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Degree In Dentistry

EVALUATION OF STAINING BEVERAGES AFTER TOOTH BLEACHING – Pilot study

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RESUMEN

Propósito: Esta investigación es un estudio piloto que evalúa el impacto de las bebidas colorantes en el color de los dientes después de un blanqueamiento dental en casa.

Materiales y Métodos: Se recogieron 25 dientes humanos (caninos e incisivos) y se dividieron en cinco grupos diferentes. A cada uno de ellos se le dio un nombre: grupo control, grupo café, grupo té, grupo del refresco (Coca Cola) y el grupo del vino tinto.

En casase realizó un blanqueamiento dental durante catorce noches utilizando una férula llena de peróxido de carbamida al 16%. Se tomaron fotografías, antes y después del procedimiento de blanqueamiento y después del procedimiento de tinción. Se realizó un análisis del color siguiendo el sistema colorimétrico CIE-L*a*b*. Se calcularon los Delta E CIE76 y CIE00 y se compararon antes y después del blanqueamiento. A continuación, los dientes se sometieron a un procedimiento de tinción que consistió en sumergir cada muestra del grupo en las bebidas correspondientes quince minutos durante dos semanas. El grupo de control se sumergió solo en agua. A continuación, se analizó el color y se compararon los valores después del blanqueamiento y después de la tinción.

Resultados: Los resultados mostraron que la Coca Cola y el Vino Tinto presentaban las mayores alteraciones de color y las manchas más intensas en la superficie de los dientes, con altos valores de Delta E, lo que anulaba el efecto del procedimiento de blanqueamiento. El procedimiento de blanqueamiento dental funcionó en todos los dientes, y los valores CIE76 Delta E del grupo de control tras el remojo en agua mostraron tonos estables.

Conclusión: Tras someterse a un blanqueamiento dental en casa, los pacientes deben evitar consumir bebidas distintas al agua, ya que alteran gravemente el blanqueamiento dental deseado obtenido tras el tratamiento.

Palabras clave: “Odontología”, “Blanqueamiento dental”, “Bebidas que tiñen”, “CIE L*a*b* espacio de color”, “Análisis de color”,” Sombra”, “Dieta Blanca”.

ABSTRACT

Purpose: This research is a pilot study that evaluates the impact of staining beverages on the color of teeth following an at home teeth bleaching.

Materials and Methods: Twenty-five human teeth (canines and incisors) were collected then divided into five different group samples. They were each given names: the Control group, the Coffee group, the Tea Group Soda (Coca Cola) and the Red Wine group sample. At home, tooth bleaching was performed for fourteen nights using a mouthguard filled with carbamide peroxide 16%. Photographs were taken before and after the bleaching procedure and after staining procedure. A color analysis was performed following the CIE-L*a*b* colorimetric system. Delta E CIE76 and CIE00 were calculated then compared before and after bleaching. Then the teeth undergone a staining procedure that consisted in soaking each group sample in the corresponding beverages for fifteen minutes over a two-week period. The control group was only in water. Then colors were analyzed, and values post bleaching and post staining were compared.

Results: Results showed that Coca Cola and Red Wine had the biggest color alterations and the most intense stains on the teeth surfaces, with high Delta E values, which negated the effect of the bleaching procedure. The tooth whitening procedure worked on all teeth, and CIE76 Delta E values of the control group after soaking only in water showed stable shades.

Conclusion: After getting an at home tooth bleaching, Patients should avoid consuming beverages other than water as they alter severely the desired tooth whiteness obtained after the treatment.

Keywords: “Dentistry”, “Tooth bleaching”, “Staining beverages”, “CIE L*a*b* Color System”, “Color Analysis”, “Shade”, “White Diet”.

1. INTRODUCTION

1.1. TOOTH DISCOLORATION LEADING TO AESTHETIC NEEDS.

Nowadays, one of the most popular cosmetic procedures is tooth bleaching.
As a matter of fact, in our society the quest for beauty has taken an important place, white teeth have been considered healthy and beautiful.

Many variables, including ingesting foods and beverages, smoking or using tobacco products, poor dental care, necrosis, tetracycline intake and a young age or in utero as well as enamel alterations due to genetic disease like Amelogenesis or Dentinogenesis and finally time can lead teeth to get discolored. (1)

Some elements have been recognized to induce and stain teeth by some types of procedures such as for Chromogens to begin with, which are compounds that produce pigmentation, they are present in several meals and beverages, including coffee, tea, red wine, soda and dark-colored berries. These chromogens can adhere to the tooth enamel and color the teeth over time.(2,3)

Then we also have Tar and nicotine included in tobacco who can leave teeth with yellow or brown stains. Smoking is also responsible for lowering our saliva production, which can cause plaque and germs which accumulate on the teeth, which will, with time, create some discoloration or staining.(4)

