Propiedades ópticas del complejo dentina-esmalte y de los materiales restauradores directos e indirectos.

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PROPIEDADES ÓPTICAS DEL COMPLEJO DENTINA-ESMALTE Y DE LOS MATERIALES RESTAURADORES DIRECTOS E INDIRECTOS.

Departamento de Restauradora Dental y Endodoncia. Facultad de Odontología
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TESIS DOCTORAL

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Gracias a esas personas importantes en mi vida, que siempre me han brindado su apoyo incondicional, ahora me toca regresar un poco de todo lo inmenso que me han otorgado.

Con todo cariño esta tesis se las dedico a ustedes:

A mi esposo Daniel

A mis padres Raúl y Julia

A mi hermano Raúl

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JUSTIFICACIÓN

Cada día aumenta la demanda estética de los pacientes que reciben tratamientos restauradores, aparte de la forma y anatomía, el color de la restauración es también un factor muy importante (1). Entendemos el 'color' como el resultado de la modificación física de la luz sobre los objetos que son percibidos por el ojo humano e interpretado por el cerebro (2).

Un método que ha sido utilizado comúnmente para determinar el color es el uso de tablas de color (siendo la más común la guía Vita). Muchas veces con este método subjetivo, no se selecciona el color apropiado; por esta razón, la tendencia actual es el uso de un dispositivo llamado espectrofotómetro, lo cual permite una medición de tipo objetiva y cuantitativa (3).

Cuando se realiza una restauración estética, no solo es importante acertar el color dental, es también necesario conocer las características del diente, en cuanto a edad, desgaste, forma, textura, además de contar con materiales óptimos que mimeticen la restauración. Para ello se debe evaluar las propiedades ópticas de los componentes dentarios (esmalte y dentina), con el tiempo las propiedades ópticas de los dientes sufren cambios significativos, uno de los cambios principales ocurre en el tercio incisal, según la literatura los dientes pueden clasificarse en 3 grupos de edades: jóvenes, adultos y adultos mayores (4). Cada uno de estos grupos presenta características diferentes como por ejemplo el esmalte en el grupo joven es menos traslúcido y a medida que pasa el tiempo éste vuelve más traslúcido, este junto con otros factores como los hábitos alimenticios influyen en el color general del diente y lo alteran a través del tiempo.

Existe en la literatura (5), investigaciones donde se evalúa las diferencias de color en los 3 tercios de los dientes evaluadas con la ayuda de una cámara fotográfica digital, pero hay pocas investigaciones con respecto a las características y propiedades ópticas de forma cuantitativa, del complejo esmalte-dentina y solo esmalte, las que existen están realizadas por una pequeña muestra y en todos los casos (1, 6) solo se realiza la medición en pacientes jóvenes.

La aplicación de este nuevo método (1) en un amplio grupo de personas, de diferentes edades, sirve como base de datos, para conocer y comprender más exactamente las propiedades ópticas del esmalte (cromatismo, luminosidad, etc.) y del complejo esmalte-dentina. Esta información puede ser utilizada para la cuantificación de las propiedades estéticas de los dientes (1), y a partir de ella desarrollar nuevos y mejores materiales restauradores que se adapten a cada "edad dental" y a su vez, que puedan tener un color más estable en el tiempo.

Otro factor determinante en lograr una restauración "perfecta" es que esta pueda mantener durante el tiempo sus propiedades ópticas y su estabilidad del color. Así como los dientes sufren cambios a lo largo del tiempo, las restauraciones en la cavidad oral están expuestas a varios factores que las hacen vulnerables al cambio de coloración, tales como: cambios de temperaturas, humedad, hábitos alimenticios y tabáquicos, entre otros (7). Existen muchos factores asociados a la decoloración de los materiales dentales en la cavidad oral. La estabilidad del color de los composites se debe a razones exógenas y endógenas (8, 9). Las razones exógenas incluyen la influencia de sustancias colorantes como el café y el vino tinto (10).

Según su aplicación clínica existen 2 tipos de composites; los composites directos, que son utilizados y aplicados de forma inmediata en la restauración del paciente y los composites indirectos de laboratorio, los cuales se utilizan para confeccionar restauraciones que posteriormente serán cementadas. Los composites directos podemos clasificarlos según su tipo de relleno, la principal diferencia entre estos es el tamaño de la partícula de relleno (10-12).

Los composites indirectos de laboratorio son una alternativa para la sustitución de las cerámicas y restauraciones metálicas (13). En principio estos composites tienen un menor grado de contracción y deben ser más estables en el color que los composites directos (14). Dentro de los composites indirectos encontramos 2 grupos: los composites indirectos de laboratorio y los composites indirectos en bloque CAD-CAM.

A pesar de existir en la literatura varios artículos (9, 14-21) que evalúan la estabilidad del color de los composites sumergidos en diferentes bebidas, ningún estudio compara la estabilidad del Silorano vs composites de metacrilato y mucho menos los composites indirectos de laboratorio vs composites directos de metacrilato. La comparación de estos datos podrá servirnos para saber determinar si pueden existir diferencias o cambios ópticos entre los materiales restauradores (directos o indirectos) a través del tiempo de una manera cuantitativa y objetiva, además, los datos obtenidos previamente en relación a las propiedades ópticas de la estructura dental y sus cambios según la edad, nos permitirá comparar esta relación en los cambios ópticos tanto del diente como de los materiales restauradores a través del tiempo.

HIPÓTESIS

Hipótesis Nula 1:

- Los composites de Silorano tendrán mayor estabilidad del color comparado a los composites de tipo metacrilatos en diferentes soluciones pigmentantes.

.Hipótesis Alternativa 1

- Los composites de Silorano tendrán menor estabilidad del color comparado a los composites de tipo metacrilatos en diferentes soluciones pigmentantes.

Hipótesis Nula 2:

- Las propiedades ópticas del esmalte y del complejo dentino-esmalte de los dientes no son afectadas por la edad.

.Hipótesis Alternativa 2

- Las propiedades ópticas del esmalte y del complejo dentino-esmalte de los dientes son afectadas por la edad.

Hipótesis Nula 3:

- 3.1: Los bloques de composite de CAD/CAM no tendrán mayor estabilidad del color que los composites convencionales de laboratorio.
- 3.2: El tipo de solución pigmentante no influye en la pigmentación del material.

Hipótesis Alternativa 3:

- 3.1: Los bloques de composite de CAD/CAM tendrán mayor estabilidad del color que los composites convencionales de laboratorio.
- 3.2: El tipo de solución pigmentante influye en la pigmentación del material.

OBJETIVOS

Objetivo principal:

Determinar con el uso del Espectrofotómetro las propiedades ópticas expresadas en L*a*b* y opacidad (CR) de los incisivos centrales superiores y evaluar la estabilidad del color de diferentes tipos de composites de aplicación directa e indirecta CAD-CAM o de laboratorio sumergidos en diferentes soluciones pigmentantes.

Objetivos Secundarios:

1. Determinar si existe alguna relación entre la edad y las propiedades ópticas del esmalte y del complejo esmalte-dentina en los incisivos centrales superiores de los diferentes grupos de edades.

2. Comparar con el uso del uso del Espectrofotómetro la influencia del tipo de solución pigmentante en composites de base metacrilato versus siloranos.

3. Evaluar la influencia del tiempo en la estabilidad del color en los composites de metacrilato y los composites de silorano.

4. Evaluar con el uso del uso del Espectrofotómetro la influencia del tipo de solución pigmentante en composites indirectos CAD-CAM vs. composites indirectos de laboratorio.

5. Evaluar y comparar la estabilidad de color a través del tiempo de diferentes composites indirectos CAD-CAM vs composites indirectos de laboratorio

.

INTRODUCCIÓN

Definiendo la estética como "el arte de lo imperceptible" (11) los materiales restauradores deben imitar la apariencia natural del diente (7). La odontología estética se basa en la elaboración de una restauración que se integra de forma adecuada con la estructura del diente en todos los aspectos, incluyendo el color. La percepción del color es un proceso subjetivo que involucre a varios factores influyentes(22, 23): la luz (la fuente de luz), el objeto (diente) y el observador (odontólogo)

La percepción del color de un objeto por un humano está regulada por un mecanismo de absorción y reflexión. Existen dos tipos de células, conos y bastones, que conforman la retina, ambos son sensibles a la luz. Los conos contienen producen una sensación acromática de visión nocturna, los bastones reciben sensaciones de luminosidad. Los bastones contienen pigmentos sensibles a diversas ondas del espectro y son encargadas de la visión del color (24).

Las diferentes ondas de la luz están compuestas por fotones de diversa energía, las ondas cortas poseen más energía que las ondas largas. Los ojos ven un objeto solo mediante la luz que reflejan. Es la longitud de la luz que reflejan la cual determina el color. Por ende, el color de un objeto depende de la luz que es reflejada y absorbida. Un objeto que no absorbe ningún color se ve blanco. Un objeto que absorbe todos los colores se ve negro, y un objeto que absorbe todos los colores menos el azul se ve azul. La absorción y la reflexión de la luz dependen de las características de la transparencia, traslucidez y opacidad. Un objeto transparente permite que la luz lo atraviese completamente (ej.: vidrio), un objeto traslúcido permite la transmisión parcial de la luz (este juega un papel muy importante en la odontología), y un objeto opaco bloquea la luz (24).

El color de un diente natural se determina por la relación que el esmalte, la dentina, la pulpa y los tejidos gingivales tienen con la luz durante el proceso de refracción y reflexión de la luz (25). Es el resultado de la modificación física de la luz por objetos con color, que es percibido por el ojo humano e interceptado por el cerebro (2, 26, 27). En 1898 un pintor Americano llamado A. H. Munsell propuso un sistema tridimensional del color en el cual cada color era representado en las siguientes dimensiones: valor, tono y croma. (25, 28).

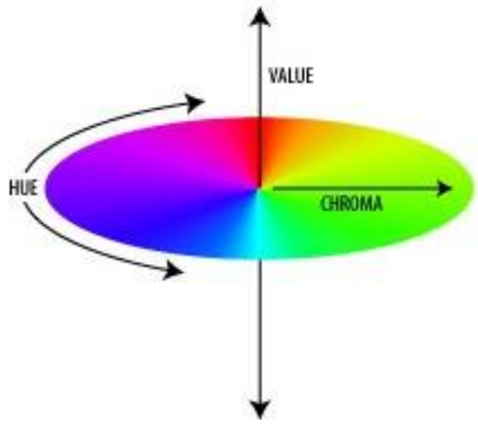

Figura 1. Dimensiones del color (28)

Valor es el grado de luminosidad o iluminación de un color, es el componente más importante del color, que va desde negro (cero luminosidad) hasta blanco (máxima luminosidad). En la práctica clínica, el valor expresa la cantidad de gris; el valor de un diente depende del grosor del esmalte. El tono es el color propiamente dicho, es decir amarillo, verde, rojo; es el color básico del diente que deriva del cuerpo dentinal interno.

Está determinado por la onda de la luz reflejada por los dientes. En la odontología el tono es definido de acuerdo a la guía Vita, la cual contiene básicamente cuatro tonos: A (predominio de rojo-marrón), B (predominio de naranja-amarillo), C (predominio de verde-gris), y D (predominio de rojo-gris). Croma es la intensidad o la saturación del color; por ejemplo el color A en la guía Vita puede ser A1 o A3. Ambos serán del mismo tono, pero A3 presentará mayor saturación (25, 26)

El color del diente se determina utilizando métodos visuales y/o instrumentales (9, 16, 29). La selección visual es el método más frecuentemente aplicado en la odontología clínica (2, 3). Es una comparación del diente con guías de color comerciales, siendo la Clásica Vitapan (VITA) la más utilizada (3, 26). La determinación visual del color es considerada altamente subjetiva ya que depende de muchas variables como las condiciones externas de luz, experiencia, edad, guías de color, fatiga del ojo humano y variables fisiológicas (2, 3, 26, 30). Además, las guías de color no están distribuidas sistemáticamente en el espacio de color; ninguna guía es exactamente igual a la otra y por último, y las guías y los dientes son materiales físicamente distintos por lo que los resultados de las mediciones pueden ser dependientes del material (3, 31).

Los métodos instrumentales tienen el potencial de eliminar errores subjetivos en la evaluación del color. Estos instrumentos pueden ser clasificados como espectrofotómetros, colorímetros, analizadores digitales de color, o una combinación de los mismos (9, 15, 29, 32, 33). Los colorímetros y los espectrofotómetros son ampliamente utilizados para determinar el color del diente. Un análisis de colorímetro se basa en el color de los tres receptores del ojo humano, siendo rojo, verde y azul, mientras que un espectrofotómetro analiza cada 1-10nm del espectro visible (6). Este método es objetivo y permite una evaluación cuantitativa del color, eliminando la subjetividad del clínico(26)

El espectrofotómetro mide los valores del color según la escala de la Comisión International de Iluminación (CIE); esta escala expresa las mediciones de color de conformidad con los tres valores de coordenadas (*L*a*b**) del espacio de color (26, 34). La L* representa la iluminación o la oscuridad, que va desde el negro (0) al blanco (100), el valor *a** representa el rojo (valor positivo) y el verde (valor negativo), y el valor *b** representa el amarillo (valor positivo) y el azul (valores negativos) (7, 18, 28, 34-37). La American Dental Association (ADA) recomienda el uso del sistema de diferenciación de color CIE Lab. Por eso es una técnica utilizada ampliamente por los investigadores en la odontología (32).

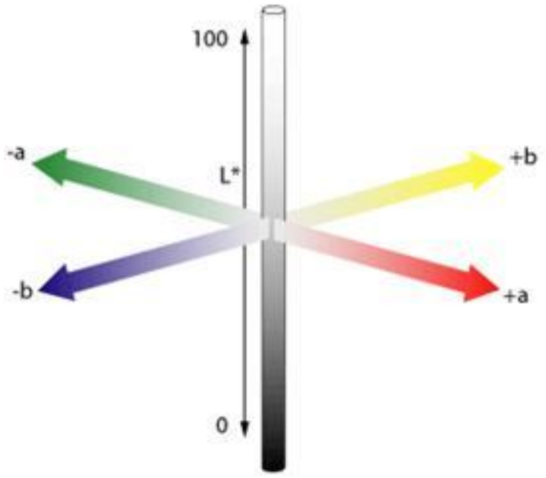

Figura 2. Coordenadas de valores CIELAB del espacio de color (28)

CIELAB se utiliza frecuentemente para medir cambios en el color, diferencia de color; la diferencia de color (ΔE) representa el cambio de color general, es la distancia entre 2 puntos en el espacio de color 3-dimensional (3D). Este valor es calculado en base a la media de ΔL* Δa* y Δb* mediante el uso de la siguiente fórmula (7, 9-11, 16, 18, 32, 35-37)

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

Existe controversia en la literatura con respecto a cuál es el valor ΔE que puede ser visto por el ojo humano o que sea clínicamente relevante (10, 38). En principio, si un material es completamente estable en cuanto al color, no se detectará diferencia de color tras la exposición al ambiente (ΔE= 0) (39). Mientras que Viohl y Seher señalan que las diferencias totales de color ΔE de 2 a 3 son sencillamente visibles, Seghi et al afirman que un valor ΔE de 1 es un valor distinguible. Sin embargo, Kuehni y Marcus determinaron que solo la mitad de los participantes de la prueba pudieron verificar una diferencia total de color de ΔE =1. Ruyter et al. describió la decoloración de ΔE= 3.3 como clínicamente no aceptable (38) Goldstein y Schitt reportaron que cuando ΔE es mayor a 3.7, no está ya dentro de los límites de aceptación clínica (19). En general, los estudios concluyen que cuando ΔE > 3 las diferencias de color son perceptibles, y el cambio de la restauración es necesario (7, 9, 10, 26, 32, 37). Algunos estudios sobre mediciones de color dental no identificaron el fondo y otros utilizaron fondos variados. Cuando se emplea un fondo sólido, las propiedades tales como la reflectividad pueden influenciar el color medido de forma significativa (40-42).

