GRADUATION PROJECT

Degree in Dentistry

Color in dentistry: spectrophotometry, intraoral scanner

Madrid, academic year 2022/2023

Identification Numbers 77

Resumen

Introducción : La medición del color del diente fue fundamental en el plan de tratamiento. Permitió reducir el fracaso del tratamiento y aumentó la satisfacción del paciente. Muchos factores influyeron en la toma de color como la luz y todos estos parámetros. Era fundamental conocerlo para tener buenos resultados. Se han desarrollado muchos dispositivos que permiten mejorarlo.

Objetivos : El objetivo principal de este trabajo fue evaluar y comparar los resultados obtenidos en términos de precisión de medida, repetibilidad del color gracias a las múltiples técnicas utilizadas en la actualidad. Los objetivos secundarios eran saber cuál de las medidas de color era la mejor teniendo en cuenta otros factores que eran útiles en el uso cotidiano (facilidad de uso, relación de la prótesis…)

Metodología : Para obtener resultados significativos se utilizaron diferentes recursos como PubMed, Wiley, Springer, JPD. Se utilizaron principalmente artículos científicos, libros y tesis.

Resultados: Tras aplicar los criterios de inclusion y exclusion se obtuvieron un total de 692 articulos. Finalmente, se incluyeron en la revision 11 articulos, que comparan los differentes resultados en la toma de colores comparando el escaner intraoral, los espectrofotometros y las differentes guias visuales.

Conclusiones : Los métodos digitales tuvieron mejor resultado que el obtenido por el método visual. Vita 3D master y Vitapan 3D ofrecieron mejores resultados que la clásica guía visual. El espectrofotómetro fue considerado como la referencia en la toma de color en odontología. Por otro lado, el escáner intraoral mejoró considerablemente y tuvimos mejor precisión y repetibilidad con este dispositivo. La diferencia era bastante pequeña. Pero las herramientas de referencia tenían muchas ventajas como la velocidad de uso y la no influencia de las fuentes de luz ambiental.

palabras clave: escáner intraoral, espectrofotómetro, guía visual de colores, selección de colores dentales, determinación del color dental.

Abstract (English)

Introduction: The measurement of color of the tooth was essential in the treatment plan. It permitted to reduce the failure of treatment and increased the patient satisfaction. Many factors influenced the take of color, like the light and all these parameters. It was essential to know it to have good results. Many devices have been developed that permits to improve it.

Objectives: The main objective of this work was to evaluate and compared the results obtained in terms of precision of measurement, repeatability of color thanks to those multiples techniques used nowadays. The secondary objectives were to know which of the color measurement was the best in taking account other factors that was useful in use of everyday (facility of use, prothesis relationship…)

Methodology: To obtain significant results, different resources were used such PubMed, Wiley, Springer, JPD. Scientific articles, books and thesis were mainly used.

Results: After applying the inclusion and exclusion criteria, a total of 692 articles were obtained. Finally, 11 articles were included in the review, which compare the different results on taking of colors comparing the intraoral scanner, spectrophotometers, and the different visual guides.

Conclusions: The digital methods had better result than one obtains by visual method. Vita 3D master and Vitapan 3D offered better result than the classical one visual guide. The spectrophotometer was considerate as the reference on the take of color in dentistry. In other side intraoral scanner improved considerably and we had better precision and repeatability with this device. The difference was quite small. But the reference tools had many advantages like the speed of use and the no influence of the ambient light sources.

keywords: intraoral scanner, spectrophotometer, visual shade guide, dental shade selection, tooth color determination.

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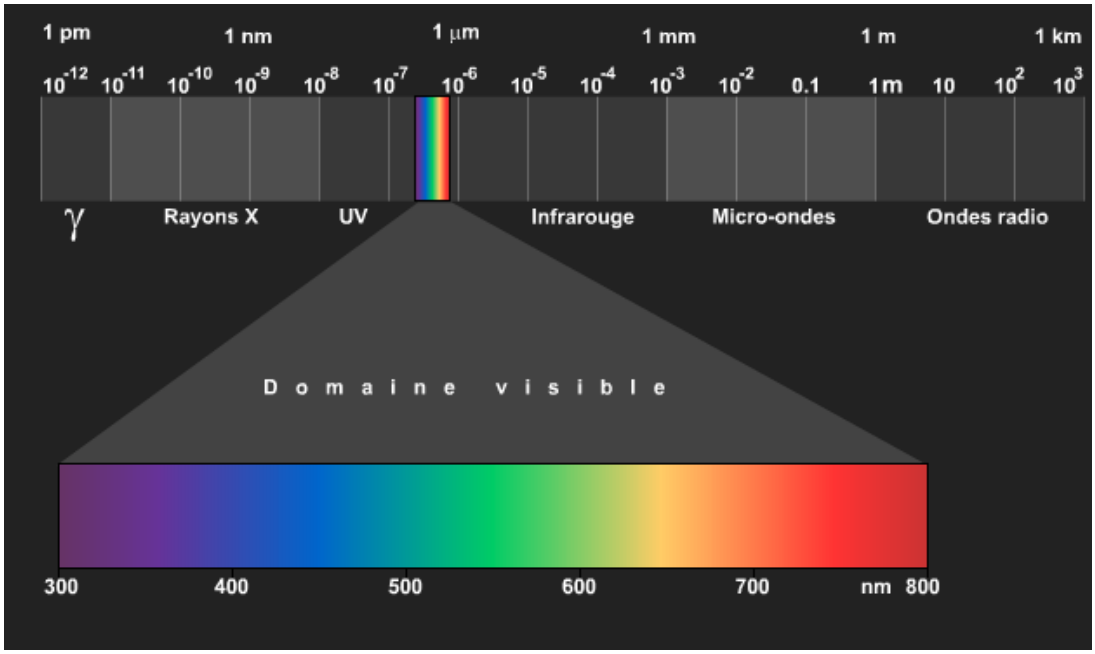
1 Introduction

1.1 Color

1.1.1 Quick history and definition

To understand the principles of color perception, we must talk about firstly on the basis of the properties of light. Natural light is composed of a large electromagnetic spectrum. Humans are only able to see wavelengths between 380 nanometers (violet) and 760 nanometers (red). Below it is ultraviolet radiation and above it is infrared radiation. All visible colors can be created by mixing three primary colors: red (760-620 nanometers), green (560-490 nanometers) and blue (490-430 nanometers).



Picture from (1)

Color perception is the relation between the light, the object, and the observatory. When light interacts with matter, some of it is absorbed and some reflected. The reflected portion defines an object's color.

To perceive color correctly, two rules are paramount: 1. incident light must contain all visible wavelengths; 2. incident light must be neither too weak nor too strong.

