angles. The algorithm of cumulative calculus of color's code (CC), realizes the correction of the chromatic analysis on the basis of specific transparency depending on the dimensional parameters of the execution material.

At the dental technician level it is elaborated the color combination reciper of the composite or porcelain material. Using the composition reciper prescribing algorithm, after introducing the entrance data (ED), relating to available colors, there are prescribed the combination colors and their percentage.

The e-services between the dentist and the dental technician are realized through bidirectional communication modules (BCM), using the TCP-IP protocol. The physical connection is assured by the Ethernet interconnection, by using a meeting server.

B. The 3D e-Shade system's benefits

One important stage in realizing the dental restorations (dental prosthesis) is represented by a correct color determination. This operation, realized through manual or automated comparison, is followed by color code transmission to the dental technician, who is in a laboratory situated in a different geographical place from the one of the dentist's [5].

The recent clinical studies realized according to United States Public Health Service (USPHS) norms, are pointing out the fact that the dental restoration chromatic matching percent is approximately 40% and depends on the type of the used equipment. This way, for the Vita Classical shade guide, using a representative sample of investigated persons, it was obtained a 46,67% chromatic matching, for Vita 3D Master guide: 56.67% and for ShadeEye automated system: 40%.

In this context, the objective is to develop an advanced information system able to minimize the chromatic matching errors of the dental prosthesis, errors caused because in the present it isn't discussed the transparency problem of the material used for the prosthesis and the possibility of realizing chromatic recipers at dental technician level.

The novelty of the present system, at general level, is given by the development of a new prosthetical work color establishing system, with a high degree of performance comparing to the existent procedures/equipments at this moment, which will minimize the influences of the sources identified as chromatic shade matching errors generators.

Actually, the novelty of the system is given by the development of new dedicated algorithms which allows accomplishing the objective:

- 3D geomatrix synthesizing algorithm based on multiple 2D images acquisition, which allows, through cumulative estimation, correcting the color code, prescribed through comparative chromatic analyze between the reference and the resident formations, and which regards the negative influences generated by the transparency degree of the materials used in dental prosthesis realization;
- The algorithm of realizing chromatic combinations with the existent elements in the dental technician's medical case, by prescribing the composition reciper.

The originality of the proposed solutions regards the development of the *3D e-Shade* system (operating compatibility viewpoint) on the existent hardware architecture in dental laboratory, as an intraoral video camera, so that the implementing costs, regarding the dentist and the dental technicians, will be reduced at software acquisition level.

II. Conclusions

This system relates to a method for determining a patient's tooth shade comprising the steps of electronically imaging a patient's tooth to obtain an image which includes color information representative of tooth color; determining the patient's tooth color from the color information of the image; and displaying the determined tooth color to identify one or more tooth shades having a combined color corresponding to the determined tooth color.

The displayed data includes HSL chromaticities of the color image, and the patient's tooth is determined by averaging the color information at selected locations of the image which correspond to different spatial locations of patient's tooth. If desired, the color information can be electronically stored for use at a later time. Both the shade matching environment and communication between dentist and technician should be optimized with use of visual and instrumental shade matching systems [6].

The objective of this paper 's proposal is to develop an advanced information system able to minimize the chromatic matching errors of the dental prosthesis, errors caused because in the present it isn't discussed the transparency problem of the material used for the prosthesis and the possibility of realizing chromatic recipers at dental technician level.

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