Los dientes pueden ser clasificados en tres grupos de edades: jóvenes, adultos y adultos mayores (4, 43). Los dientes jóvenes tienen una estructura dentinal interna inalterada con los lóbulos de desarrollo intactos. Esta dentina está cubierta totalmente por el esmalte, incluyendo el borde incisal.; el esmalte usualmente tiene un tinte blanco, con baja traslucencia, alta reflectividad, densidad y luminosidad (4, 25). Los dientes adultos tienen una estructura interna global inalterada pero los bordes de los lóbulos de desarrollo pueden estar expuestos en el área del borde incisal, el esmalte tiene una apariencia más neutral, un tinte neutral y una traslucencia intermedia (4). Los adultos mayores tienen la estructura dentinal alterada debido a la atricción en el borde incisal. En este grupo de edad, el esmalte muestra un grosor reducido con poca textura en su superficie, alta traslucencia, y baja densidad, luminosidad y reflectividad (4, 25, 44).

A B C

Figura 3. A. Diente joven. **B**. Diente Adulto. **C**. Diente adulto mayor (25)

La selección del color en un diente natural es uno de los retos más difíciles en la clínica, un color acertado nos garantiza parte del éxito a la hora de realizar una restauración, pero también es importante conocer el material restaurador y su comportamiento en la cavidad oral. (45) Las restauraciones en la cavidad oral están expuestas a muchos factores que las hacen vulnerables al cambio de color como: temperatura, humedad, hábitos tabáquicos y alimenticios, entre otros. (8). La estabilidad del color del composite se debe a causas exógenas y endógenas (7, 18, 32)

Los composites de resina han jugado un papel muy importante en la odontología restauradora. (7), ningún otro material restaurador ha sido modificado y mejorado tanto desde que fue introducido por Bowen. Debido a las mejorías tanto fisicomecánicas como estéticas, los composites se consideran el material restaurador más popular en la práctica dental. (7, 46, 47)

El uso de composites se ha ido expandiendo, yendo desde materiales restauradores directos, que son usados durante una restauración en el paciente, hasta composites indirectos de laboratorio, que se usan para la fabricación de coronas, incrustaciones, inlay, onlay que posteriormente son cementados. (48, 49) Hoy en día el uso de composites indirectos ha aumentado substancialmente debido a mejoras en sus propiedades (35, 50). Estos fueron inicialmente desarrollados como una alternativa para la sustitución de la cerámica y de las restauraciones metálicas (14). Los composites indirectos puedes ser divididos en dos grupos: los composites de CAD/CAM (composites de diseño asistido y elaboración asistida por ordenador) y los composites de laboratorio.

La primera restauración de CAD/CAM fue fabricada en 1985 con la unidad CEREC 1. La misma estaba hecha de un bloque de cerámica prefabricado. Desde entonces la técnica ha evolucionado, tornándose menos costosa, más fácil, más rápida y precisa. Pocos años después se desarrollaron los bloques de CAD/CAM de resina de composite, que surgen como una alternativa los bloques de cerámica, siendo una de sus mayores ventajas el hecho de que pueden ser reparadas y conservadas de forma más fácil que las cerámicas.(50)

ARTÍCULOS

5.1. Color stability of siloranes versus methacrylate-based composites after immersion in staining solutions

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Artículo publicado online en el Clinical Oral Investigation el 20 de Septiembre de 2012:

Factor de impacto: 2.200. Primer Cuartil (Dentistry, Oral Surgery & Medicine)

COLOR STABILITY OF SILORANES VERSUS METHACRYLATE-BASED COMPOSITES AFTER IMMERSION IN STAINING SOLUTIONS

Mariana A Arocha, Juan R Mayoral, Dorien Lefever, Montserrat Mercader, Juan Basilio y Miguel Roig.

ABSTRACT

Objectives: The purpose of this study was to determine, by using a spectrophotometer device, the color stability of Silorane in comparison with four methacrylate-based composites after being immersed in different staining solutions such as coffee, black tea, red wine, orange juice, coke and distilled water as control group.

Methods: Four restorative methacrylate-based composites (Filtek Z250, TetricEvoCeram, Venus Diamond, Grandio) and one Silorane (FiltekSilorane) of shade A2 were selected to measure their color stability (180 disk samples), after 4 weeks of immersion in six staining solutions: black tea, coffee, red wine, orange juice, coke and distilled water. The specimen's color was measured each week by means of a spectrophotometer (CIE L*a*b* system. Statistical analysis was carried out performing an Anova and LSD Test in order to statistically analyze differences in L*a*b*and ΔE values.

Results: All materials showed significant discoloration ($p < 0.05$) when compared to the control group (immersed in distilled water). The Highest ΔE observed was with red wine, whereas coke led to the lowest one. Silorane showed the highest color stability compared with methacrylate based-composites.

Conclusions: Methacrylate based materials immersed in staining solutions showed lower color stability when compared with Silorane. Great differences in ΔE were found among the methacrylate based materials tested.

Clinical Relevance: Although color stability of methacrylate-based composites immersed in staining solutions has been widely investigated, this has not been done for long immersion periods with silorane-based composites.

***Keywords:* Resin composites, Staining, Color stability, Silorane.**

INTRODUCTION

During the last decades resin-based composites have undergone many modifications. Improvements of not only physicomechanical but also esthetic properties have made that the use of these materials for the restoration of anterior teeth has begun to increase [1-3]. The esthetic restoration of the anterior dentition presents one of the greatest challenges in daily practice. Defining esthetics as "the art of the imperceptible" [4], esthetic restorative materials should mimic the appearance of natural teeth. The latter is directly related to the material's degree of opacity and translucency, opalescent and iridescent effects and fluorescence. In the long term, also other factors such as color stability, surface roughness and surface gloss can determine success or failure of restorations [1,4,5]. Unacceptable color match is one of the main reasons for replacement of resin-based composite restorations [6].

When exposed to the oral environment [1,6,7], resin-based composites may present color instability due to intrinsic discoloration or extrinsic staining [4,5,8-10]. As described in many studies, extrinsic staining may be caused by insufficient degree of polymerization, heat, UV irradiation, water sorption or adsorption of food colorants such as red wine, coffee, coke, tea [1,6-14]. The degree of discoloration varies according to the oral hygiene, eating-drinking and smoking habits of the patient [5,7,10,13]. These external color changes may be eliminated by subsequently scaling and polishing the surface, but if deeper layers are involved the discoloration is mostly irreversible [1,8]. Intrinsic discoloration on the other hand, involves the staining of the resin material itself [1,5,6,9,10,11]. This may be related to: the type of resin matrix; e.g. urethane dimethacrylate (UDMA) seems more stain resistant than bis-GMA because his low viscosity and low water absorption [10,11], the fillers e,g. an unfilled resin specimen generally exhibited less color change than did resin based composite specimens [5,10], the fillers particle size and distribution seem to be directly correlated to optical properties, a smaller filler size might contribute to decrease staining and enhance esthetic appearance [1].

In order to avoid these problems related to the intrinsic structure of methacrylate-based composites, a newly developed material has been recently introduced onto the market. This innovative monomer system known as “Silorane”, is obtained from the reaction of oxirane and siloxane molecules [15,16,17]. Siloranes have been suggested as alternatives to methacrylates as matrix resin components for resin-based composites because of their hydrophobicity and lower polymerization shrinkage [15,18,19]. Various studies have confirmed a decreased water sorption, solubility and associated diffusion coefficient of Silorane compared with conventional methacrylate-based composites [16, 19, 20]. In light of these favorable properties, this new monomer system may be a promising solution to overcome the negative effects of oral fluids on the mechanical properties of resin-based composites [21]. Although color stability of methacrylate-based composites immersed in staining solutions has been widely investigated [1,4-6,8-11], there are no *in-vitro* studies that have evaluated the color stability of silorane immersed in staining solutions.

The purpose of this study was therefore to determine the color stability of Silorane in comparison with four methacrylate-based composites after immersion in different staining solutions such as coffee, black tea, red wine, orange juice and coke, using reflection spectrophotometry based on the CIE L*a*b* color system. There were three null hypotheses:

- The type of material does not influence the color stability of the material.
- The type of staining solution does not influence the staining of the material.
- The duration of storage in the staining solution does not influence the color stability of the material.

MATERIAL AND METHODS

One hundred and eighty disk samples were prepared from five different resin-based composite materials (Table 1) of shade A2 (n=30) by condensing the material into a standardized metal mould. The mold with the composite resin was held between 2 glass slides, each one covered with a transparent polyester strip (Mylar, DuPont, Wilmington, Del., USA). The slides were then gently pressed together to remove excess material. All specimens were polymerized by a LED light-curing lamp Bluephase (IvoclarVivadent AG, Schaan, Liechtenstein) with light intensity of 1.200 mW/cm^2 for 20 seconds of exposure on top and bottom surfaces, respectively. Irradiance was tested by a radiometer Demetron LED (Kerr Corp, Orange, CA, USA). The distance between the light source and the specimen was standardized by the use of a 1 mm glass slide. Specimens' dimensions were 10 mm diameter and 2 mm thick. After polymerization, the specimens were stored in distilled water at 37°C for 24 hours for rehydration and completion of the polymerization, following methodology of previous studies [4,6,8,10,12]. Before the immersion in staining solutions, specimens of each composite were randomly divided in 6 groups, corresponding to 6 samples per staining solution (coffee, black tea, red wine, orange juice, coke and distilled water, as control group) (Table 2).

Table 1 Composites used in the investigation

Composite	Composition[a]	Manufacturer	Color	Lot
Filtek silorane (A)	Bis-3,4-Epoxycyclohexylethyl-Phenyl-Methylsilane 3,4-Epoxycyclohexylcyclopolymethylsiloxane	3M/ESPE, St. Paul, MN, USA	A2	9BY/9CC
Filtek Z250 (B)	Bis-GMA, Bis-EMA, UDMA, TEGDMA	3M/ESPE, St. Paul, MN, USA	A2	8HU/9JA
Tetric evoceram(C)	Bis-GMA, UDMA, DDDMA	IvoclarVivadent AG, Schaan, Principality of Liechtenstein	A2	M08007
Venus diamond (D)	TCD-DI-HEA, UDMA	HeraeusKulzer, Hanau, Germany	A2	010026
Grandio (E)	Bis-GMA, UDMA, dimethacrylate, TEGMA	Voco, Cuxhaven, Germany	A2	918270

Bis-GMA Bisphenol-A diglycidylether methacrylate, *Bis-EMA* bisphenolApolyethyleneglycoldietherdimethacrylate, *UDMA* Urethane dimethacrylate, *TEGDMA* Triethyelene glycol dimethacrylate, *DDDMA* DecandiolDimetacrylate, *TCD-DI-HEA* 2-Propenoic acid, (octahydro-4,7-methano-1H-indene-5-diyl) bis(methyleneiminocarbonyloxy-2,1 ethanediyl) ester

[a] Composition as given by manufacturers

Table 2 Different staining solutions used in this investigation

Solution	Abbreviation	Manufacturer
Black tea	BT	Label Tea, Lipton Tea®, Unilever, France
Coffee	CO	Nescafé Classic®, Nestlé, Spain.
Red wine	RW	Enate®, Tempranillo-Cavernet Sauvignon 2004, Spain.
Orange juice	OJ	Granini Orange®, Spain.
Coke	CK	Coca-Cola®, The Coca-Cola Company, Spain.
Distilled water	CG	Lasda S.A, Spain

The specimen was rinsed for 10s with distilled water and wiped dry with gauze before being immersed in staining solutions. At this moment, baseline color measurements (T0) were made. These measurements were performed using a reflectance spectrophotometer (SpectroShade, Handy Dental Type, MHT, Arbizzano, Italy) using the CIE L*a*b* system. The SpectroShade consisted of a D_{65} light source (6.500K). This light was split so that the specimen could be illuminated simultaneously from a 45-degree angle using an intraoral camera. Spectrophotometric measurements were made using a white background, as in other studies [22]. Before each measurement session the spectrophotometer was calibrated according to manufacturer recommendations using the supplied calibration standards. Color measurements were then made according to the same procedure at a time interval of 1 week (T1), 2 weeks (T2), 3 weeks (T3) and one month (T4). Staining solutions were renewed every two days to avoid bacteria or yeast contaminaton [23].

Using the SpectroShade software, differences in color (ΔE) and color coordinates (ΔL*, Δa*, Δb*) between baseline (T0) and T1, T2, T3 and T4 measurements were calculated for each resin-based composite material and staining solution, where ΔL* is the change in luminosity, Δa* the change in red-green parameter and Δb* the change in yellow-blue parameter. Color stability was determined evaluating the color difference (ΔE). The latter was calculated from the mean ΔL* Δa* and Δb* according to the formula of Pythagoras [1,4,8,10-14,24-26]:

$$\Delta E= [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

As data were normally distributed (Kolmogornov-Smirnov, Shapiro-Wilk), statistical analysis was performed using multifactorial ANOVA and LSD test in order to evaluate differences in ΔE, ΔL, Δa and Δb between groups. The data-analysis was carried out using the Statgraphics software, (Statpoint Technologies, Warrenton, Virginia, USA) with a significance set at $p = 0.05$.

RESULTS

The mean values of color change of the evaluated materials after the first week immersion in the staining solutions are represented in Table 3. Regarding the stainability of the materials, in the first week TetricEvoceram immersed in red wine showed the lowest color stability overall (ΔE=30.9), while the highest color stability was Filtek Z250 immersed in coke (ΔE=1.1). Red wine had the highest staining potential overall, followed by coffee, black tea, orange juice and coke. No statistically significant differences were found in ΔE between orange juice and coke ($p>0.05$). For the second week, the behavior of the materials and colorants is represented in Table 4. TetricEvoceram immersed in red wine showed the lowest color stability overall (ΔE=27.3), while the highest color stability was Filtek Z250 immersed in coke (ΔE=1.4). Regarding the staining potential, red wine showed the highest potential overall, followed by coffee, black tea, orange juice and coke. Coffee and black tea showed no statistically significant differences in ΔE between these materials ($p>0.05$); also no statistically significant differences in ΔE were found between orange juice and coke ($p>0.05$). The behavior of the materials and colorants for the third week are represented in Table 5. Regarding the stainability of the materials, Grandio immersed in coffee showed the lowest color stability overall (ΔE=28.0), while the highest color stability was Filtek Z250 immersed in coke (ΔE=1.6). Red wine had the highest staining potential overall, followed by black tea, coffee, orange juice and coke. Red wine, black tea and coffee showed no statistically significant differences in ΔE between these materials ($p>0.05$), also no statistically significant differences in ΔE were found between orange juice and coke ($p>0.05$). For the fourth week the behavior of the materials are represented in Table 6. Filtek Z250 immersed in red wine showed the lowest color stability overall (ΔE=30.2), while the highest color stability was once again Filtek Z250 immersed in coke (ΔE=1.4).

Regarding the staining potential, red wine showed the highest potential overall, followed by coffee, black tea, orange juice, coke and distilled water. Coffee and red wine showed no statistically significant differences in ΔE between these materials ($p>0.05$), and coffee and black tea showed no statistically significant differences in ΔE between these materials ($p>0.05$). Also no statistically significant differences in ΔE were found between orange juice, coke and distilled water ($p>0.05$). Control group showed the lowest staining potential overall, after 4 weeks Silorane showed the highest color stability (ΔE=1.9) according to table 6.