To respect these 2 rules, determination of color must be done with the daylight. In esthetic dentistry, it is recommended to work with the lamp between 3000-4000 lux. The rest of the room must be at 1000 lux. Another important aspect is the observatory. Sensorial retinal cells implicated are the cones Red, Green, Blue (chromatic perception) and beam (luminosity perception). However, observatory can be affected by trouble that modify the perception of colors.(2)

1.1.2 Different factor to take in account.

1.1.2.1 Hue (tone)

Hue is the quality that distinguishes one family of colors from another. The wavelength reflected by an object is what determines color, and there are many colors like purple, blue, green, yellow, orange. Color has a lesser influence than shape when considering how two objects might look alike. (3)

1.1.2.2 Luminosity (value)

It corresponds to the quantity of white that we have in the color, and it is measured by the degree of clarity or obscurity of an object. White is the color that reflects lighter and has a value of 100; other side black has a value of 0. This estimation must be done with low luminosity environment to stimulate better cones of retinas. (3)

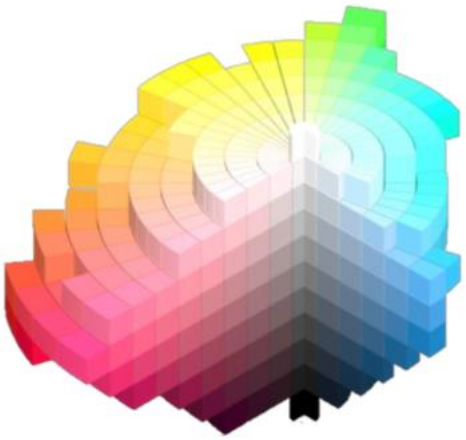
1.1.2.3 Saturation (chroma)

Saturation is the intensity or density of a color. It is defined by the purity of the color's pigment and by this quantity. The more saturated a color is, the more it will look like its corresponding hue, and inversely, less saturated colors will appear grayish or blackish. (4) (3)

1.1.3 Representation of system of color

1.1.3.1 Munsell color system

This system was presented by albert D. Munsell at the beginning of the 20th century. It is designed as a wheel that contain all color inside. It was organized according to three parameters: the Hue, Value and Chroma (4)



Picture from (5)

1.1.3.2 Trichromatic

This system takes only the primary colors (red, green, and blue). In mixing these three colors, we can find all the different colors. The three-color system was developed because humans are trichromatic creatures--our eyes have three kinds of cones that have different

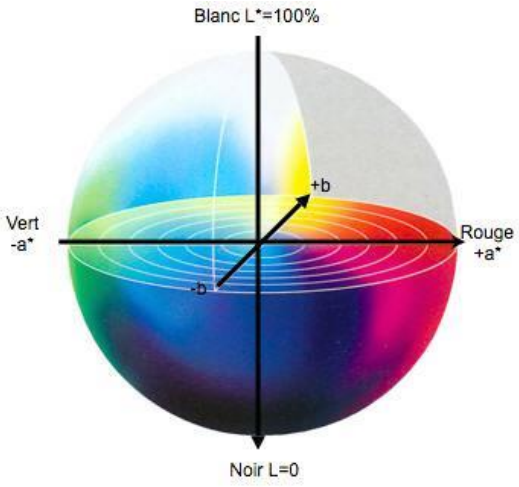
sensitivities to light. We see all these colors because of this biological trait. Nowadays, this system is not used anymore. (5)

Picture from (1)

*1.1.3.3 CIE L*A*B* model*

In 1976, the International Commission on Illumination (CIE) developed a new tridimensional color system based on three axes--the L* axis corresponding to luminosity (white: 100, and black: 0), the A* axis to green when it is positive and red when under 0, and the B* axis blue when is positive and yellow when it is negative. All colors are defined by a value for each of these axes. Other parameters like saturation and hue are also defined.

Its main advantage is the fact that we can express the difference of color in units. This result can be related in clinical and visual perception. (1)(4)



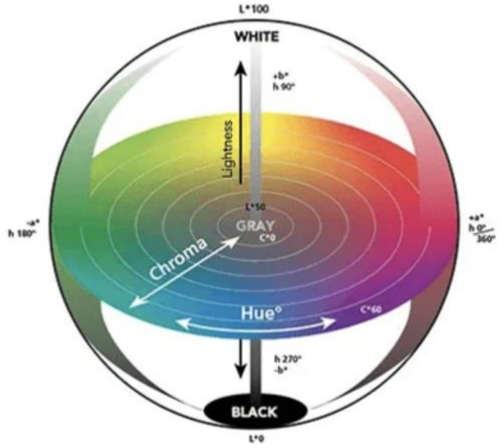
Picture from (1)

1.1.3.4 Model LCH

It uses the same diagram of the L*A*B* system, but it also exploits the cylindrical part instead of rectangular value (LAB).

L is the same that L* and corresponds to the luminosity. C (chroma) is the saturation and H the tone (hue). The valor is 0 at the center of the diagram and increases when we will go to the extremities.

The Tone (H) extends between 0° to 360°; angles between 0° to 90° represents reds, oranges, and yellows. To the 90° to 180°, it will be yellow, yellow-green, green. 180°-270°: green, cyan, and blue. Finally, between 270° to 360° it corresponds to blues, magenta and finish to the red (0°).



Picture from (1)

1.2 Light

1.2.1 Definition

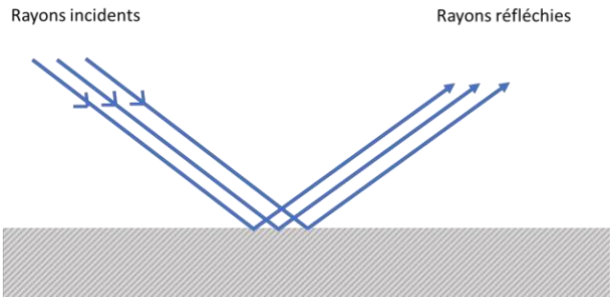
The visible light spectrum that humans can see corresponds to electromagnetic waves between a specific wavelength. The term "visible spectrum" refers to wavelengths between 380 and 780 nanometers. While we cannot see beyond this range, ultraviolet, infrared, micro-nodes, radio waves and gamma rays exist in this range as well. Color phenomena results from the interaction of three factors: the light source itself, lightning strikes on objects, and subjective experience by observers. (5)

1.2.2 Factors that influence light

When light hits the surface of an object, it can be reflected, either directly or by passing through other objects. Three different types of reflection can occur: specular reflection, diffuse reflection, and total internal reflection.

The specular reflection is caused by light bouncing off a shiny surface at right angles to its surface; the diffuse reflection is when light is reflected off an uneven surface; whereas total

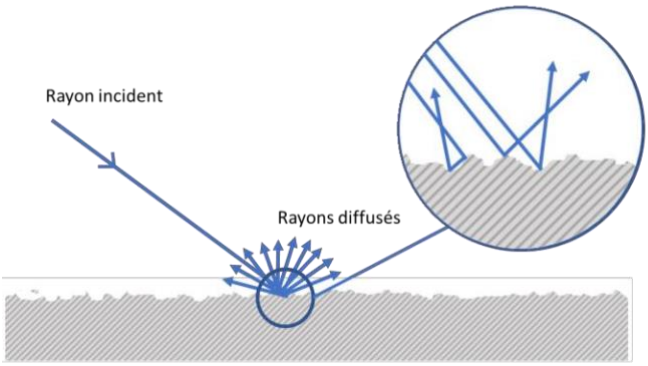
internal reflection occurs when light enters a medium such as air or water and reflects out again. (5)



Picture from (5)