Table 3 Mean (SD) of color changes (ΔE) for each composite and colorant (week 1)

Composite	Color change (ΔE)						
	Black Tea	Coffee	Red wine	Orange Juice	Coke	Distilled water	Homogeneous Groups
Silorane	5.4 (0.93)	6.1 (3.6)	4.2 (1.2)	2.2 (1.0)	2.0 (0.9)	1.1 (0.2)	A
Filtek Z250	16.2 (2.7)	13.4 (5.7)	24.7 (3.2)	3.1 (0.9)	1.1 (0.3)	0.5 (0.2)	C
TetricEvoceram	15.7 (5.9)	15.9 (3.7)	30.9 (1.3)	1.6 (0.6)	1.7 (0.3)	1.3 (0.7)	C
Venus Diamond	9.1 (2.6)	12.4 (2.9)	16.1 (4.9)	1.6 (0.7)	2.1 (0.5)	0.8 (0.3)	B
Grandio	10.0 (0.8)	26.3 (10.4)	19.5 (2.8)	2.1 (0.6)	1.7 (0.5)	0.5 (0.1)	C

Groups not connected with the same letter are significantly different

Table 4 Mean (SD) of color changes (ΔE) for each composite and colorant (week 2)

Composite	Color change (ΔE)						
	Black Tea	Coffee	Red wine	Orange Juice	Coke	Distilled water	Homogeneous Groups
Silorane	8.2 (0.7)	7.4 (3.7)	7.4 (1.3)	2.4 (0.9)	1.9 (0.5)	1.2 (0.4)	A
Filtek Z250	22.7 (2.7)	17.5 (2.4)	26.8 (7.6)	4.4 (1.1)	1.4 (0.5)	1.0 (0.5)	C
TetricEvoceram	23.6 (4.2)	18.2 (4.0)	27.3 (10.8)	2.4 (0.5)	2.2 (1.4)	2.0 (0.2)	C
Venus Diamond	8.9 (3.0)	15.1 (2.7)	18.6 (5.5)	2.9 (0.3)	2.7 (0.8)	1.5 (0.1)	B
Grandio	14.2 (2.4)	25.0 (7.3)	20.7 (4.0)	2.7 (0.6)	1.6 (0.1)	1.1 (0.2)	C

Groups not connected with the same letter are significantly different

Table 5 Mean (SD) of color changes (ΔE) for each composite and colorant (week 3)

Composite	Color change (ΔE)						
	Black Tea	Coffee	Red wine	Orange Juice	Coke	Distilled water	Homogeneous Groups
Silorane	9.1 (1.9)	7.5 (3.8)	6.9 (1.4)	2.6 (1.6)	2.7 (0.7)	1.8 (0.3)	A
Filtek Z250	27.5 (8.6)	18.4 (1.5)	26.4 (8.5)	6.3 (1.5)	1.6 (0.4)	1.5 (0.5)	C
TetricEvoceram	26.4 (2.9)	19.8 (2.9)	26.1 (8.9)	3.5 (0.6)	3.1 (0.7)	2.6 (0.3)	C
Venus Diamond	11.7 (2.0)	16.1 (2.6)	18.0 (4.3)	3.1 (0.8)	2.3 (0.4)	2.1 (0.3)	B
Grandio	18.6 (5.0)	28.0 (9.0)	22.5 (7.1)	3.7 (1.1)	2.4 (0.5)	1.9 (0.3)	C

Groups not connected with the same letter are significantly different

Table 6 Mean (SD) of color changes (ΔE) for each composite and colorant (week 4)

Composite	Color change (ΔE)						
	Black Tea	Coffee	Red wine	Orange Juice	Coke	Distilled water	Homogeneous Groups
Silorane	12.9 (3.6)	7.6 (3.4)	8.1 (1.5)	3.4 (1.2)	2.9 (0.7)	1.9 (0.5)	A
Filtek Z250	16.9 (5.9)	20.1 (2.3)	30.2 (7.7)	7.3 (1.8)	1.4 (0.2)	2.1 (0.6)	C
TetricEvoceram	29.1 (3.5)	23.7 (2.3)	26.3 (8.5)	3.3 (1.0)	3.6 (0.6)	3.0 (0.6)	D
Venus Diamond	12.7 (2.3)	16.4 (1.5)	16.4 (4.7)	3.8 (0.6)	2.9 (0.5)	2.6 (0.2)	B
Grandio	19.0 (6.1)	29.9 (9.1)	23.8 (4.8)	3.9 (0.8)	2.6 (0.5)	2.8 (0.2)	CD

Groups not connected with the same letter are significantly different

DISCUSSION

Restorative dental materials are continuously exposed to saliva, beverages and food stains in the oral environment [1,6,21]. It is important to determine their both intrinsic color stability and staining resistance, as this will influence the restorations' imperceptibility [1]. Color stability has been previously studied in vitro and in vivo studies [36-42] for a variety of aesthetic restorative materials [1,4,7,10-14]. In this study, a severe clinical situation was simulated. Therefore, samples were not polished but obtained by pressing the resin between two glass plates. This is an attempt to simulate the most severe clinical situation, where the restorative material is polymerized against a Mylar strip, thus richer in matrix resin, as can occur especially in the proximal region [23].

The color stability of a resin composite is related to the resin matrix, dimensions of filler particles, depth of polymerization and coloring agents. Satou *et al.* [43] remarked that the chemical differences amongst resin components such as purity of the oligomers and monomers, concentration or type of activators, initiators and inhibitors, oxidation of the unreacted carbon-carbon double bonds may also affect the color stability. Microcracks and microvoids located at the interface between the filler and the matrix are the most likely penetration pathways for stain. The roughness of the surface caused by wear and chemical degradation may also affect gloss and consequently increase the extrinsic staining. The staining susceptibility of resin based composite materials is directly related to their degree of water sorption, related to the hydrophilic/hydrophobic nature of the resin matrix. If a composite resin can absorb water, it is also more likely to absorb water-soluble pigments, resulting in composite discoloration [1,11,44,45].

The staining solutions used in this study were black tea, coffee, red wine, orange juice and coke. These are common in our daily diet, and some are known to have potential to stain restorative materials [1,8,36,37]. Storage in distilled water was used as control group. For this group color differences were clinically acceptable ($\Delta E<3.0$), these results confirm that water absorption by itself did not alter the color of composites to a considerable extent [6,46]. An immersion period of 4 weeks was chosen, as according to Ertas *et al.* [36], which should be equivalent to about 2.5 years of clinical aging (24 hours of staining in vitro corresponds to about 1 month *in vivo*).

To avoid bias due to individual subjective evaluation of color, a spectrophotometric device was used in this study, allowing a quantitative color assessment [10,11,13,22] The CIE L*a*b* system was chosen to measure color of the samples, as it is well suited for the determination of small color differences and has been widely used in previous studies [14,23]. It has been actually claimed that a color difference of $\Delta E<1.0$ is imperceptible for the human eye, while a $\Delta E>3.3$ is clinically unacceptable [11,44]. A white background was used as according to Dietschi *et al.* [22], as in small Class III restorations, a white background is clinically the most relevant background.

Regarding staining potential, the solutions were ranked in the following order: red wine > coffee > black tea > orange juice > cola. Surprisingly, cola showed ΔE values similar to the control group. This is probably due to the low staining potential of the components. As according to Um and Ruyter [44], even if cola has an acidic pH that might deteriorate the surface of the material, it contains few yellow stains with low polarity. Red wine, on the other hand, performed the highest staining potential, followed by coffee and tea. Several studies have reported that alcohol facilitates staining by softening the resin matrix [5,10,37]. However, it was not explained whether staining by red wine was due to the alcohol or the presence of pigments in wine [5]. The staining ability of tea may be attributed to the presence of tannic acid and stains. Regarding coffee, it contains yellow stain molecule that seem to be responsible for the staining because of their affinity to the polymer network. [23].

Regarding the stainability of the materials**,** FiltekSilorane showed the highest color stability ($\Delta E=8.1$), according to table6, as described by various studies [15,16,18,32,33,46]. This might be due to the reduction in water sorption and solubility, which can be attributed to the hydrophobic backbone of the silorane molecule formulated from the incorporation of siloxane groups. Venus Diamond ($\Delta E=16.4$), was the second composite with the highest color stability, followed by Grandio($\Delta E=23.8$), Tetric ($\Delta E=26.3$) and Filtek Z250 ($\Delta E=30.2$), according to Table 6. Venus Diamond contains a modified urethane dimethacrylate resin matrix (TCD) and is bis-GMA free. This matrix consists of resin-containing aliphatic chains that are less hydrophilic, which results in a lower water sorption and water solubility when compared to conventional BisGMA resin matrix having hydrophilic hydroxide groups, as present in Z250, Tetric and Grandio [45].

Statistically significant differences in ΔE were not found between Grandio, Z250, and Tetric. Visually imperceptible differences in ΔE values (ΔE<1.0) between Z250, Tetric and Grandio were observed. These may be attributed to small differences in chemical composition of the materials, quality of filler-resin silanization or different affinity of the colorants to specific resin matrix components.

It is important to emphasize the impossibility of establishing the exact correlation between *in vitro* and *in vivo* tests, since the oral environment cannot be reproduced in the laboratory, and restorative materials are never subjected to staining medias for such a long consecutive period of time. The drinking habits of the patients must be considered when choosing restorative composite materials, especially on the aesthetic zone. The restorative material's composition is also important, as well as the polymerization degree, an adequate surface texture, and use it in a competent way to obtain its best properties, thus guaranteeing longevity and success [10].

CONCLUSION

Within the limitations of the present study, all three hypotheses were rejected, as ΔE values depended on the material and the staining solution in which the material was immersed. Further, from T0 to T4 ΔE increased gradually for every material, for which the stainability is also time-depending. Silorane composite showed the highest color stability overall.

It can be concluded that the drinking habits of the patients must be considered when choosing restorative composite materials, as the staining potential of a solution is material dependent. It can be supposed that color of esthetic restorations can be maintained over a longer period of time in the oral environment either by introducing some restrictions to a patient's dietary habits or carefully choosing the type of material best compatible with the dietary lifestyle.

Conflict of Interest: The authors declare that they have no conflict of interest.

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5.2 *In-vivo* spectrophotometric evaluation of pure enamel and enamel-dentin complex in relationship with different age groups.

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In-vivo spectrophotometric evaluation of pure enamel and enamel-dentin complex in relationship with different age groups.

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Abstract

Objective: The aim of this in vivo study was to investigate the influence of age on optical properties of pure enamel and enamel-dentin complex.

Methods: A spectrophotometric study was performed on two different age groups: young (10-35 years old) and adult (36-60 years old). In both groups, the tooth's total area of the upper right central incisor was recorded. Areas of 2 mm thick pure enamel and 3mm enamel-dentin complex were detected and their L*a*b* and CR evaluated.

Results: For 2mm pure enamel medians in the young group were L*74.8, a*3.1, b*15.1, against white background; and L*65.5, a*0.9, b*10.3 against black background. The correspondent opacity was 75%. In the adult group medians were L*70.0, a*4.1, b*15.4 against white background; and L*61.2, a*1.6, b*9.6, against black background. The correspondent opacity was 75%. For 3mm enamel-dentin complex medians in the young group were L*77.8, a*3.0, b*19.8 against white background; and L*74.2, a*1.1, b*15.9, against black background. The correspondent opacity was 89%. In the adult group medians were L*73.4, a*4.0, b*18.5 against white background; and L*71.0, a*2.0, and b*15.3 against black background. The correspondent opacity was 90%.

Discussion: The application of this method on a larger group of subjects of different ages may serve as a database for a more exact characterization of optical properties of natural enamel and dentin.

Conclusions: L* values in enamel, as well as a* value of 3mm thick enamel-dentin complex and 2mm pure enamel were significantly higher in the young age group.

Keywords: Spectrophotometer; L*a*b*; contrast ratio; dental colour.

Clinical Significance: L* and a* values of enamel over white and black backgrounds are statistically different within the 2 age groups considered. L* values over white background and a* values over black background of the enamel dentin complex seem to change with age. The opacity (CR) for enamel nor for enamel dentin complex doesn't change within the two age groups considered in this study.

Introduction

Optical properties of human teeth depend mainly on their external and internal morphology. Teeth consist of soft tissue (pulp) that is surrounded by dentin and enamel.[1] Due to ageing, optical properties of teeth suffer significant changes, especially visible in the incisal third.[2] According to literature, teeth can be classified in three age groups: young, adult and old.[2,3] Young teeth have an unaltered internal dentin structure with intact developmental lobes. This dentin is entirely covered by enamel, including the incisal edge. Enamel usually has a white tint and low opacity.[2] Adult teeth have an unaltered internal global structure, but developmental lobe tops might be exposed in the incisal edge area; enamel has a more neutral appearance, neutral tint and intermediate translucency. Old teeth have an altered dentin structure due to attrition on the incisal edge. In this age group, enamel shows a reduced thickness and minimal surface texture. Higher translucency and yellowish tint are described in literature[2] and these optical changes are supposedly due to an increase of mineral content in enamel. As a result, enamel and the whole tooth look greyer than adult or young teeth.[1,2] Of course, all of these elements have to be taken into account when a free hand bonded restoration has to be executed into a patient's mouth and the layering technique has to be adapted to his or her age.

Currently, visual shade determination performed by means of shade tabs is still the most common method used.[4-6] Unfortunately, the visual colour selection is a subjective determination method, which leads often to an imperfect colour match, [5] as classic shade guide tabs are not systematically distributed in the colour space and they do not exhibit a uniform colour over the entire tab. Moreover, these tabs are made by mixing the colour information of enamel and dentin[5,7] and none of the shade guides are identical.[6] Therefore, the use of a spectrophotometer should be preferred to visual shade assessment of human teeth.[6] This is a quantitative and therefore objective colorimetric method that can be used under routine clinical conditions and allows the measurement of selected tooth's area.[1,5,6] The approach of analysing a selected area of pure enamel or enamel-dentin complex consisting of a specific thickness[5,7] has already been used in prior studies in order to evaluate aesthetic properties of human teeth. Here not only L* a* b* values were analyzed, but also the opacity of selected tooth's area. Moreover, contrast ratio (CR) or opacity gives complementary information on colour, these being the capacity of a material to hide the background. This characteristic can be of major importance when, for example, in a class IV restoration it is important to hide the background in order not to have an unnatural grayish aspect.

Therefore, the aim of this *in-vivo* study was to investigate if there was a relationship between age and optical properties of specific pure enamel and enamel-dentin complex of upper central incisors. The null hypothesis was that the optical properties of teeth are not influenced by age.

Materials and methods

Sixty randomly chosen patients from the International University of Catalonia between the ages of 10 to 60 years gave their written informed consent approved by the ethical and scientific committee for a spectro-photometric analysis and stone replica of their upper central incisors through a polysiloxane impression. Whenever patients were under 18 years old their parents signed the informed consent for them. Only patients with intact vital upper central incisors without malformations and significant intrinsic colorations, fissures or restorations were included in the study.

The two age groups were divided as follows: the 'young' group was defined by including patients between 10 and 35 years old, and the 'adult' group by including patients between 36 and 60 years old. Each age group consisted of 30 patients. Tooth brushing of their front teeth was carried out using 70 RDA toothpaste and a standard toothbrush (Colgate Total, Colgate-Palmolive, Thalwil, Switzerland) prior to spectrophotometric measurements. Caution was used in order not to dehydrate teeth.

Spectrophotometer measurements

A calibrated reflectance image spectrophotometer (SpectroShade, Handy Dental Type 713000, Serial No. HDL0090, MHT, Arbizzano di Negar, Verona, Italy) was used in this study. The validity and reliability of the measurements of this device have been demonstrated in previous studies. [8,9] With this device, CIE L*a*b* measurements of the entire surface of the central upper incisors of each subject were performed against white and black backgrounds. These plastic backgrounds i.e white (L* 96.61; a*-0.68; b*2.56) and black (L*0.44; a*0.09; b*-0.13) were placed behind the upper right central incisor and patient was asked to bite on it in order to secure a tight contact between the palatal tooth's area and the plastic background. In order to avoid teeth's dehydratation patient was asked to rinse his mouth with water for 30 seconds between spectrophotometric measurements.

All details about the methodology are widely presented in a prior publication[7] as well as all the mathematical formulas used for CR calculations.[5,7]

Tooth shape determination

A vinyl polysiloxane impression (Express fast set light body, 3M ESPE Dental Products, St Paul, MN, USA) of upper front teeth of each specimen was taken and poured with plaster in order to obtain a replica as well as to enable registration of 3D tooth dimensions. The oro-facial thickness and the length of the tooth were measured on the model by using a dental calliper.