1.2.3 Diffuse reflection

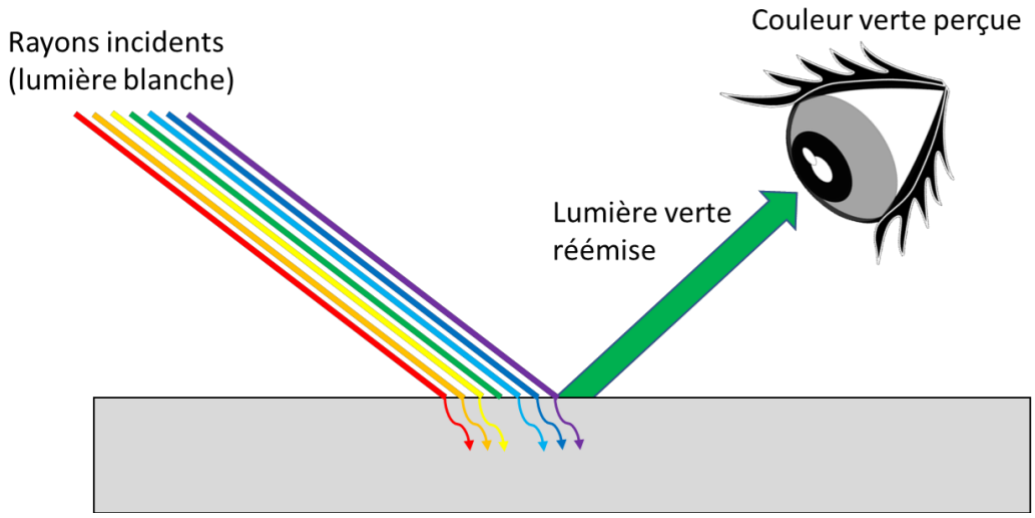
In the case of diffuse reflection, we have a roughness in our surface. The wave is not only reflected, but also diffused in all directions. These rays have the same light spectrum than the incident light, which will give the luminosity. (5)



Picture from (5)

1.2.4 Absorption

The fact that light is absorbed by a transparent or semi-transparent object is due to the diminution of its energy in contact with the object. The absorbed rays are subtracted from the color of the object, and we talk about selective absorption. (5)



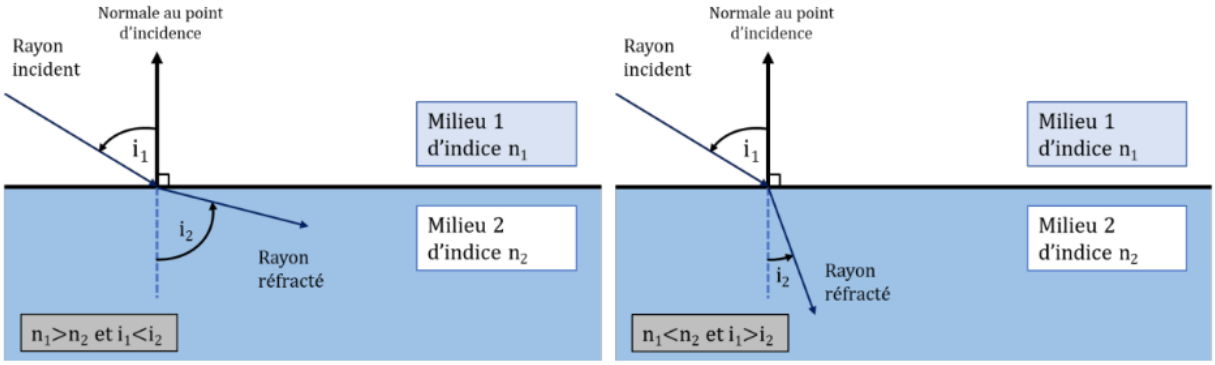
Picture from (5)

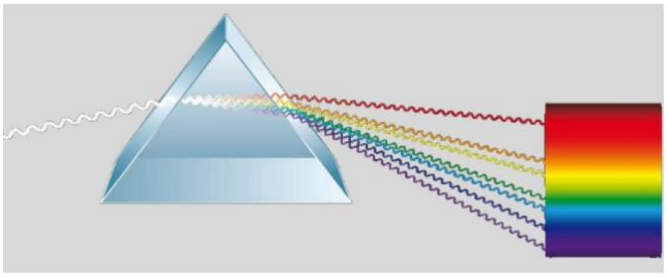
1.2.5 Transmission

Transmission of light can take different forms: refraction or diffusion. (5)

1.2.6 Refraction

Deviation is the phenomenon of light change its direction according to the speed when they pass to another state. It depends on the wavelength. Red is less deviated than the orange, and we follow this order. The light propagation in the dentin tubules follows this principle; We have a total refraction, and in this case the incident light is not reflected. (5)

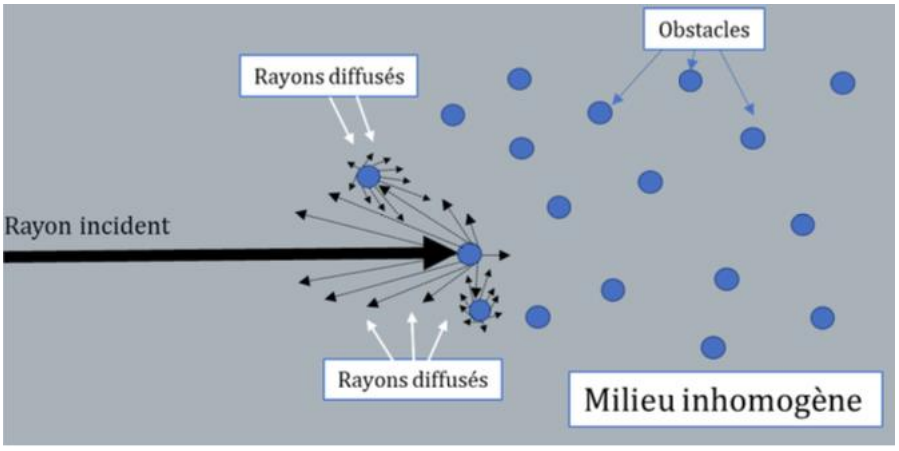




Picture from (5)

1.2.7 Diffusion

It is the deviation of light rays in many directions as they pass through a place that is not homogeneous. Heterogeneous composition of dental tissue termites produces these phenomena by producing diffusion between enamel and dentin. Organic and inorganic parts are at the origin of this diffusion process. (5)



Picture from (5)

1.2.8 Opalescence

It is a property of enamel that creates different colors depending on the direction of light. It results from wavelength dispersion, diffraction and dispersion occurring as light passes through hydroxyapatites crystals and organic parts. Furthermore, It is present mainly at the incisal end with slight bluish color. (2)(3)

1.2.9 Translucency

The quantity of light that passes into an object is called the transmissivity of the material. Transmissivity refers to the ratio of how much light passes through a surface (translucency) compared to how much light is reflected by that surface (opacity). Translucent enamel has a low transmissivity and translucent dentin has a high one due to their differing composition: dentin is composed mainly of organic matter, while enamel is mainly composed of inorganic minerals. Since the mineral content is higher in dentin, it reflects lighter than enamel does. (2)(3)

Picture from (2)

1.2.10 Fluorescence

It is defined by a decade emission of light to a part by a superior light energy. Natural teeth have a with-blueish fluorescence who is more produce by the dentin than enamel.