Opacity determination

Areas of 3 mm tooth thickness consisting of an equal amount of enamel and dentin according to Schillingburg and Scott[10] were determined, and CIE L*a*b* values on white and black backgrounds were obtained by comparing optical data of the MHT device in gloss mode with the plaster models by using a digital calliper to measure their thickness in oro-facial direction. Once the appropriate area was detected, CIE L*a*b* measurements were performed on the corresponding SpectroShade images with white and black backgrounds. Two millimeters of pure enamel in the interproximal area were then analysed performing the same methodology as described above for enamel-dentin complex. No direct measurements on pure dentin samples were possible due to the absence of exposed dentin in intact teeth.

CIE L*a*b* values of enamel and enamel-dentin were used to calculate opacity. (Table 1) CIE L*a*b* values of 3 mm thick enamel-dentin complex and interproximal area with white and black backgrounds of the two different age groups were then converted into Yxy scale to obtain contrast ratio (CR) values. An exhaustive description of the whole methodology was reported in previous publications.[5,7]

Table 1 – Formulas used for the calculations of Yxy, and contrast ratio (CR) out of CIE L*a*b* measurements.

```
CIE-L*ab → XYZ

var_Y = (CIE-L* + 16)/116
var_X = CIE-a*/500 + var_Y
var_Z = var_Y – CIE-b*/200

if (var_Y^3 > 0.008856) var_Y = var_Y^3
else                    var_Y = (var_Y – 16/116)/7.787
if (var_X^3 > 0.008856) var_X = var_X^3
else                    var_X = (var_X – 16/116)/7.787
if (var_Z^3 > 0.008856) var_Z = var_Z^3
else                    var_Z = (var_Z – 16/116)/7.787

X = ref_X * var_X     //ref_X = 95.047   Observer = 2°,
Illuminant = D65
Y = ref_Y * var_Y     //ref_Y = 100.000
Z = ref_Z * var_Z     //ref_Z = 108.883

XYZ → Yxy

//Where X = 0 ÷ 95.047     Observer = 2°, Illuminant = D65
//Where Y = 0 ÷ 100.000
//Where Z = 0 ÷ 108.883

Y = Y
x = X/(X + Y + Z)
y = Y/(X + Y + Z)

CR (opacity): Yb/Yw
```

w = white background.
b = black background.

Statistical Analysis

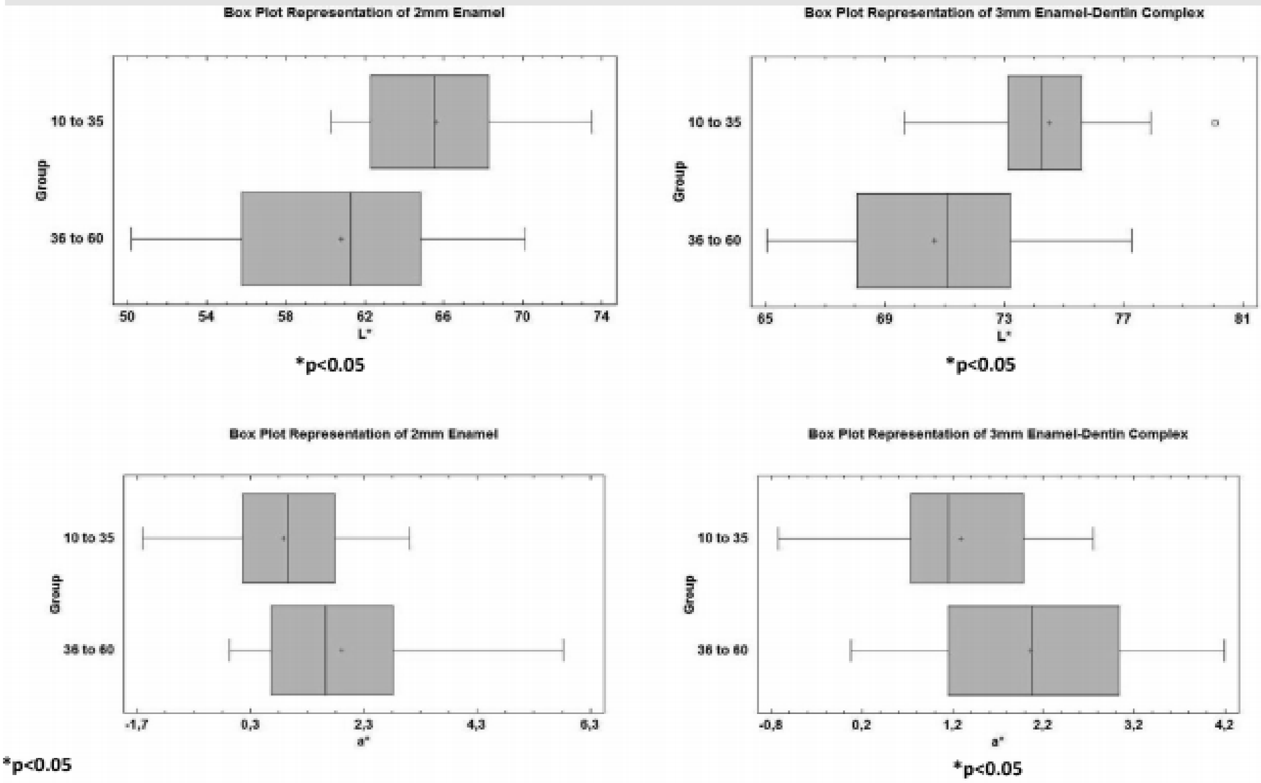
The differences between age groups were determined statistically by using a one-way ANOVA at a significance level of 0.05.

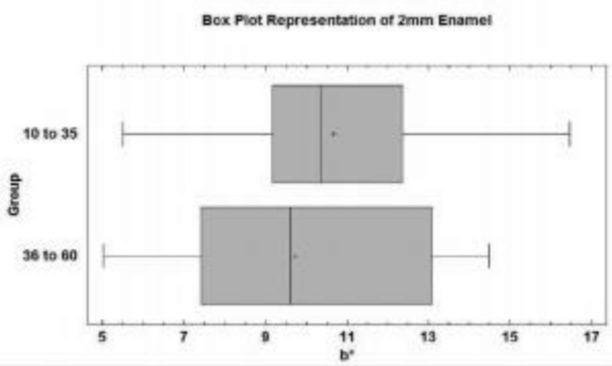
Results

When young vs. old group were compared at 2mm of pure enamel against a white background, the median values obtained were respectively L* 74.8, a* 3.1 and b* 15.1 for the young group; and L* 70.0, a* 4.1, and b* 15.4 for the old group. When the same area and the same groups were compared against a black background the median values obtained were: L* 65.5, a* 0.9, and b* 10.3, for the young group; and L* 61.2, a* 1.6, and b* 9.6, for the old group. A One-way ANOVA was used to investigate the differences between young and old group on L* a* b* values of 2mm pure enamel. From this analysis, it was shown that significant statistical differences ($p<0.05$) were found for L* and a* values when analysed against white and black backgrounds. The median values of opacity (CR) of young vs. old group for 2mm pure enamel area was 75%for the young group and 75%for the old group. Evidently no statistical differences (p>0.05) were found between these groups.

Regarding 3mm thick enamel-dentin complex, when comparing young vs. old group against a white background the median values obtained were: L* 77.8, a* 3.0, and b* 19.8 for the young group; and L* 73.4, a* 4.0, and b* 18.5 for the old group. When young vs. old group were compared at 3mm thick enamel-dentin complex against a black background the median values obtained were: L* 74.2, a* 1.1 and b* 15.9 for the young group; and L* 71.0, a* 2.0 and b* 15.3 for the old group. A one-way ANOVA was used to investigate the differences between young and old group on L* a* b* values of the 3mm thick enamel-dentin complex. From this analysis it was shown that significant statistical differences were found (p<0.05) for L* values when analysed against white background, as well as for a* values when analysed against black background. Regarding the opacity (CR) of young vs. old group at 3mm thick enamel-dentin complex the values were 89% for the young group and 90% for the old group. No significant statistical differences (p>0.05) were found between these groups. The complete representation of the data distributions are shown in Tables 2, 3 and 4.

Table 2 – L*, a*, b* graphical representation of 2 mm pure enamel and 3 mm enamel–dentine complex against a black background ($p < 0.05$ means statistical significant differences).





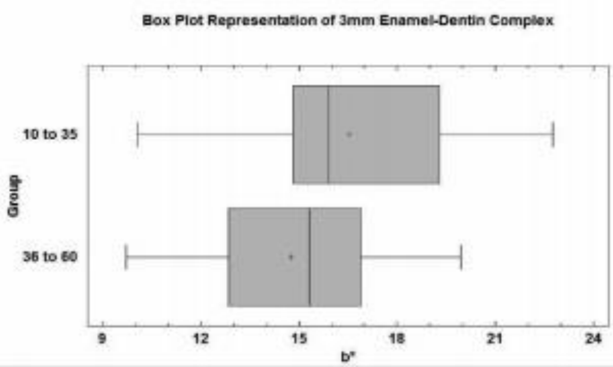
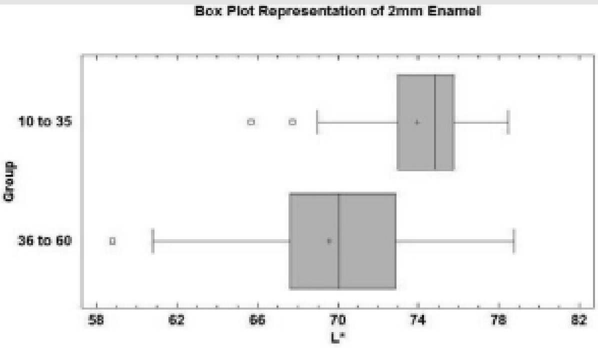
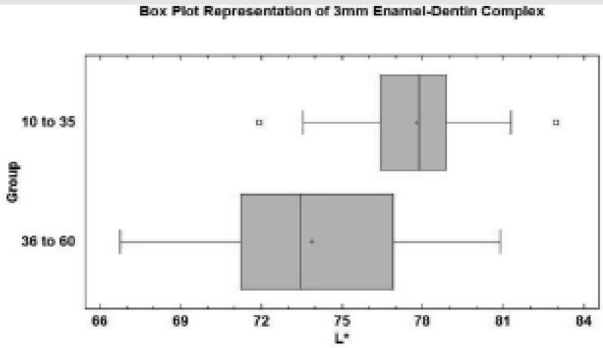


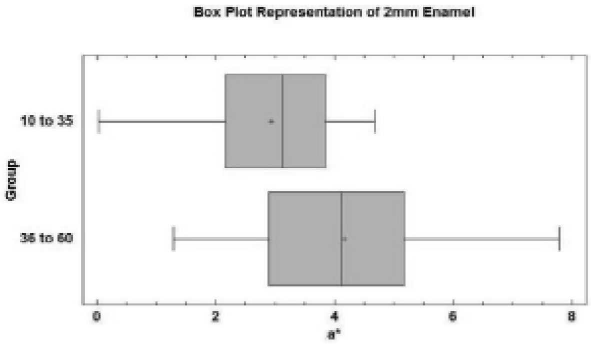
Table 3 – L^*, a^*, b^* graphical representation of 2 mm pure enamel and 3 mm enamel-dentine complex against a white background ($p < 0.05$ means statistical significant differences).



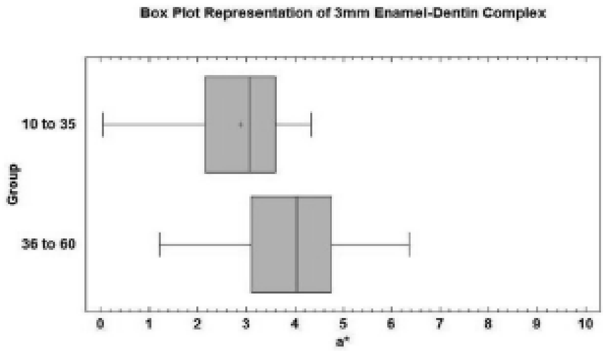
*p<0.05

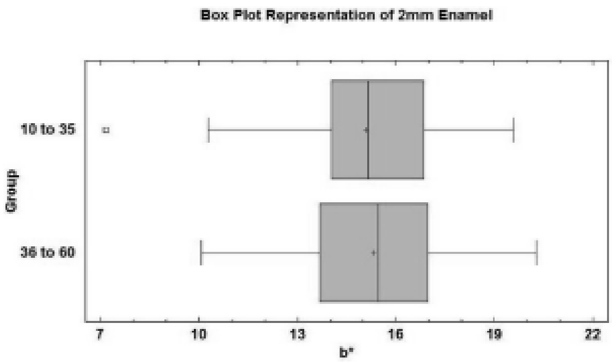


*p<0.05



*p<0.05





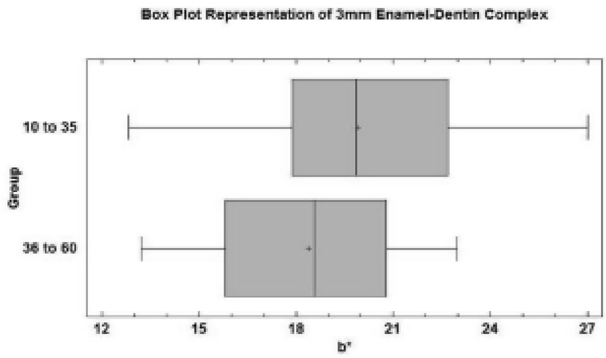
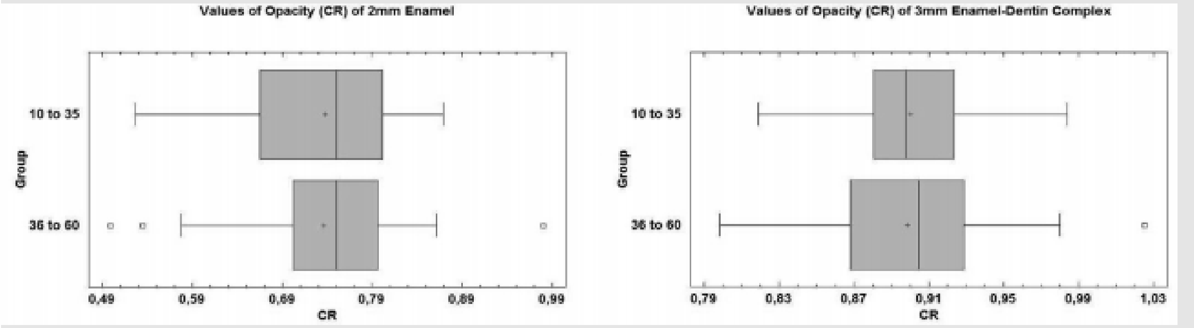


Table 4 – CR graphical representation of 2 mm pure enamel and 3 mm enamel–dentine complex ($p < 0.05$ means statistical significant differences).



Discussion

Only a limited number of previous studies have described optical properties of enamel and dentin *in-vitro* and only one of them developed a method that discriminates enamel and dentin and characterizes opacity.[5,7] L*a*b* values were obtained in order to investigate all components of color, as according to other studies,[5,7] and the opacity of 2mm of pure enamel and 3mm thick enamel-dentin complex was calculated.[5]

Clinically it is, in fact, impossible to analyze separately the same thickness of enamel and dentin, as exposed dentin cannot be found in intact teeth.[11] That is why the majority of studies have been performed by mixing the two information sets together.[12, 13] Therefore, in this study L*a*b* values of 2mm thick pure enamel were obtained in the interproximal zone of the teeth, and 3mm thick enamel-dentin complex was evaluated in the incisal third of the front teeth. According to Shillingburg and Grace, this area consists of 50% dentin and 50% enamel.[7,10] On the other hand, the localization of "pure" interproximal enamel was possible due to the visual determination of enamel on MHT images in gloss mode and a parallel measurement of the enamel thickness on the stone model of the respective anterior teeth.[5] In the present study, in contrast to Ardu et al,[5,7] measurements of 2mm thickness of pure enamel was performed at the interproximal area and not in the incisal area, as in the adult teeth the incisal edge is altered and worn, and frequently at this point there are areas of exposed dentin.[2,11] Due to this difference a direct comparison with the previous data is not possible. In any case, some general considerations can be made. Regarding 2mm pure enamel, L* values over white background are lower while L values over black background are higher in our study (74.8 vs. 76.3 for white background and 65.5 vs. 63.5 for black background). This could be due to the median age, which is higher in our group test, as well as the influence of the enamel opacity which is much higher (75% against 64.4%). The choice of the interproximal area could be the key point for the interpretation of these results. Interproximal area seems, in fact, to be much more opaque than the corresponding incisal pure enamel zone.

The 3 mm enamel dentin complex confirmed lower values of L* over white and black backgrounds (77.8 vs. 79 for white background and 74.2 vs. 74.9 for black background) and a slightly higher opacity (89 vs. 84.4). Finally, some differences could be due not only to the different age-range analysed, but even to possible differences due to the different population employed in the study (Swiss against Spanish).

In our *in-vivo* study, the aim was to compare the eventual differences in the main component of tooth's color i.e. L*a*b* coordinates between young and old patients. When considering 2mm pure enamel, L* values were significantly higher in the young age group. This might be due to the fact that younger teeth have greater luminosity with a milky chalky white color.[14] On the contrary, in the 36-60 years adult group, a higher a* value could be observed in the 3mm thick enamel-dentin complex as well as in 2mm of pure enamel. In this group, thinner enamel is present, resulting in a more pronounced influence of the hue of the dentin within the green-red range.[15] Statistical differences were detected when values obtained against white and black backgrounds of 2mm pure enamel and 3mm enamel dentin complex were analysed. It is of interest that b* values of pure enamel, as well as of enamel dentin complex seem to be stable in the two different age groups while the increase in chroma seems to be due only to higher a* values.

Opacity (CR) was not significantly different between young and old individuals in the 3mm enamel dentin complex. However, in young teeth the superficial layers of enamel are reported in literature to be more opaque. [2,3] Frequently they have a frost-white appearance, and they are less mineralized. They also have more empty space between enamel crystals, which causes increased opacity. On the contrary, in adult teeth the pulp shows a decrease in volume, while dentin becomes thicker and more saturated.[2,3,14,15] Also the mineral content increases due to deposition of mineral salts within the tubule lumens but reaches a point of saturation after a particular age.[16] These two processes seem to lead to a stable opacity value over time.

Regarding 2mm thickness of pure enamel there were no differences in opacity between young and adult group. This result might be due to the fact that enamel does not seem biologically affected by age, at least in the interproximal area.[16]

Caution has to be paid in interpreting these results due to the fact that even small errors in measuring dental thickness of specific areas could influence the final results. Future multicentre studies on higher number of subjects and different age intervals could be interesting in order to develop resin composite materials based on natural tooth colours changes over time.

Conclusions

With the results found in this *in vivo* study, the null hypothesis was partially rejected because when young versus old group values were analysed, L* and a* were statistically different over white and black backgrounds for 2mm enamel, while for 3mm enamel dentin complex statistically differences were found for L* over white background as well as for a* over black background.

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5.3 Color stainability of indirect CAD-CAM processed composites vs. conventionally laboratory-processed composites after immersion in staining solutions

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Artículo se encuentra en 2da revisión para su publicación en Journal of Dentistry Factor de Impacto: 3.200. Primer cuartil (Dentistry, Oral Surgery & Medicine)

Color stainability of indirect CAD-CAM processed composites vs. conventionally laboratory-processed composites after immersion in staining solutions

Mariana A Arocha, Juan R Mayoral, Jaume Llopis, Miguel Roig y Stefano Ardu

Abstract

Objectives: The aim of this study was to determine, by using a spectrophotometer device, the color stainability of two indirect CAD/CAM processed composites in comparison with two conventionally laboratory-processed composites after being immersed in staining solutions such as coffee, black tea, and red wine, using distilled water as control group.

Methods: Two indirect CAD/CAM composites (Lava Ultimate and Paradigm MZ100) and two conventionally laboratory-processed composites (SR Adoro and Premise Indirect) of shade A2 were selected to measure their color stability (160 disk samples) after 4 weeks of immersion in three staining solutions (black tea, coffee, red wine) and distilled water. The specimen's color was measured each week by means of a spectrophotometer (CIE L*a*b* system). Statistical analysis was carried out performing a repeated measures ANOVA and LSD Test in order to statistically analyze differences in L*a*b*and ΔE values.

Results: All materials showed significant discoloration ($p < 0.05$) when compared to the control group (immersed in distilled water). The highest ΔE observed was with red wine, whereas black tea showed the lowest one. Indirect laboratory-processed resin composites showed the highest color stability compared with CAD/CAM resin blocks.

Conclusions: CAD/CAM processed composites immersed in staining solutions showed lower color stability when compared to conventionally laboratory-processed resin composites.

Significance: The demand for CAD/CAM restorations has been increasing recently; however, the color stainability for such material has been insufficiently studied. Moreover, this has not been performed comparing CAD/CAM processed composites versus laboratory-processed indirect composites by immersing in staining solutions for long immersion periods.

Keywords: Resin-composites, CAD/CAM, Staining, Color stability, Stainability.

Introduction

Restorations in the oral cavity are exposed to several factors that make them vulnerable to color changes, such as temperature, humidity, food and smoking habits.[1] There are many factors associated with the discoloration of the dental materials in the oral environment. The color stability of the composites, is due to exogenous and endogenous reasons.[2-6] The exogenous reasons include the influence of staining solutions such as coffee and red wine.[5, 7] The endogenous reasons include the system of initiator systems, duration of polymerization, resin matrix composition, conversion of the matrix monomers, particle size and hardness and oxidation of the unreacted carbon double bonds.[5, 6, 8-10] Today there are multiple materials that can be used when performing an esthetic restoration. It is important to know their optical, mechanical and physical properties to guarantee the success of the restoration.[5]

The use of resin composites has expanded, going from a direct restorative material, to an indirect laboratory-processed composite.[11, 12] Today the use of indirect composite materials has increased substantially.[10, 13] This might be related to their higher conversion degree, making them more stable in color than direct composites,[9] and also due to their improvements in the properties of the materials.[10] They were initially developed as an alternative for the substitution of ceramic and metallic restorations.[9, 14] The indirect composites can be subdivided into two groups: the indirect computer-aided design/computer-aided manufacturing (CAD/CAM) processed composites and the conventional laboratory-processed composite. CAD/CAM processed composites are industrially polymerized under standardized parameters at high temperatures and pressure to ensure constant quality in the properties.[6] The first CAD/CAM restoration was fabricated in 1985 with the CEREC 1 unit. It was made out of a prefabricated ceramic block. Since then, the technique has evolved becoming less expensive, easier, faster and more accurate.[13] Within years CAD/CAM processed composites were developed as an alternative to the ceramic blocks, being one of the major advantages their optical stiffness and the fact that these resins can be repaired and maintained easier than ceramics.[12,13] Also, compared to direct composites, they have less porosity, less polymerization shrinkage and more homogeneity.[12] Some CAD/CAM processed composites like Paradigm have similar composition to direct and indirect resin composites; they have Bis-GMA as part of their resin matrix. The hydrophilicity of this monomer is well known;[2, 5, 6, 15]. New types of CAD-CAM processed composites like Lava Ultimate added nano-ceramic particles embedded in a highly cured resin matrix.[16]

Currently, there are few studies in literature that evaluate the color stainability and stability of indirect laboratory-processed composites.[6, 9, 10] Furthermore, no studies compared or evaluated the color stainability of indirect CAD/CAM processed composites vs. conventionally laboratory-processed composites immersed in staining solutions. The aim of this study was therefore to compare and evaluate the color stainability of indirect CAD/CAM processed composites versus conventionally laboratory-processed composites by means of a spectrophotometer. The two null hypothesis of the study were that 1) color stainability of CAD/CAM processed composite is not higher than color stainability of conventionally laboratory-processed composite. 2) The type of staining solution does not influence the stainability of the material.

Material and methods

One hundred and sixty disk samples were prepared from four different indirect resins (two indirect CAD/CAM processed composites: Lava ultimate (LULT) and Paradigm (PRD) and two indirect laboratory-processed composites: Adoro (ADR) and Premise Indirect (PMI)) composite materials (Table 1) of shade A2 (n= 40). A diagram of the study design is shown in Figure 1. The samples of laboratory-processed indirect composites were made by condensing the material into a standardized metal mold. The mold with the composite resin was held between two glass slides, each one covered with a transparent polyester strip (Mylar, DuPont, Wilmington, Del., USA). The slides were then gently pressed together to remove excess material. All specimens were polymerized by a LED light-curing lamp Bluephase (IvoclarVivadent AG, Schaan, Liechtenstein) with a light intensity of 1,200 mW/cm2 for 20 s. Irradiance was tested by a radiometer Demetron LED (Kerr Corp, Orange, CA, USA). The distance between the light source and the specimen was standardized by the use of a 1-mm glass slide. Specimens' dimensions were 10 mm in diameter and 2 mm in thickness. After polymerization samples were polished with Sof-lex fine and superfine grit discs (3M/ESPE, St. Paul, MN, USA), all samples were light cured and prepared following the manufactures recommendations. The samples of CAD-CAM processed composite were fabricated by cutting the block with an ISOMET (Buehler, Lake Bluff, USA) at 2 mm thickness. In order to standardize the samples, the diameter for these discs were marked with the metal mold and cut using a diamond bur. Afterwards the samples were polished with Sof-lex fine and super fine grit discs. A digital caliper was used to measure the discs' thickness. The specimens were stored in distilled water at 37 °C for 24 h for rehydration and completion of the polymerization, following the methodology of previous studies.[5, 9, 10, 15] Before the immersion in staining solutions, specimens of each composite were randomly divided into four groups, corresponding to 10 samples per staining solution (coffee, black tea, red wine, and distilled water as control group) (Table 2).

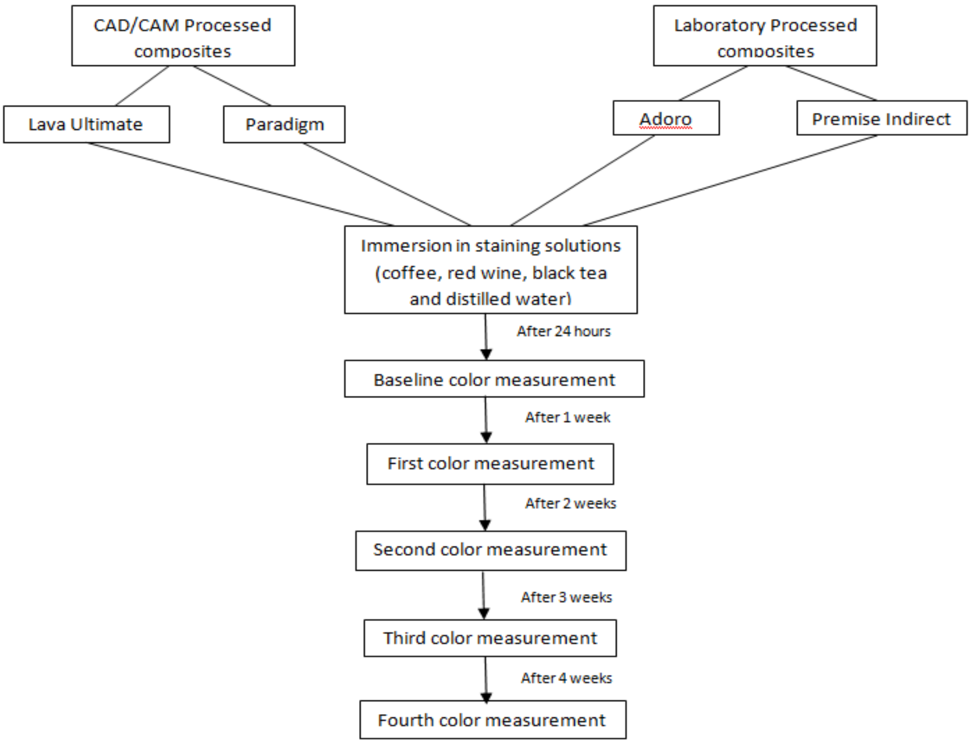
Table 1. Indirect resins used in the investigation. Bis-GMA: bisphenol-a-glycidyl methacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis-EMA: ethoxylated bisphenol a-methacrylate DMAEMA: Dimethylaminoethyl Methacrylate; UDMA: urethane dimethcarylate
*Composition as given by manufacturers.

COMPOSITE	COMPOSITION*	MANUFACTURER	COLOR	LOT	TYPE
LAVA ULTIMATE	Bis-GMA, UDMA, TEGDMA and Bis-EMA	3M/ESPE, St. Paul, MN, USA	A2-LT	N373563	CAD/CAM
PARADIGM MZ100	Bis-GMA, TEGDMA	3M/ESPE, St. Paul, MN, USA	A2	N375547	CAD/CAM
SR ADORO	Bis-GMA, TEGDMA, UDMA	IvoclarVivadent AG, Schaan, Principality of Liechtenstein	A2 Dentin/Body	R48350	*InLab* composite
PREMISE INDIRECT	DMAEMA	Kerr Corporation, Orange, CA, USA	A2 Facial dentin	4463218	*InLab* composite

Table 2. Different staining solutions used in this investigation.

Solution	Manufacturer
Black tea	Label Tea, Lipton Tea®, Unilever, France
Coffee	Nescafé Classic®, Nestlé, Spain.
Red Wine	Enate®, Tempranillo-Cavernet Sauvignon 2004, Spain.
Distilled water	Lasda S.A, Spain

Fig 1. Diagram of the study design



The specimens were rinsed for 10 s with distilled water and wiped dry with gauze before being immersed in staining solutions. At this moment, baseline color measurements (T0) were made. These measurements were performed using a reflectance spectrophotometer (SpectroShade, Handy Dental Type, MHT, Arbizzano, Italy) using the CIE L*a*b* system. The choice of this spectrophotometer has been made due to its accuracy in measurements and easy handling. All details concerning the functioning of the SpectroShade are detailed in previous studies. [8,17-21] The validity and reliability of the measurements of this device have been demonstrated in previous studies. [5, 15, 19, 20]

Spectrophotometric measurements were made using a white background, as in other studies. [5,15] Before each sample measurement, the spectrophotometer was calibrated according to manufacturer recommendations using the supplied calibration standards. Color measurements were then made according to the same procedure at a time interval of 1 week (T1), 2 weeks (T2), 3 weeks (T3), and one month (T4). Staining solutions were kept at 37 °C, and renewed every 2 days to avoid bacteria or yeast contamination.[5, 15, 22] Using the SpectroShade software, differences in color (ΔE means) between baseline (T0) and T1, T2, T3, and T4 measurements were calculated for each resin-based composite material and staining solution, according to the following formula of Pythagoras:[5, 8-10]

$$\Delta E = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{1/2}$$

Where ΔL* is the change in luminosity, Δa* is the change in red–green parameter and Δb* the change in yellow–blue parameter. Color stainability was determined evaluating the color difference (ΔE).

As data were normally distributed (Shapiro–Wilk Test), statistical analysis was performed using a repeated measures ANOVA and LSD test in order to evaluate differences in ΔE, between groups. [23] The data analysis was carried out using the Statgraphics software (Statpoint Technologies, Warrenton, Virginia, USA) with a significance set at $p=0.05$.

Results

The mean (SD) values for the color differences (ΔE*) of the evaluated materials after each week of immersion are represented in Tables 3, 4, 5 and 6. For the first, second and fourth week statistically significant differences ($p<0.0001$) were detected between all composite materials tested as shown in Figure 2; only in the third week, no statistically significant differences ($p>0.05$) were detected between LULT and PRD. Throughout all the four weeks, the group with the highest color stainability was LULT, while ADR had the lowest values, as shown in Figure 2. Also, the CAD/CAM composites had the highest color stainability compared to conventionally laboratory-processed composites. Stainability was higher over time for all groups.