This property is in relation to organic part of collagen fibers. It is well seen in presence of UV light or photograph accessories that we can use in dental. (3)

1.3 Color in dentistry

1.3.1 Property of color of dental component

The optical properties of the teeth originate from their hard tissues: dentin and enamel. These two do not have the same behavior with light; this influences the color of the tooth. Dentin is opaque, it reflects light and defines mainly the color. It corresponds to parameter A* and B*. Enamel is translucent: it considers like a specter that free pass-through light to dentin. It regulates the quantity of light that can go to dentin. Corresponds to parameter L*

1.3.1.1 enamel

The crystalline structure of enamel is made of hydroxyapatite crystals that contain 87% of inorganic matter, 11% of water and 2% of organic matter. These crystals allow for the transmission of most visible light to dentin. Enamel is translucent and has a low ability to affect color. It exists in phenomena of light diffusion thanks to the crystals that interact with short wavelengths (near blue). This will give a blue property to the tooth at the border (opalescence). It is also responsible for fluorescence; it is linked with its organic part, which absorbs ultraviolet light and then re-emits visible light at short wavelengths (blue). (5)(6)

1.3.1.2 dentin

Dentin has a less mineralized structure and more heterogeneity than enamel. It is composed of 50% mineral matter, 30% organic matter and 20% water. The structural and chemical heterogeneity of dentin influences the spread of light; it contains 15 times more

proteins than enamel do, which generate an opacity for the light and produce a yellowish color. At the structural level, that are the orientation, density, numbers, and diameters of tubules that play a role in the propagation of the light. (5)(6)

1.3.1.3 composite

There are many types of composite resins used to reproduce teeth. They can be divided into four groups: body, dentin, enamel, and translucent. The main difference between them is translucency (the body and dentin are less translucent). The shade of composite depends on the technique used by the practitioner; however, special shades for bleached teeth (white or extra white) are also used. Polishing has a lot of influence in reflection light. (7)(8)

1.3.2 different biotype of teeth

The evolution of dental tissue depends on the age of the patient and is one of the main factors for a prosthetist to determine color and texture. Classics phenomena include diminution of luminosity, augmentation of saturation, little change in texture.

Change in color depends mainly on hygiene of patient. Chevalier and Coll have proposed a classification of stratification of color comprising 4 biotypes where all teeth are included. 5 criteria of classification are selected: dentin core (color, shade, and luminosity), dentin part of incisal third (visibility and coloration), enamel (whiteness, transparency, opalescence), enamel at contact point level (color), incisal edge characterization (characterization) (2)

1.3.2.1 « Simple » Biotype

It is teeth that have low characteristic with a low degrade at cervical level, not have a transparent enamel and no effect at incisal edge, dentinal part is not visible, and contact points are well-defined. (2)

1.3.2.2 « opal » biotype

It is characterized when we have an incisal edge with blue opalescence with characteristic of a white line light at incisal level. Enamel is quite transparent, and dentin is more visible. Contacts points are quite bluish. It is one of the most frequent one. (2)

1.3.2.3 « Deep dentin » biotype

These teeth are characterized by a dentin that is clearly visible with an enamel transparent and little opalescent. Dentin can have many shades with effect of saturation in deeper and gradient pronounced. Contact points are gray. It is one of the most frequent one. (2)

1.3.2.4 « Bi zone » biotype

These teeth have two zones quite differences. On cervical half has dentin which is quite luminous, uniform, and opaque and the incisal part where it is the enamel that give the color, which is transparent or gray, sometimes opalescent. (2)

Illustrations des quatre biotypes de stratification selon J.-M. Chevallier, J.-P. Pia et J.-F. Lasserre : Biotype 1 dit « Simple » (a), Biotype 2 dit « Opale », Biotype 3 dit « Profond dentinaire » et Biotype 4 dit « Bi-zone ». Les biotypes 2 et 3 sont les plus fréquents.
(Biotype 4 CreditPhoto@Quintessence_International)

Picture from (2): picture A is simple biotype, B opal biotype, C deep dentin biotype and D is bi-zone biotype

1.4 Subjective take of color

Nowadays, it is the most famous and convenient way to select the tooth shades. It is not expensive and the guide that is made take in account all the different color of teeth that are the most frequent.

1.4.1 Vita guide

1.4.1.1 Vita classical shade guide (VC)

It is mainly based on the Hue. We have 16 values that are divided into 4 groups of color (chroma):

- A: reddish brownish
- B: reddish, yellowish
- C: grayish
- D: reddish gray

The luminosity varies between 1 and 4 (the whitish one until the darker) (9)

Picture from (1)

1.4.1.2 Vita tooth guide 3D master (V3DM)

It has 26 tabs that are divided into five groups, depending on the color and lightness. The first number (1 to 5) in front of the letter corresponding to the lightness level indicates how light or dark a tooth is; 1 is lighter and 5 is darker. The number just below (1; 1.5; 2; 2.5; and 3) below the letter corresponds to hue or chroma--how close to white or black a tooth is. The characteristic of this guide is the presence of new parameter that is bleaching shades (0M1, 0M2, 0M3) that indicates more lightness, middle hue and three levels of chroma. The main difference with the classical one is made depending on color value, where the classical one is made depending on color hue. (9)

Picture from (1)

1.4.1.3 Custom shade guides

Vita guide (both classic and master) is useful for 85% of color selection. For the rest, it is possible to prepare a custom of shade tabs to have the best measure as we can. It is made with composite resin, ceramic, or acrylic material. We reproduce the color of the tooth with surface colorant or abrasion, and we can make fine line marker to reproduce any details. It is very useful for the prosthetist; he knows exactly all the parameter that affects the color of the tooth. (4) (10)

1.4.1.4 Dentin and extended shade guides

This system is useful in case of the fabrication of veneers and ceramic crown. Dies are used to custom the guide. It comprises the tabs of all materials used to fabricate the restoration and purpose more choice.

Assistance tools like a calibrated lamp or photography can help to improve the take of color.

The calibrated lamp produces the ideal light (between 5500 and 6500 k) in a calibrated and continuous way. (10)(11)

Figure 22 : Lampe calibrée Smile Lite®

Source : Smile Line SA, « Smile Lite », 2020.

Picture from (11)

1.5 Objective takes of color.

1.5.1 Colorimeter

This instrument measures the light reflected from the object using the same sensitivity as the human eyes. It used the three sensors filtered. the method is the same as our eyes. Furthermore, it depends on the trichromatic value.

One of its disadvantages is the necessary to have a standardized illuminant background to produce objective color data. Furthermore, metamerism is also produces. it is the property of a color to modify at this visual aspect according to the light nature. Colorimeters are quite sensible to the elders of light source. Calibrating with white color before any use is essential . (8)(12)

1.5.2 spectrophotometry (SS)

This equipment permits to measure the color of natural, whitening, or restored tooth. It is used to determinate the color speedily and independent with her environment. The first utilization in dentistry was in the 1970s. According to many studies it has a reproducibility of 80% of the color, human eyes have only a 65%.

How it works?

Spectrophotometer mades a punctual measure of the reflecting specter of the tooth. It emits a flash of white polychromatic light generated by a LED. This light has a temperature of color of 6500K (natural light in mid of day)

It is necessary to calibrate the light before any measure. A white balance is effectuated with the support of the spectrophotometer. Once done, we can measure.

Thanks to the white flash, the result is not influenced by the environmental light. It is one of his main advantages when we compare with other instruments.

This light flux interacts with the tooth and will be reflected in part. Other part is absorbed. The light spectrum that goes back to the spectrophotometer corresponds to the color. This apparel has a receptor for any 10 nm of the visible wavelength (30 in total). It assures a good precision of measure.