Table 3. Mean (SD) of color changes (ΔE) for each composite and colorant. Week 1. Groups not connected with the same letter are significantly different

	Color change (ΔE means)				
Composite	**Coffee**	**Red Wine**	**Black tea**	**Distilled water**	**HomogeneousGroups**
Lava Ultimate	15.5 (1.6)	24.4 (3.1)	11.7 (3.1)	2.9 (1.0)	A
Paradigm	11.2 (0.8)	25.9 (3.4)	5.2 (2.0)	4.1 (0.9)	B
Adoro	7.3 (1.7)	17.1 (5.2)	3.5 (1.5)	1.9 (0.3)	C
Premise Indirect	9.8 (2.7)	19.9 (4.3)	4.6 (2.3)	1.9 (0.8)	D

Table 4. Mean (SD) of color changes (ΔE) for each composite and colorant. Week 2. Groups not connected with the same letter are significantly different

	Color change (ΔE means)				
Composite	**Coffee**	**Red Wine**	**Black tea**	**Distilled water**	**Homogeneous Groups**
Lava Ultimate	17.7 (2.0)	28.9 (4.9)	12.2 (2.6)	2.5 (0.6)	A
Paradigm	13.1 (1.7)	30.9 (4.2)	9.7 (1.4)	4.1 (0.7)	A
Adoro	9.4 (2.2)	19.1 (3.2)	4.9 (1.1)	2.1 (0.4)	B
Premise Indirect	12.6 (4.0)	21.3 (3.2)	7.8 (2.4)	2.1 (0.9)	C

Table 5. Mean (SD) of color changes (ΔE) for each composite and colorant. Week 3. Groups not connected with the same letter are significantly different

	Color change (ΔE means)				
Composite	**Coffee**	**Red Wine**	**Black tea**	**Distilled water**	**Homogeneous Groups**
Lava Ultimate	18.0 (1.5)	31.5 (6.6)	19.4 (2.4)	1.7 (0.9)	A
Paradigm	16.3 (1.7)	30.6 (4.5)	14.7 (2.9)	4.4 (1.2)	A
Adoro	10.4 (2.8)	21.4 (3.3)	4.9 (1.0)	2.0 (0.6)	B
Premise Indirect	14.3 (3.8)	25.5 (2.8)	9.3 (2.4)	1.9 (1.1)	C

Table 6. Mean (SD) of color changes (ΔE) for each composite and colorant. Week 4. Groups not connected with the same letter are significantly different

	Color change (ΔE means)				
Composite	**Coffee**	**Red Wine**	**Black tea**	**Distilled water**	**Homogeneous Groups**
Lava Ultimate	19.7 (1.6)	37.0 (2.2)	17.7 (2.4)	2.8 (1.1)	A
Paradigm	17.5 (2.5)	34.6 (3.5)	17.7 (1.6)	3.6 (0.9)	A
Adoro	10.5 (2.2)	24.5 (3.3)	7.0 (2.5)	1.8 (0.6)	B
Premise Indirect	16.1 (4.2)	27.9 (5.7)	12.4 (2.1)	2.0 (1.4)	C

As shown in Figure 3, for the LULT and PRD CAD/CAM processed composites, as well as for the ADR and PMI conventionally laboratory-processed composites, the highest color stainability were caused by red wine during all weeks; while the lowest color stainability was obtained from black tea also in every week. With the exception of PRD in the fourth week, there were no statistical significant differences ($p>0.05$) between coffee and black tea.

Figure 4 shows the relation between all staining solutions and groups. Statistical significant differences ($p<0.00001$) were found in all groups for all staining solutions except in red wine, where no statistical significant differences ($p>0.05$) were found between LULT and PRD. In the control group the lowest color stability was found for PRD.

Figure 2. Interaccions of staining potential between all groups and all weeks

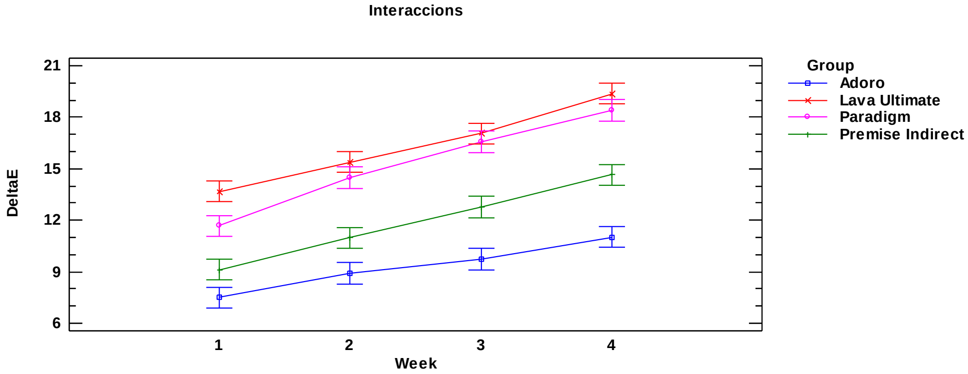


Figure 3. Comparison of staining potential for all type of staining solutions used in this study within groups

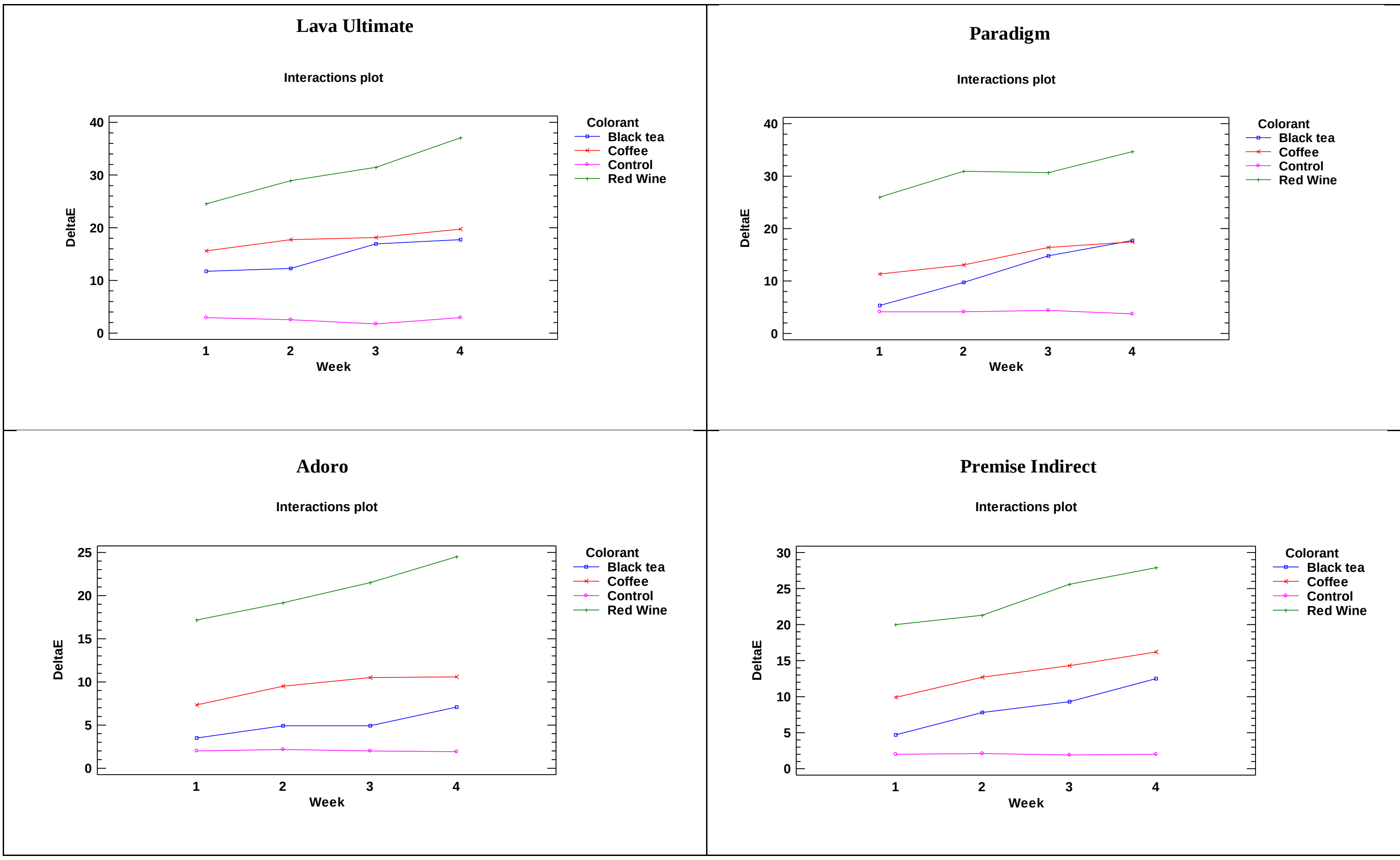
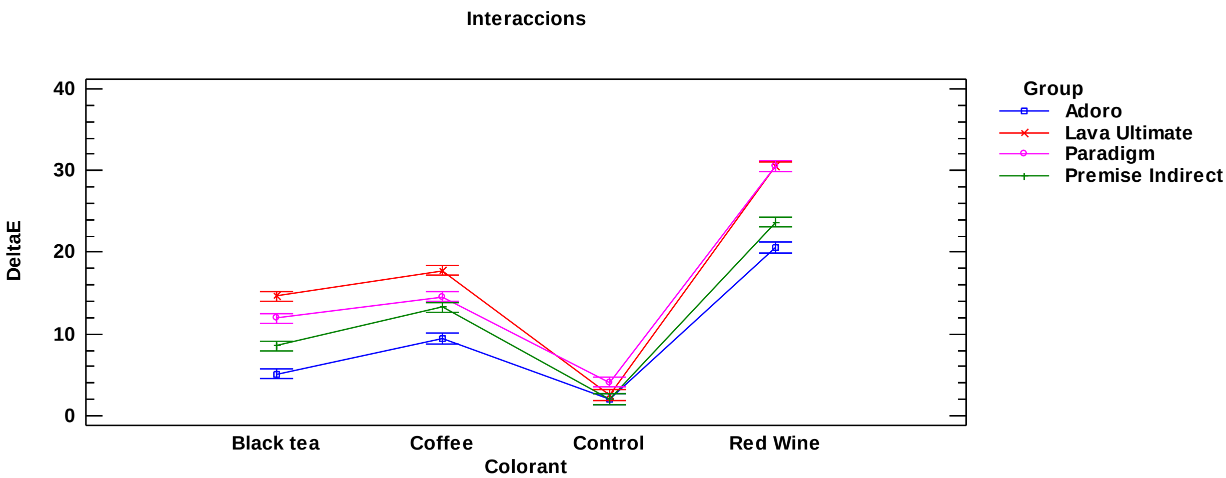


Figure 4. Interaction between staining solutions and each groups for all weeks



Regarding the staining potential, when all types of solutions were compared within groups (Figure 3), red wine showed the highest potential overall in every week, followed by coffee, black tea and distilled water. No statistical significant differences ($p > 0.05$) were found between coffee and black tea during the fourth week for PRD. Naturally, the control group showed the highest color stability.

Discussion

One of the problems associated with the failure of esthetic restorations is their unpredictable color stainability and stability.[4, 10, 24] Color changes of resins have been attributed to a wide variety of possible causes, such as dental plaque accumulation, pigmentation by staining agents, dehydration, water sorption, surface roughness chemical degradation, oxidation of unreacted carbon double bonds, amongst others.[4, 9, 10, 15, 24]

In order to perform an objective evaluation of color, a spectrophotometric device was used in this study, allowing a quantitative color assessment.[3, 5, 15, 18, 25] The CIE L*a*b* system was chosen to measure the color of the samples as it is well suited for the determination of small color differences and has been widely used in previous studies.[5-9, 15, 26]

The color stainability in this study was evaluated using beverages that are frequently ingested in our daily diet, such as coffee, red wine, and black tea, and some of them are known to have the potential to stain restorative materials.[2, 9, 27, 28] Storage in distilled water was used as control group. For this group, color differences were clinically acceptable ($\Delta E<3.0$) for Lava Ultimate, Adoro and Premise Indirect; these results confirm that in most of the cases water sorption by itself did not alter the color of composites to a considerable extent.[5, 29] For CAD/CAM processed composite Paradigm ΔE values were $\Delta E>3.6$, this value being considered clinically unacceptable. An immersion period of 4 weeks was chosen, as according to Ertas *et al*.[28] This should be equivalent to about 2.5 years of clinical aging (24 hours of staining in vitro corresponds to about 1 month *in vivo*).[5, 15]

Regarding staining potential, the solutions were ranked in this order (from highest to lowest staining potential): red wine > coffee > black tea. These results were similar to previous studies.[5, 15, 28] Red wine has shown the highest potential of discoloration. Several studies have reported that alcohol facilitates staining by softening the resin matrix; [5, 15, 22, 28] however, it was not explained whether staining by red wine was due to the alcohol or the presence of pigments in wine.[30] In the case of coffee, this substance precedes black tea since it contains yellow stain molecules with low polarity that seems to be responsible for the staining due to their affinity to the polymer network. The staining ability of tea may be attributed to the presence of tannic acid and pigments.[15]

Concerning the stainability of the materials**,** the two indirect CAD/CAM processed composites showed lower color stainability compared with conventionally laboratory-processed composites. This might be due to insufficient polymerization of the CAD/CAM resins.[6] Unfortunately, details of this process were not available from the manufacturer. Similar results were found in another study[6] comparing CAD/CAM processed composites versus direct composites resins. Also, previous studies report the poor esthetic and mechanical properties of the CAD/CAM processed composites.[12, 13]

According to Table 6, Adoro showed the highest color stainability (ΔE=7.0) in all staining solutions. This composite has UDMA monomer which compared with Bis-GMA does not have hydroxyl side groups. Previous studies [6,15,19,31,32] have reported the low hydrophilicity, low viscosity and solubility of this monomer which contributes to a less water sorption and therefore more color stainability. Premise Indirect (ΔE=27.9) was the second composite with the highest color stainability, followed by Paradigm (ΔE=34.6) and Lava Ultimate (ΔE=37.0) (Table 6). Premise Indirect contains DMAEMA (dimethylaminoethy Methacrylate) and is Bis-GMA free, which might result in a lower water sorption and water solubility when compared to conventional Bis-GMA resin matrix.[5, 15] In general, none of the composites obtained a $\Delta E<3.3$, thus all color changes due to red wine, coffee and black tea are visible for the human eye and not clinically acceptable. These results are similar to the ones in previous studies.[5, 6, 9]

The staining susceptibility of resin-based composite materials is directly related to their degree of water absorption, which is affected by the hydrophilic/hydrophobic nature of the resin matrix.[4, 8] This may also be influenced by the chemical composition of beverages, which represents an important feature of the color stainability and surface integrity of composites.[4] If a composite resin can absorb water, it is also more likely to absorb water-soluble pigments, resulting in composite discoloration.[2, 5, 8, 25,26, 29, 32-34]

Conclusion

Within the limitations of this *in-vitro* study, the first null hypothesis stating that color stainability of CAD/CAM processed composites is not higher than color stainability of conventionally laboratory-processed composites was accepted. On other hand, the second null hypothesis was, on the other hand rejected, as ΔE values depended on the material and the staining solution in which the material was immersed.

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DISCUSIÓN

La finalidad de este estudio es crear una base de datos de las características ópticas de los dientes a diferentes edades, de esta manera no solo le sirve al odontólogo a la hora de realizar restauraciones estéticas sino que también sirve de ayuda a los fabricantes de composites para desarrollar materiales que cada vez sean más parecidos y compatibles con la naturaleza, así como también más estables en el tiempo.