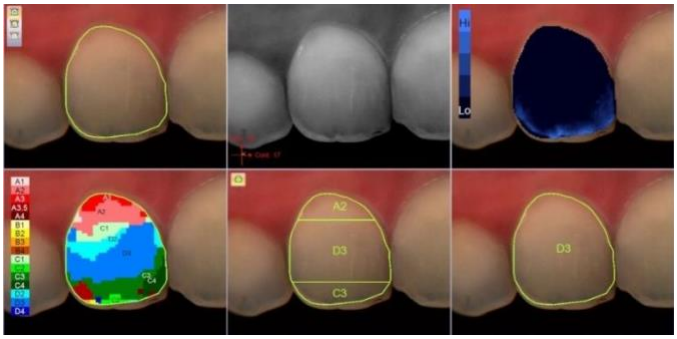
We have a panel of 81 different colors that we can measure. It is nearly three time more than the vita 3D master guide that we use to measure with the eyes.

We can measure in two different ways.

We can take all the tooth in account and the value will be the average of the measure of the teeth. We have 30 measures in this case.

Other side it is possible to measure part by part (incisal, central, apical). It will be more precise and permits to have a perfect color of teeth that will look like more natural if it is for prothesis use. It is quite useful in case of problem of enamel like fluorosis, MIH, or tetracycline stains. We will measure the part that is less affect by its change. (5) (13)

Picture of vita easy shade compact from (1)



Picture of degudent shade pilot from (1)

1.5.3 Intraoral scanner (IOS)

Intraoral scanner has made huge progress in dentistry for 10 years. It is comprised in the CAD/CAM system that permits to do everything digitally. We take an impression of the oral cavity thanks to the scanner, and we will design restoration model with the computer-aided-

design (CAD). Computer-aided manufactured (CAM) selects the Materials and builds the final Product.

For 10 years, there are many improved that are made to make the impression rapidly, precise, and easy to do. It will transcribe the oral cavity including the target teeth and the tissue that surrounds. We have a 3D representation. It takes in account, the shape of the teeth, the colors, and the gingival parts.

The mains advantages of this apparel are the reducing of patient pain and discomfort; we do not need to do alginate impression or silicone to a prothesis impression; it facilitates our uses and the comfort of patient. It measures the color in an objective way, and we have less error than an objective one. After training, it is easy to use intraoral scanner and it permits to reduce error of impression.

nowadays, another point is needed to take in account is the infection. The scanning tip of a scanner is sterilizable. The Transfer of the 3D images do not require handling of impression material, which are source of infection.

We have also a virtual follow-up, that is useful in long-term.

In the other sides, it presents some disadvantages. It needs training to perfectly use the scanner. It is necessary to have a dry operating field, in the presence of oral fluid it could produce measuring error due to optical reaction. Patients with sialorrhea are contraindicated. In some case, when the patient has a small mouth, it is difficult to have a good representation of the system. Nowadays, it is an apparel that is expensive and not every dental work can permit to use it. (14)(15)(16)

Picture from (14)

This subject permits us to have a global presentation of the different ways to take a color in dentistry. We have a comparison between them, and we can know which one is the better and the advantages and disadvantages of each one.

1.6 Justification of my work

This thesis permits to have a good comparison between the different technique of take of colors. It is essential nowadays to improve our daily use with the news technologies

2 Objectives

2.1 General objective

- To evaluate and compare the results obtained in term of precision of measurement, repeatability of color thanks to those multiples techniques used nowadays.

2.2 Secondary Objective

- To know which of the color measurement is the best in taking account other factors that is useful in everyday use (practice facility, prothesis relationship…)

3 Methodology

This work was done thanks to the use of different information tooked by means of scientific articles, books, document, thesis.

The search strategy was made through 7 different sites of research (written below). I used the following keywords: intraoral scanner, spectrophotometer, visual shade guide, dental shade selection, tooth color determination, tooth shade selection, tooth color matching, Munsell color guide, teinte des dents. The “OR” and “AND” varies according to the sites that were used.

I used inclusion criteria and exclusion criteria in the choice of my articles.

First, I selected only articles that were written in French, English. All my articles are published less than 6 years ago (2016). I do not take in account articles where the full text is not available, or the scientific origin is not clearly said.

Here are the different keywords used for the different sites:

PubMed (434 results): (((visual shade guide) OR (spectrophotometer dental color)) OR (intraoral scanner dental color)) OR (dental shade selection)

Journal of dentistry of Thailand (10 results): Spectrophotometers

WILEY (34 results): (Intraoral Scanner) AND (digital spectrophotometer) AND (visual shade assessment)

Springer (19 articles): (tooth) AND (color) AND (matching) AND (Intraoral) AND (Scanner) AND (Munsell) AND (color) AND (system)

JPD (164 articles): (tooth color determination) AND (intraoral digital scanner)

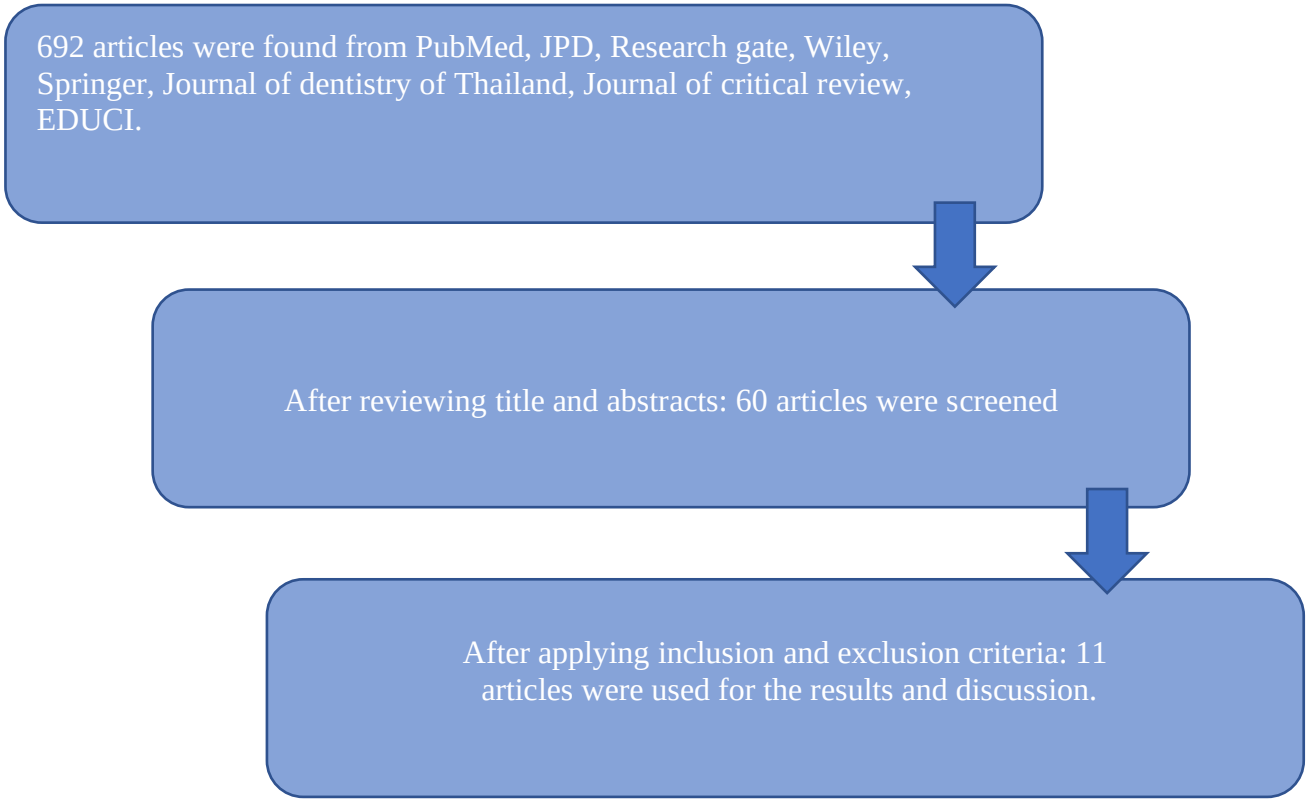
EDUCI (1 article) : Teinte des dents

PICO	**TERMS**
PATIENT	Intact or extracted teeth that have no problem of dyschromia or discoloration
INTERVENTION	Visual shade guide, Colorimeter, Spectrophotometer, Intra Oral scanner, SLR camera
COMPARAISON	take of color

OUTCOME	Color measurement: precision and reliability

4 Results

4.1 Study selection process :



4.2 Tabs

Authors/journals	Methodology (study time and control)	Samples	Materials	Results	Conclusions
Comparison between conventional visual and instrumental methods for teeth shade selection: a systematic review (12) Kouadio K, Balou OD, Kouame KM, Kpangui KN, Koffi NJ, Amani SR, Djeredou KB, Assi KD 2016	Review of 14 articles (2000-2016)	- natural teeth (7 articles) - prosthetic teeth (6 articles) - both (1 article)	Shades guides: - Vita Classical (10 studies) - Vita 3D master (3 studies) - Chromoscope (1 study) Colorimeter: (2 articles) - Shade vision - Shade Eyes Spectrophotometers (12 articles): - Shade Pilot (2 articles)	On 14 selected articles, 12 (85.71%) revealed that we have better repeatability and precision of the instrumental method than the visual one. Shade pilot SS has repeatability of 92,2% Easy Shade has repeatability of 96,4% and precision of 93,75% Easy shade advance is more precise than easy shade compact. Repeatability of 57.4% for visual one, 5.2% for	Easy shade advance is the more efficiency instrument to measure the color. Colorimeters could also be used but it is better if we associate it to visual method. Association of these 3 it is the best solution.

			- Easy Shade (4 articles) - Spectro shade (4 articles) - Crystal eye (1 article) - Color Tron (1 article)	the colorimeter (metamorphism) 3D master better than VC and 3D master linearguide better than 3D master Toothguide	
A comparison between visual, intraoral scanner and spectrophotometer shade matching: a clinical study (17) Walleska Liberato, Welson Pimentel, Cristina costa de Almeida, Rodrigo Tiosso 2018	research	- 28 volunteers aged between 20-40 years. - sound right maxillary central incisor and without enamel anomaly or pigmentation	Visual shade - vita classical - vita 3D master - With and without help of light correcting device (smile lite) Intraoral scanner – TRIOS; 3Shapes Spectrophotometer - vita easy shade advance	The instrumental methods showed a higher reliability than the visual one. We obtain these following results according to fleiss' kappa value: - IOS configurated with vita 3D master shade: 0.874 (better than with vita 0.639) - Spectrophotometer configurated with Vita classical shade: 0.805 (better	Instrumental methods for color matching were more reliable than the visual methods tested. Best result for IOS configurated with 3DM and SS with VC 3DM better than VC. Light correcting device (smile lite) provide improvement in tooth color selection.

				than with 3DM: 0.700) - Visual shade without light correcting: Vita classical: 0.177, Vita 3D master: 0.206 - // with light correcting: 0.306 for 3DM and 0.322 for VC	
Accuracy of an intraoral digital scanner in tooth color determination (18) Vygandas Rutkunas, Julie Dirse, Vytautas Bilius	Research	- total of 120 teeth - 20 students aged between 20-23 years old. - maxillary anterior teeth (2 canines, 2 lateral, 2 central incisors)	Shade guide: - Vita classical (VC) - Vita 3D master (VM) spectrophotometer - Spectro shade intraoral scanner - TRIOS 3 All comparison as based of result of vita easy shade 4.	We have a slight difference of results between T3 and SS using VM/VC values. % of color matching of T3 compared with these of SS was 53,3 % for VM and 27,7% for VC. The B* value is equally distributed between VM and VC. Repeatability of T3 and SS is similar. Highest reliability observed with SS according to VC	Measurement done by VITA easy shade advance 4.0 is considered as one of the best in term of precision and reliability and as reference. VM shade guide is considered better than VC one due to broader range of coverage and better distribution of color sample.

				(93.5%); slight lower for VM (92%) For T3 we have repeatability of 90.3 for VM and 87.2% for VC.	Repeatability of SS and T3 are good (87%) and similar. T3 not exactly match the SS so we must do additional tests.
Repeatability of the human eye compared to an intraoral scanner in dental shade matching (19) Juan reyes, pamela Acosta, Dalina Ventura 2019	Research	30 observers (15 men and 15 women) Right maxillary central incisors of 10 different patients Three different occasions - 2 under studio clinic lighting - 1 under natural light	Shades guides: - Vita tooth guide 3D master under natural light - Vita tooth guide 3D master under studio clinic lighting intraoral scanner - TRIOS	IOS has the repeatability of shade matching of 86,66% Visual method has one of 75,22% We have a 10,45% of difference between two light setting used in the visual methods. However, for the IOS we have a difference of only 4%. For the visual method, we have better determination of the Hue and value but low one for the chroma. In	The 3shape TRIOS intraoral scanner shows higher repeatability than visual methods. The repeatability of visual method does not depend on the experience of the examiners and the sex. However, the light has a direct effect.

				other side for iOS, we have better result in the determination of the Hue than the value and chroma.	
the role of intraoral scanners in the shade matching process: a systematic review (20) Mohammed A. Akl, Dina E. Mansour, Fengyuan Zheng 2022	Review	15 articles were used.	Shade guide spectrophotometer - Spectro shade - Easyshade 5 - RayPlicker quickshade - ShadeEye-NCC intraoral scanner - TRIOS 3 - Cerec Omnicam - Cerec primescan Smartphone DSLR camera	We compare the precision between these different instruments. The repeatability of TRIOS 3 scanner configurated with Vita 3D master guide is better than the one of the Vita easy shade spectrophotometer and visual shade matching. We do not find the same L*A*B* value between the TRIOS 3 and the spectrophotometer. The intraoral scanner tends to calculate shade with the lower value. The light condition has a significant impact on the accuracy of IOS. It	Intraoral scanner shows high precision when used for shade selection, above all when it is used with vita 3D master. However, ambient light source may impact the accuracy and precision of the intraoral scanner. It is important to also use the visual guide to confirm the result obtained by a digital method.

				does not affect the result of the SS.	
In vivo evaluation of teeth shade match capabilities of a dental intraoral scanner (21) Carina Culic, Mihai Varvara, George Tatar, Meda-Romana Simu, Radu Rica, Anca MEsaros, Smaranda Buduru, Cristina Gasparik, Bogdan culic 2018	Research (in vivo)	- 4 subjects of an average of 20 teeth - 80 teeth in total Color measurement on: - Incisal - Middle - Cervical third	Shade guide - Vitapan - vitapan 3D master codification Intraoral scanner - Cerec Omnicam (Sirona) Spectrophotometer - vita easyshade	Color measurement was done by IOS and SS on the cervical, incisal, and coronal part: - 15% like the 2 detection methods for both color methods - 17.5 % comparing VC with detection methods. - 12,9% comparing V3DM with detection methods. We have also different values according to the places: VC: - Cervical: 21.5% - Middle: 22% - Incisal 10% V3DM:	The intraoral scanner should not use as an accurate method of shade selection according to many differences results with the SS. Objective method is more precise and accuracy than visual one. Vita easyshade offer better result comparing to subjective method and is independent of environmental lighting. We have better result with V3DM comparing to VC due to better