Existen muchas investigaciones que evalúan el color de los dientes de manera general, solo un número pequeño de estudios han descrito las propiedades ópticas del esmalte y la dentina. Clínicamente *in-vivo* es imposible analizar el esmalte y la dentina como dos estructuras independientes, por eso muchos estudios analizan la información como un todo (31, 51) y otros lo hacen con los dientes extraídos (*in-vitro*) o dientes bovinos. El problema de estos estudios cuando se hacen *in-vitro* es que el color del diente se altera, ya que si bien es verdad que el esmalte y la dentina representan factores fundamentales en el color la pulpa y los tejidos gingivales también contribuyen en la apariencia del mismo (44)

Ardu et al (1, 6) desarrollaron un nuevo método que discrimina *in-vivo* el esmalte y el complejo esmalte-dentina y caracteriza la opacidad, los valores de L*a*b* son obtenidos en dos lugares del diente (con ayuda de un pie de rey): en 2mm de grosor del esmalte en el área interproximal donde existe únicamente esmalte y en 3 mm de grosor donde según Shillingburg y Grace (6), esta área consiste en 50% dentina y 50% esmalte. A diferencia del artículo de Ardu et al, en este estudio la medición de los 2 mm de esmalte se realizó en el área interproximal y no en el borde incisal ya que ese estudio no tomaba en cuenta la edad del paciente, mientras que aquí al tratarse de 2 grupos de edades hacer esta medición en el grupo de adultos es difícil por el descaste del borde incisal (4, 52). Debido a esto una comparación directa de los resultados con otros estudios es imposible. Sin embargo se pueden realizar ciertas comparaciones. Con respecto a la medición en 2 mm de esmalte los valores para L* y los valores de opacidad tanto en fondo blanco como en fondo negro fueron superiores que los valores de L* del estudio de Ardu (6), esto pudo deberse a que la edad promedio de nuestro estudio era más alta por lo que pudo influir los cambios de opacidad en el esmalte. En cuanto a las mediciones realizadas a 3 mm en el complejo esmalte-dentina se obtuvieron valores inferiores para L* en comparación con el estudio de Ardu (6) aquí las diferencias pueden atribuirse también a la diferencia de población.

Con respecto al método utilizado para la medición del color de la investigación, en los 3 casos se utilizó como en estudios anteriores (7, 8, 16-18, 20) el sistema CIELAB ya que con dicho sistema se pueden detectar pequeñas diferencias del color. La American Dental Association (ADA) recomienda el uso del sistema de diferencia de colores CIE Lab. Es por esto que esta técnica está siendo utilizada ampliamente por investigadores en la odontología (9, 15, 16, 19, 23, 53).

Para realizar una medición objetiva del color se utilizó un espectrofotómetro, ya que a diferencia de los colorímetros, el uso del espectrofotómetro resalta dos parámetros fundamentales en el color: la luminosidad y la cromaticidad; además, la data obtenida por el espectrofotómetro no es afectada por la luz en el ambiente, y la cantidad de luz reflejada del objeto es medida sobre una onda completa de espectro. (6, 9, 15, 16, 23, 53).

La validez y fiabilidad de las mediciones de este dispositivo ha sido demostrada en estudios anteriores (12, 17, 20, 32, 54, 55).·

Para determinar la estabilidad del color se utilizaron bebidas de consumo diario (café, te negro, cola, zumo de naranja y vino tinto), en ambos casos, las soluciones fueron calificadas en el siguiente orden (desde el mayor potencial de coloración al menor potencial de coloración): vino tinto > café > té negro > zumo de naranja > cola. Estos resultados fueron similares a a estudios previos(17, 20, 32). El vino tinto mostró el potencial más alto de coloración. Diversos estudios anteriores reportan que el alcohol facilita la pigmentación por el reblandecimiento de la matriz de resina; (17, 20, 32, 56) sin embargo, no ha sido explicado si la pigmentación del vino tinto es debido al alcohol o a la presencia de pigmentos en el vino(12). En el caso del café, esta sustancia contiene moléculas amarillas pigmentantes con baja polaridad que parece ser responsable de la pigmentación debido a su afinidad con la red de polímeros. La pigmentación del té puede ser atribuida a la presencia de ácido tánico y diversos pigmentos (17). El grupo control fue almacenado en agua destilada.

La preparación de las muestras de composite y su almacenamiento se realizó basándonos en cuenta estudios anteriores (7, 8, 17, 57, 58), de esta manera se garantizaron condiciones similares para ambos estudios. (59) Se escogió período de inmersión de 4 semanas, como lo sugiere Ertas *et al (20)*. Esto es equivalente a aproximadamente 2.5 años de envejecimiento clínico (24 horas de pigmentación in vitro corresponden a aproximadamente 1 mes *in vivo*) (17, 32)

Con respecto a la estabilidad del color de los materiales, en el caso de los composites directos Filtek Silorane mostro la estabilidad de color más alta, esto concuerda con estudios previos donde el Silorano también obtuvo una alta estabilidad del color. (59-64). Esto puede deberse a la composición del Silorano que tiene un compotente hidrofóbico lo que disminuye su capacidad de absorción de agua y solubilidad.

En el caso de los composites indirectos los bloques de composites de CAD-CAM tuvieron menos estabilidad del color comparados con los composites indirectos de laboratorio. Estudios previos han reportado que las propiedades mecánicas y la estética son pobres para los composites de CAD-CAM (49, 50).

Los composites tanto directos e indirectos que tuvieron más estabilidad del color fueron los que tenían UDMA en su composición como es el caso de Venus Diamond y SR Adoro. Este monómero UDMA comparado con el monómero Bis-GMA no tiene grupos de hidroxil. (17, 55, 65-67) Estudios anteriores han reportado la baja capacidad hidrofílica, la baja viscosidad y solubilidad de este monómero, lo que contribuye a menor absorción de agua y por ende más estabilidad del color.

En general, ninguno de los composites obtuvo un $\Delta E<3.3$, por ende todos los composites sufrieron una pigmentación visible para el ojo humano y clínicamente no aceptable. Estos resultados fueron similares a estudios anteriores. (14, 32, 66)

La susceptibilidad de coloración de los materiales de composite con base de resina está directamente relacionada a su grado de absorción de agua, la cual se ve afectada por la naturaleza hidroflilica/hidrofóbica de la matriz de resina.(18, 65, 68, 69) Esto también puede verse influenciado por la composición química de las bebidas, la cual representa una característica importante en la integridad de la superficie de los composites.[4] Si una resina de composite puede absorber agua, también tiene más posibilidades de absorber pigmentos solubles en agua, resultando en decoloración de los composites (7, 16, 32, 37, 65, 69).

CONCLUSIONES

1. Una vez evaluadas las propiedades ópticas y la opacidad (CR) de los incisivos centrales superiores podemos determinar que existen diferencias fundamentales entre el esmalte y el completo dentino-esmalte, estas diferencias además se acentúan con la edad. Al evaluar también la estabilidad del color de diferentes tipos de composites de aplicación directa e indirecta CAD-CAM o de laboratorio encontramos que cada composite tiene un comportamiento distinto al ser sumergido en las soluciones pigmentantes

2. Existe una clara relación entre la edad y las propiedades ópticas del esmalte y del complejo dentino-esmalte, ya que por ejemplo, podemos observar que un diente joven presenta valores de L* (luminosidad) mucho mayores que los observados en un diente de adulto mayor..

6. Cada solución pigmentante tuvo un comportamiento diferente para cada composite. La bebida que más pigmentó en general fue el vino tinto, seguido del café, té negro, zumo de naranja y refresco de cola. Sin embargo para todas las bebidas se encontraron diferencias estadísticamente significativas.

4. Comparando la estabilidad del color en el tiempo de los composites de metacrilato con los composites de silorano encontramos que los de silorano son significativamente más estables que los de metacrilatos, mostrando menor pigmentación.

5. La solución más pigmentante para los composites tanto para los composites indirectos CAD-CAM como para los composites indirectos de laboratorio fue el vino tinto, seguido del café y por último el té negro,

6. Los composites indirectos de laboratorio tienen mayor estabilidad del color que los composites indirectos CAD-CAM

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RESUMEN

En la odontología estética para lograr una restauración "perfecta" es una regla de oro que los materiales restauradores mimeticen la apariencia natural de los dientes. Sin embargo, aun teniendo guías de color estandarizadas, dicha tarea de "mimetización" no puede ser realizada de forma automática, puesto que las propiedades ópticas de los dientes naturales se ven afectadas en el transcurso de la vida de la persona, tomando tonalidades distintas según cada grupo de edad. Además, no se trata de solo realizar una restauración que imite el color del diente, sino que se deben conocer las diversas características del diente para poder asemejar la restauración en cuanto a textura, forma, tamaño, entre otros. En este sentido, se realizaron diversos estudios, de los cuales uno de los objetivos fue determinar las propiedades ópticas del esmalte y del complejo dentino-esmalte en diferentes grupos de edades con el fin de crear una base de datos más precisa de las propiedades ópticas del esmalte natural y de la dentina.

Por otro lado, los materiales restauradores utilizados también se ven afectados por productos y bebidas que consumimos en nuestra dieta diaria. Con respecto a este tema se analizaron las variaciones que dichos materiales pueden presentar al entrar en contacto - frecuentemente y por períodos prolongados – con bebidas frecuentemente ingeridas por la población en general. Se encontró que ciertas bebidas influían en un mayor grado sobre la pigmentación de los composites.

Los resultados de esta investigación podrán servirnos para determinar si existen diferencias entre los materiales restauradores (directos o indirectos) y diferencias en las propiedades ópticas del esmalte y del completo dentino-esmalte a distintas edades; esto nos permitirá entender el comportamiento que tendrán tanto del diente como los materiales restauradores a través del tiempo

ANEXOS

ANEXO I. Carta de Aprobación del Proyecto de Tesis

Comitè d'Ètica de Recerca | Universitat Internacional de Catalunya

CARTA APROVACIÓ DIRECTA PROJECTE PEL CER

Codi de l'estudi: EST-ECL-2011-01-NF
Versió del protocol:1.0
Data de la versió:04/02/13
Títol:"Propiedades ópticas del complejo dentina-esmalte y de los materiales restauradores directos e indirectos"

Sant Cugat del Vallès, 19 de febrer de 2013

Investigadora: Mariana Arocha Rothe

Títol de l'estudi: "Propiedades ópticas del complejo dentina-esmalte y de los materiales restauradores directos e indirectos"

Benvolgut(da),

Valorat el projecte presentat, el CER de la Universitat Internacional de Catalunya, considera que, el contingut de la investigació, no implica cap inconvenient relacionat amb la dignitat humana, respecte als animals, ni atempta contra el medi ambient, ni té conflictes econòmics i d'interessos.

Per aquests motius, el Comitè d'Ètica de Recerca, RESOLT FAVORABLEMENT, emetre aquest CERTIFICAT D'APROVACIÓ, per que pugui ser presentat a les instàncies que així ho requereixin.

Em permeto recordar-li que si en el procés d'execució es produís algun canvi significatiu en els seus plantejaments, hauria de ser sotmès novament a la revisió i aprovació del CER.

Atentament,

Dr. Josep Argemí
President CER-UIC

1

ANEXO II. Carta de aprobación del Comite de Etica

Comitè d'Ètica de Recerca | Universitat Internacional de Catalunya

CARTA APROVACIÓ DIRECTA PROJECTE PEL CER

Codi de l'estudi: EST-ECL-2011-01-NF
Versió del protocol:1.0
Data de la versió:04/02/13
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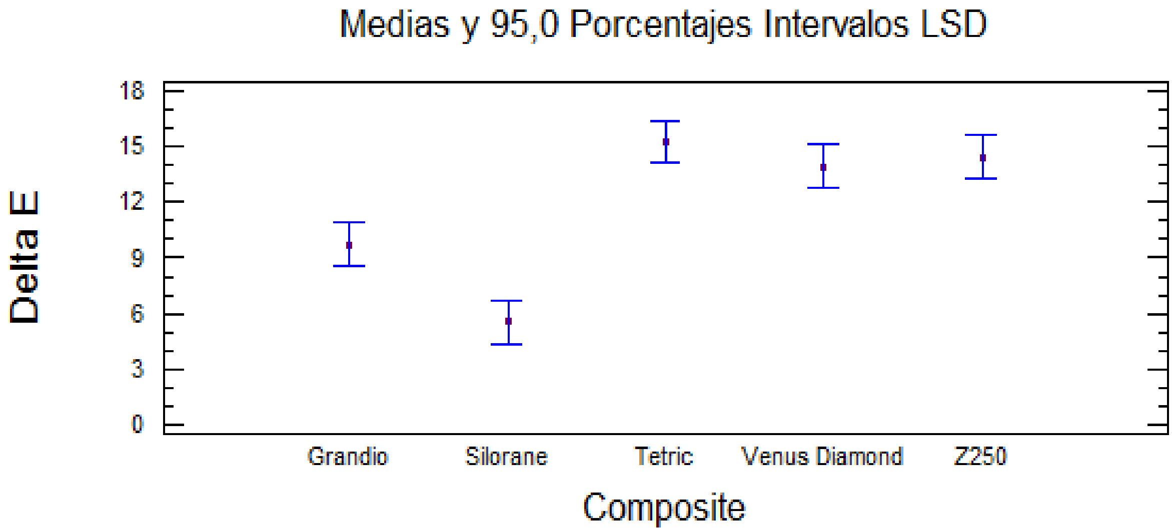
Atentament,