				- Cervical: 20% - Middle 19% - Incisal 8%	shade distribution in the color space. In tooth area, we have better correlation on the cervical and middle third and lower one on incisal third. Spectrophotometer has more error on the incisal part due to the light reflection and the translucent part that induces a grey color.
Comparing the effectiveness of shade measurement by intraoral scanner, digital spectrophotometer, and visual shade assessment (22) Alexandra Czigola, Ivett Roth, Viktoria	Research (in vivo)	10 dental students measuring super visioned by an experienced dentist. 10 participants for each student: 100 in total Inclusion criteria: - Full dentition - Intact hard tissue	Shade guides: - Vita classical A1-D4 shade tabs (VC) - Vita linear guide shade tabs (LG)	Most difference found in case of VC. Values of LG, ES and TR are close to each other. Median ΔE: - LG: 2.73 - ES: 4,29 - TR: 4,29 - VC: 16,35	Only the trios 3 and the VC median delta E are below 1.8 which is the acceptability color threshold. Digital system is better for their speed and their

Vitai, Dora Feher, Peter Hermann, Judit Borbely 2021		- No prosthetic restoration or filling - No periodontal problem Target teeth: - Upper right central incisor with 3 points (cervical, middle, and incisal) - Upper right first premolar (middle third) - Upper right first molar (middle third)	Spectrophotometer (ES) - Vita easyshade (VE) Intraoral scanner: - Trios 3 (TR)	The scanner always as the same measured the 10 examinations. Time spent on the tooth. - ES: 14,12 sec - TR: 40,06sec - VC: 52,42 sec - LG: 70,47sec	communication. Disadvantages are the price. Trios is the best repeatable measurement, but the LG is the most suitable for examinate teeth. VC is the less consistent. Best matching shade is LG. TR is best repeatable one but use it with visual method
Evaluation of accuracy and characteristics of tooth-color matching by intraoral scanners based on Munsell color system: an in vivo study (23) Mingming Huang, Hongqiang Ye, Hu Chen, Yongsheng	Research (an in vivo study)	23 volunteers (16 women and 7 men) with at least one vital and intact maxillary anterior teeth. Exclusion of restored congenital, bleached tooth. Total of 138 anterior maxillary teeth where 8	Shade guides: - vita classical A1- D4 - Vita system 3D master Spectrophotometer: - vita easyshade 5	We take the SS as reference and the result of this study indicated that the Trios 3 as better color determination than visual method. Trueness of T3 in incisal area is lower than that of the cervical and middle part. Not	In this study, the best take of color is spectrophotometer after we have trios3 and Trios4. In last place the visual method

Zhou, Yunsong Liu, Yong Wang, Yuchun Sun 2022		teeth are excluded: 130 in total. Measurement of the cervical, middle, and incisal part. 390 sites are recorded.	- Intraoral scanner: - 3 Shape TRIOS 3 - 3 shape TRIOS 4	perform well in area of high transparency. Trueness of the Hue of T3 was slightly lower than one of the experienced prosthetists (EP) with visual method. We have better result on VC than V3D due to lower risk of error of choice. T3 has best result for hue B and lightness 1,2,3 when compared to T4 and EP Trueness of T4 is lower than that of T3	
Evaluation of accuracy of shade selection using two spectrophotometer systems: Vita easy shade and degudent shade pilot (24)	Research (in vitro study)	30 patients who have a perfect central incisor with a contralateral one that needs complete coverage restoration. Three metal ceramic crowns were fabricated for each patient:	Shade guide: - Vitapan classical shade guide spectrophotometers:	7,6% of convectional method were considerably acceptable by the evaluator (1:13) However, 73% of crown made with spectrophotometer were acceptable.	Better result in crown fabricated with spectrophotometer than visual method. No significant matching result between easy

Mohammad Hassan Kalantari, Seyed Ahmad Ghoraishian, Mina Mohaghegh 2017		- One fabricated according to visual shade - Two fabricated with these two different spectrophotometers	- Vita easy shade - Degudent shade pilot	In comparison of the 2 groups of spectrophotometers, we do not have a significant difference	shade and shade pilot spectrophotometer
The study of difference in clinical tooth color measurement among visual method using white light box, intraoral scanner, and spectrophotometer (25) Paweena Sangasaeng, Chaivut Prunkngarmpun, Wilawan Weraarchakul 2019	Research	40 participants where we measure maxillary right central incisor and canine in 18-40 years old patients on vital teeth. Measurement on the middle third of the tooth	Shade guide: - Vitapan 3D master shade guide - white light box - ring light Spectrophotometer Intraoral scanner	We have significant difference when we compared the L*a*b* value between visual method and intraoral scanner, visual method, and spectrophotometer. We compare the L*a*b* value of the maxillary central incisor and canine. For the maxillary right molar, we find consequently difference in the L*a*b* value between the visual method (0.62) and the other methods: IOS (0.81), SS (0.88)	Visual methods had low accuracy and reliability when compared to the spectrophotometer. Intraoral scanner showed higher color difference than the perceptible range which has lower reliability than spectrophotometer
The accuracy and reliability of tooth		Model of upper arch made of resin from	Spectrophotometer:	It is done two repetitions of each	The intraoral scanner has

shade selection using different instrumental techniques: An in Vitro study (26) Nattapong Sirintawat, Tanyaporn Leelaratrungruang, Pongsakorn Poovarodom, Sirichai Kiattavorncharoen, parinya Amornsettachai 2021	Research (in vitro study)	molar to molar. 18% gray color is selected. We take color on the 11 with vitablocs mark II wich is monochromatic feldspathic. Uses 9 different shade of Vita 3D master: - 1M1 - 1M2 - 2M1 - 2M2 - 2M3 - 3M1 - 3M2 - 3M3 - 4M2 For the fabrication of 30 teeth with same size and shape Measuring on the middle third	- Vita easy shade advance 5.0. Intraoral scanner - 3shape Trios 3 basic DSLR camera - Nikon D500 connected with adobe photoshop 2020. - With twin flash: macro twin lite flash MK-MT24 and polarized filter: LightThrough for Meike twin flash - With Ring flash: Metz	method on nine different crowns according to the data of the CIE Lab. On the value of color difference (ΔE), DSLR as the highest of this value. IOS is also in the overside as the least difference. Spectrophotometer has bigger difference than the IOS. For the L value (luminosity)we have high value difference except for the IOS. For the b value only the DSLR +RF has a significant difference The L value obtained from all groups were significantly correlated to the values of the control group in test with the smartphone and spectrophotometer compared to the rest.	better result and DSLR camera combined with a ring flash system provided the least accurate and significant value.

			mecabilltz ring flash 15MS-1 and polarized filters for ring flash: LightThrou gh for metz ring flash Smartphone - Samsung Galaxy Note 20 Ultra 5G camera. - With smartphon e light corrector		

5 Discussion

5.1 Comparison of the visual method compared to the digital one.

In this study, it shows better result on 85 of case for the repeatability and precision of the instrumental method compared to the visual one. The measurement is taken in natural teeth (7 articles on 14) and prosthetic one (6 on 14). The sample is representative. Materials is also quite significant, we have 4 different shades guides, 2 models of colorimeters and 5 of spectrophotometers. We obtain a repeatability according to the chromatic length (ΔE) between 92% and 96% on the different spectrophotometers comparing to 57,4% for the visual methods. Vita 3D master is considered as the best instrument for the visual methods and Easy Shade advance as the best spectrophotometer. Colorimeter is not a reference instrument due to the metamorphism. It is necessary to associate it with the visual method. (12)

In other study there is a comparison according to the Fleiss' kappa value on the color matching. We obtain a value around 0.8 for spectrophotometer and intra oral scanner, besides we obtain a value of 0.206 for vita 3D master and 0.177 for vita classical. One important thing on this article is the fact that we test the visual method with light correcting device, and we obtain a considerably better result. 0.306 for V3DM and 0.322 for VC. But the use of polarization filter did not improve the result. The training of practician for tooth shade selection could lead to increase in the results on the visual methods. Other advantages of the use of instrumental method are the direct and professional communication with the prosthetist. But the cost of this equipment reduces its uses in clinical practice (17)

We also find a better result of the digital method than the visual one, but we have more details about the results. Environment light has a direct influence on the result of

the visual method, that is not the case on the intraoral scanner. As we can thinking the age of the patient, or the experience of the examiners do not significantly influence the results that were obtained (on the visual methods).