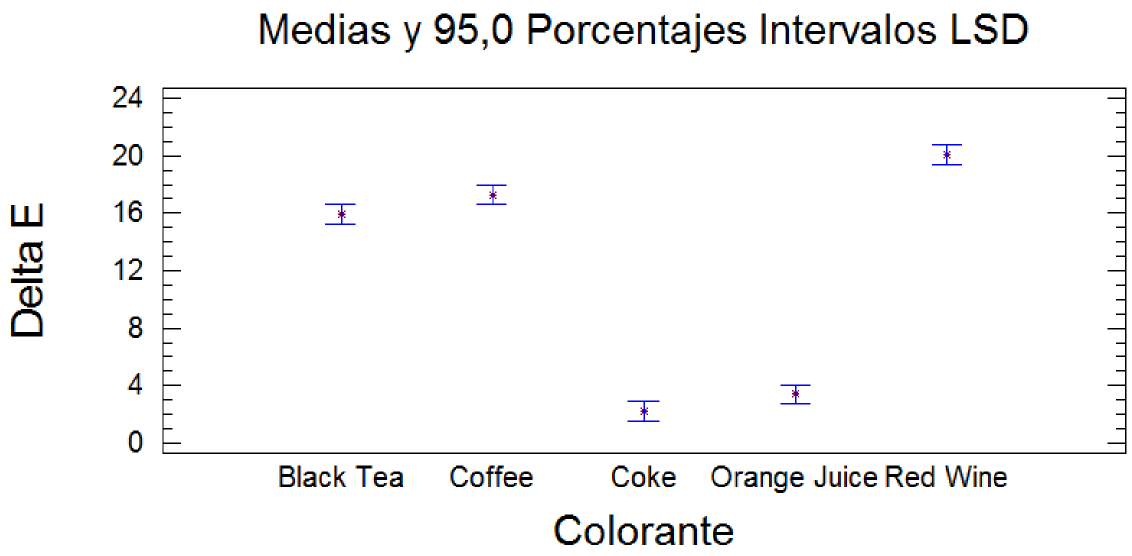
Dr. Josep Argemí
President CER-UIC

ANEXO III. Cuadros de estadística de los estudios

ARTICULO 1

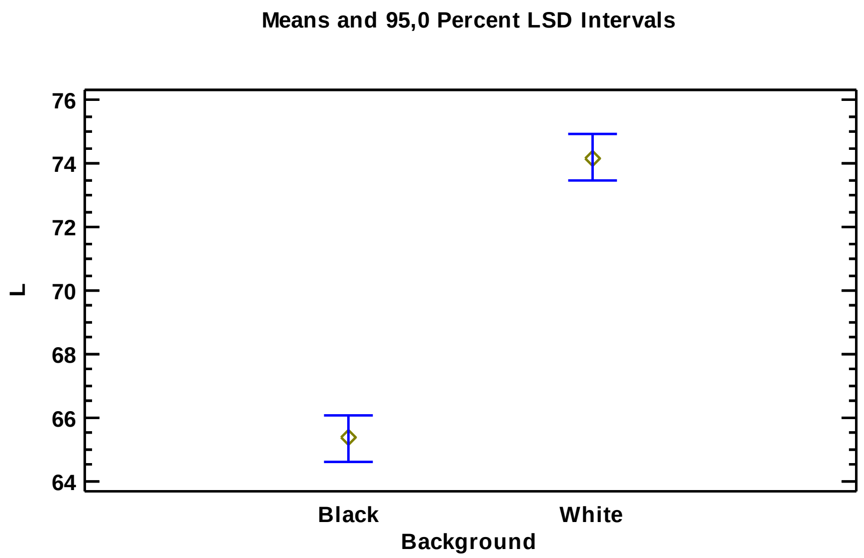


IIIa. Comportamiento general de los composites sin importar el colorante

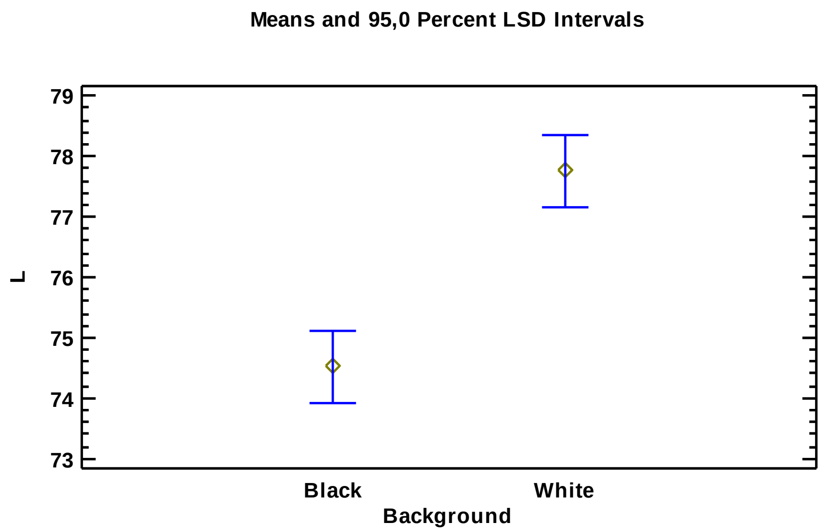


IIIb. Comportamiento general del colorante sin importar el composite

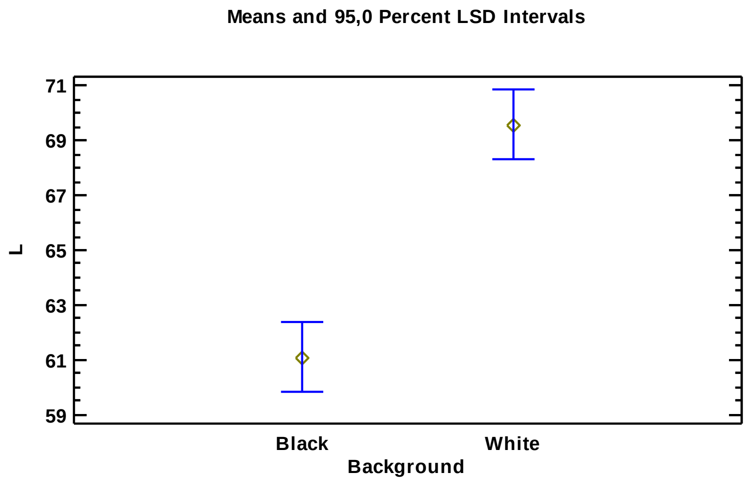
ARTICULO 2



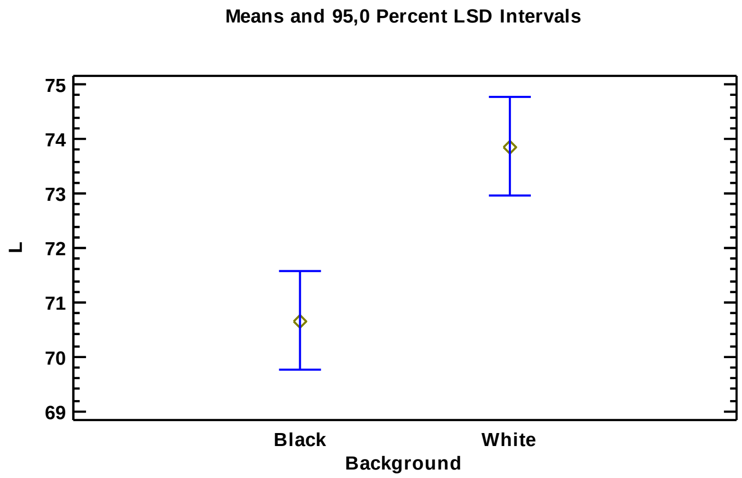
IIId. Relación de la L* con el fondo a 2 mm en el grupo Joven



IIIe. Relación de la L* con el fondo en interproximal en el grupo Joven

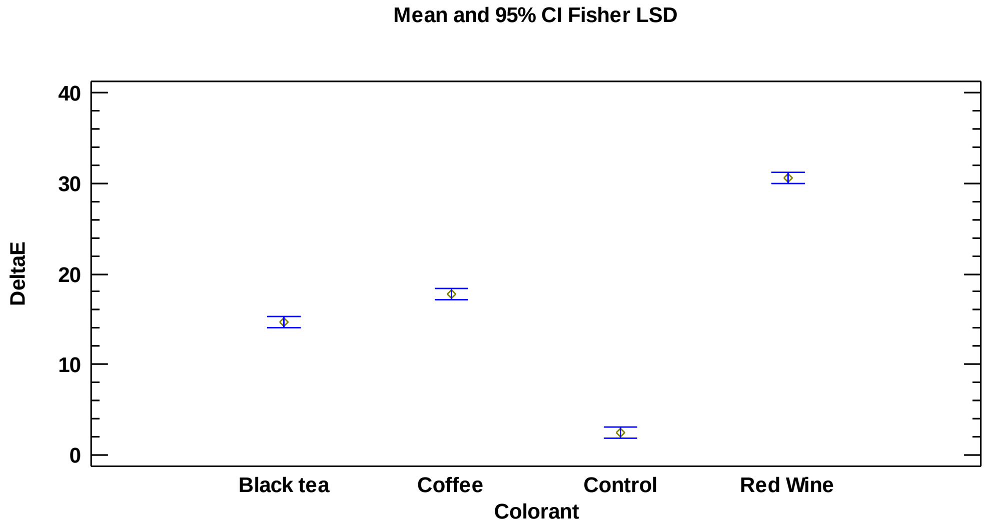


IIIf. Relación de la L* con el fondo a 2 mm en el grupo adulto

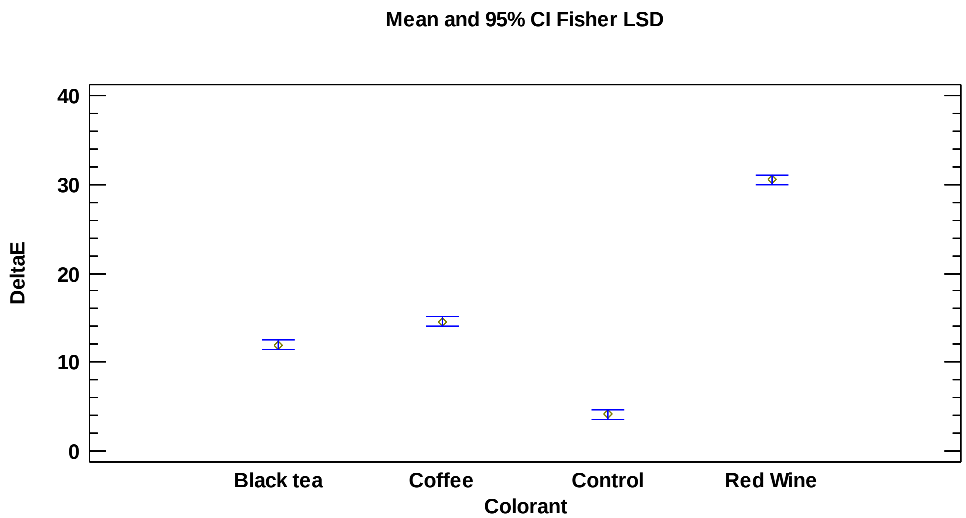


IIIg. Relación de la L* con el fondo en interproxomal en el grupo adulto

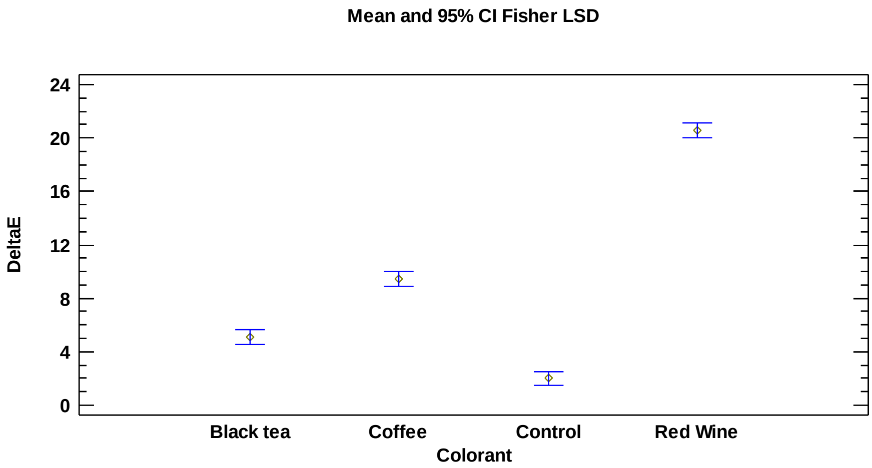
ARTICULO 3



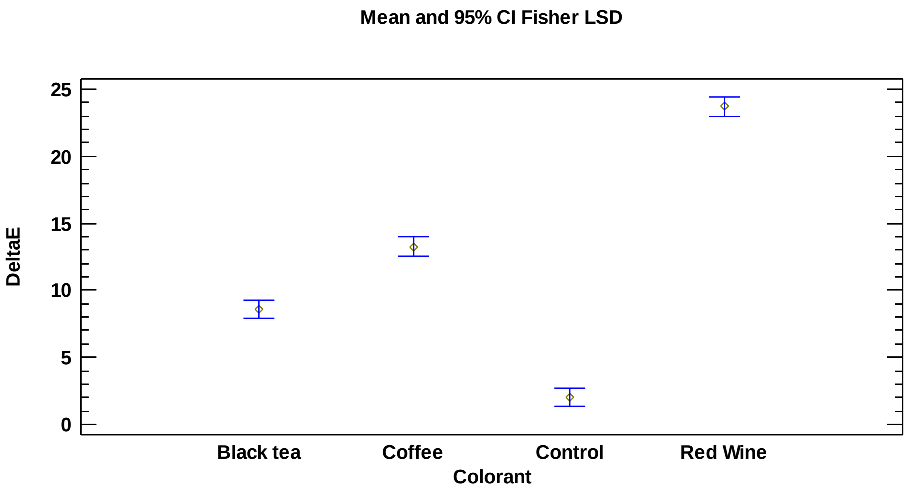
IIIh. Valores de Delta E para Lava Ultimate



IIIh. Valores de Delta E para Paradigm



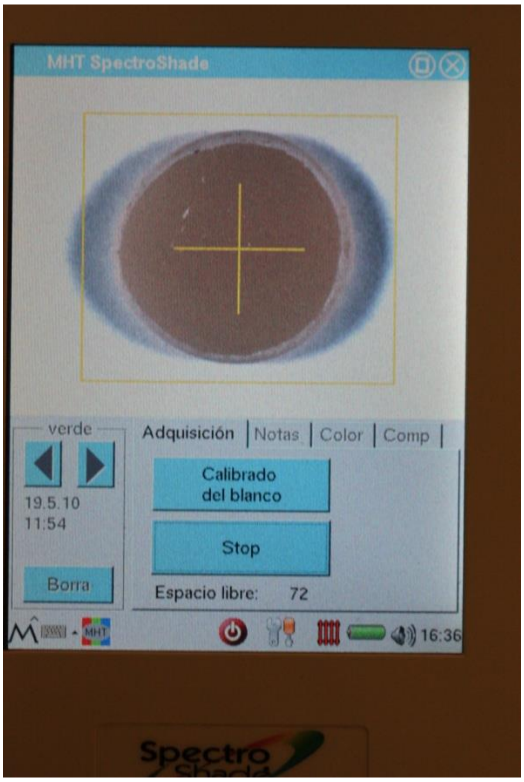
IIIi. Valores de Delta E para Adoro



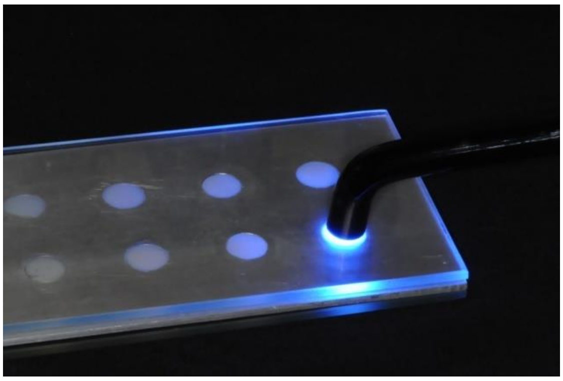
IIIj. Valores de Delta E para Premie Indirect

ANEXO IV. Fotografías del estudio

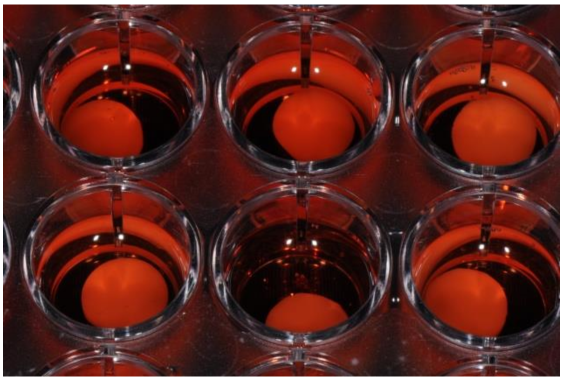
A



B

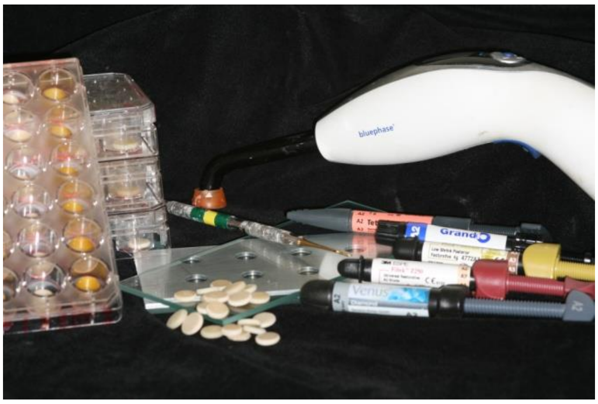


C



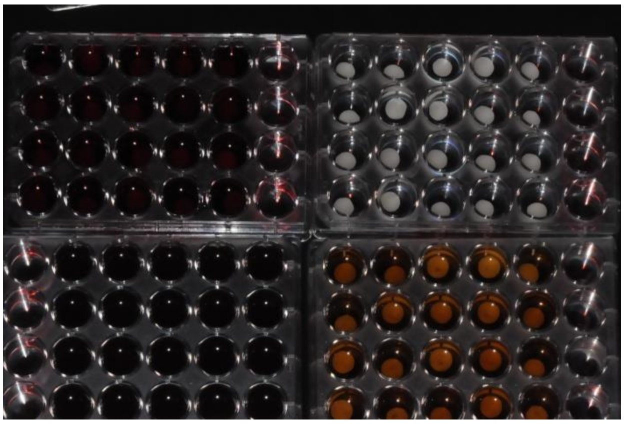
D

A. Espectrofotómetro usado en el estudio
B. Toma de color de las muestras
C. Elaboración de las muestras
D. Muestras sumergidas en vino tinto



E

F



G

H

E. Materiales utilizados
F. Composites indirectos utilizados en el articulo 3
G. Composites sumergidos en las diferentes bebidas pigmentantes
H. Discos de pulir