We have better result of the Hue and value on the visual method, determination of chroma is less efficient. However, for the intraoral scanner we find better match color on the hue than the value and chroma. (19)

In this study, the linear 3D guide has best matching shade than the digital method (IOS and SS) . However, vita classical guide has the worse value comparing in theses 4 devices.

We do not have the same the result for the repeatability, The intraoral scanner and Spectrophotometer have the best value. Other side for the linear guide (LG) is worse than the vita classical one. It is due to the difference of numbers of shade tabs (29 for LG and 16 for Vita classical).

we learn that there is a considerably difference of time in the take of measure of the color for one tooth. Spectrophotometer is the speeder (14,12 sec), following by the intraoral scanner (40,06 sec) and the one that is longer is the visual method with vita guide (52,42 sec).

V3DM shades provide better result than VC shade guides. We have a reduce need for retake of final restoration. The age and sex do not influence it, but the experience of the examiner influences the tooth color determination considerably. However, it is not the case for the digital method. (22)

In this study we take an experienced prosthetist with superior color matching competency, so we will find the best value of the visual method.

The trueness of the intraoral scanner is slightly lower than one obtained by the experienced prosthetist with the visual method.

We obtain quite same repeatability when we are using the VC and V3M for an experimented prosthetist. We have better result in measuring with IOS TRIOS 3 than

visual method. However, the second one obtains same value as IOS TRIOS 4. Repeatability is poorest using the visual method.

The Hue and in the incisal part measurement result is better with visual method. The scanner does not perform well in area with transparencies. (23)

They create for the 30 patients three different crowns for each, one according to visual shade and 2 with 2 different spectrophotometers. 7.6% of crown made with visual method was considerably acceptable by the evaluators. In other side, 73% of crown made with spectrophotometer were acceptable. We have a considerably difference in this study that the digital method is more precise and accurate than the visual method. (24)

According to the L*a*b* value, the visual method with a light box has low accuracy and reliability when we compared to the digital method. Many factors like the light, experience of the observer influences the result of the visual method. (25)

5.2 comparison between the spectrophotometer and Intraoral scanner

We have a comparison between the intraoral scanner (TRIOS 3shape) and spectrophotometer (Vita easy shade advance) according to the Fleiss kappa value on the color matching. We obtain a value of 0.874 for the intraoral scanner configurated with the V3M and 0.639 with VG. For the spectrophotometer we have 0.805 with VG and 0.7 with V3M. We can see that the intraoral scanner configurated with the good guide is more precise than the spectrophotometer. The difference is not enough to be significant. One another point, these 2 devices have not better results with the same guide, we must know how they work to select the good guide and have the better result that can purpose. (17)

Vita Easy shade advance 4 is considered as one of the best instruments in term of precision and reliability of take of color and used as reference. However, the intraoral

scanner (TRIOS 3) has also obtained good result and we have not a sufficient difference to see clearly that the SS is better.

We have same repeatability with the SS than the Trios one. The use of V3M has reference for both considerably increase the result. (18)

The ambient light condition affects the accuracy of the intraoral scanner; however, this fact does not change the result of the spectrophotometer. In most of studies reviewed on this article take the SS as a reference of take of color. We obtain the better result of intraoral scanner when it is used with Vita 3D master guide.

Intraoral scanner produces a higher overall value due to the unpolarized light their produce. (20)

The time spent on each tooth is 2 times speeder for spectrophotometer (14,12 sec) than the intraoral scanner (40,06%). It is an important parameter that we must take in account.

In term of repeatability the intraoral scanner (56%) is highly better than one of the Spectrophotometer. We have a same value between theses 2 value on the shade matching.

We obtain better result when we using as reference the 3D master shade. The TRIOS3 obtain better result for the take of color of posterior teeth (upper right first molar, it is also the case for the middle and cervical third of an upper incisor. SS obtain a slightly better result for the incisal edge, but the difference is not relevant and for an upper premolar we obtain a same result between theses 2 devices.

The TR intraoral scanner with a 3D tooth color selection can be used as a method of color selection. It is essential to verify all the time with visual method. (22)

Intraoral scanners devices are quite performant, but the spectrophotometer is considered as the reference and has better result in take of color. It is also essential to do

the visual method also as a complementary. The IOS tends to produce a lightness color than the one that is seen.

We have a comparison between 2 different IOS devices. We see that we have a considerably better result for the T3 compared to the T4. We obtain better result when the HUE is A comparing to a B one and the result on the incisal part is worse than the other part of the tooth. Repeatability is higher when using VC than V3D.

Spectrophotometer also has problem like an edge loss effect that can produce error on the take of color. The mode averaged shade selection could reduce this error. (23)

We compare the L*a*b* value obtained from a maxillary central incisor and canine. We obtain a value of 0.81 for the IOS and 0.88 for the SS. We have better result for the spectrophotometer than the intraoral scanner. But the result obtained by the IOS are in acceptable range. (25)

For the luminosity value we have better result for the intraoral scanner. The DSLR camera and SS one has high value difference that is not acceptable. B value is relevant for both (IOS, SS). In general, IOS has better value of Spectrophotometer in this study. The L value is considerably better for IOS than the SS that is the most important value. In the A and B value we have same result. In this study, the Spectrophotometer does not have a clinical acceptance. It could explain by many reasons and one of it is the edge loss effect in the place where we measure.

Both instruments were calibrated with Vita 3D master guide instead of Vita classical shade guide. It shows that we have a considerably better result. (26)

6 Conclusion

The digital method has better result than one obtains by visual method. It has many advantages like the reducing time to take the color, better result on the repeatability. It also facilitates the relation with prosthetist and the explanation with the patient.

However, we see that the Vita 3D and Vitapan 3D offer better result than the vita classical and vita tooth guide. Hue and value have a good result with this technique, and we can use a light correcting device that permits to improve the result considerably.

Nowadays, the spectrophotometer is considerate as the reference of the take of color in dentistry. In other side, the intraoral scanner improves significantly, it has a better precision on the take of color than the spectrophotometry, but the difference is quite small. One point that the IOS is considerate better is the repeatability.

Yet, one of the advantages of spectrophotometer is the speed of use, which is clearly different than one obtains by the IOS, and the fact that that is not influenced by the ambient light sources.

Both has better result when we configure with vita 3D master from the vita classical one. One of these side effects is the less of precision on the incisal part due to light reflection and the translucency.

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