One of the most important factors is the lack of regular brushing and flossing, dental visit and poor oral hygiene that can result in plaque and tartar accumulation on the teeth, which can discolor and stain the teeth. Moreover, bad dental care can result in gum disease as well as tooth decay, both of which can discolor and stain teeth to a lesser extent of course.(1)

Age can also contribute to tooth discoloration in contrast to these additional causes. The enamel on our teeth gradually thins with age, making the dentin underneath, which is yellow by nature, more apparent and giving the appearance of more yellow teeth. (5)

For the most part, chromogens in meals and beverages, cigarette use, poor dental care, and aging-related changes to the teeth are some of the causes of tooth staining. Some forms of discoloration may be more challenging to remove and may require more comprehensive treatment, even though certain types may be eradicated with expert dental cleanings and whitening procedures.(2)

1.2. TOOTH BLEACHING PROCEDURE

One of the most common solutions to teeth staining, and one of the most popular is teeth whitening, which can brighten the smile by several shades during one visit, in fact it is one of the easiest ways to improve the smile. It is regarded as a safe, conservative and an effective procedure. (6,7)

This procedure consists of the application of chemical agent on the surface of a tooth whether inside the tooth, that is going to react and bound with the dental tissues as well as on the substances that leaded to the color change. The bleaching products used are made of oxidant agents such as hydrogen peroxide with a 35% concentration if it is a bleaching done at the clinic. If the bleaching is done at home, it will be a lower concentration of 3,5% to 6.5% or even with carbamide peroxide 10-20% for the at-home or dentist-supervised night-guard bleaching that work through a chemical process known as oxidation. (8)

Hydrogen peroxide decomposes into water and oxygen when it is applied onto the teeth. The colored dental enamel molecules, which are the cause of the discoloration, will subsequently react with by the oxygen molecules, breaking them down into smaller, less pigmented molecules, which will then result into the overall whitening of the surface.

The quantity of tooth discoloration is decreased as a result of this procedure, which is referred to as oxidation.

Similar to hydrogen peroxide in function, carbamide peroxide degrades more gradually and releases hydrogen peroxide over a longer length of time. Those who feel discomfort throughout the bleaching process may benefit from this slower release.(9)

As it was said earlier Teeth can be either discolored externally or internally. Therefore, it exists intracoronal bleaching that is used on non-vital tooth, it can be performed at home or at the clinic or with a combined technique. The other technique would be the external bleaching that can be performed on vital tooth, and that can also be done at home by the patient, and at the clinic or combined. (6,7,10)

The external procedure consists in the removal of pigments produced by the extrinsic factors that were cited before, while internal bleaching is used to whiten the teeth from the stains inside the tissues due to necrosis, root canal treatments and aging for instance. It can take weeks to reach the intended outcomes depending on the technique that was used. The application of the products can last from a few minutes to several hours depending if the treatment is performed at home or at the clinic.

It is important to keep in mind that the bleaching procedure is not without any risks and that it might have some drawbacks such as temporarily drying up the tooth enamel, which as a result will give the teeth a somewhat lighter look chalk-like appearance. Nevertheless, this impact is often ephemeral and is not the main way that bleaching chemicals function.

In summation, dental bleaching treatments reduce the amount of discoloration in the tooth by oxidizing pigmented molecules in the tooth enamel, without any “physical” invasive intervention on tooth enamel.

However, it is not a permanent treatment, the outcome of the treatment depends on many things as well as the contribution of the patient during and after the treatment, therefore following the bleaching procedure, it is asked from the patient to try to adopt a “White Diet” during at least two weeks. Which consists of the consummation of white aliments such as chicken, cheese, yogurt and it is recommended to drink exclusively water however milk is allowed. It is asked to avoid smoking, drinking coffee, tea, red wine during the duration of the treatment as well as after the end of the treatment during weeks the patient should be careful. (11,12)

Indeed, some bleaching agents may interact with certain types of beverages and alter the surface, texture and morphology of the tooth. The teeth whitening procedure weakens and opens the tubules, in the tooth enamel. Your teeth are more susceptible to stains and decay after whitening due to the weakened enamel, which will furtherly be worsened by acids. (13–15)

Some of the commonly drunk beverages are known to have chromogenic properties, among them we find coffee, tea, red wine and coca cola thanks to their acidic pH that is found to be between 4 and 7. (2,12,16)

Moreover, they contain tannins which are complex substances made of phenolic acids. Tannins are naturally occurring substances that may be found in a variety of plant-based foods and beverages, including certain fruits, tea, coffee, and wine. Tannins can make your mouth feel dry or pucker up since they have astringent characteristics. When ingested, tannins may attach to the proteins in saliva and oral tissues, thus robbing the mouth of its natural lubrication.(17–20)

The astringent qualities of tannins can also make them adhere to tooth enamel, which over time may result in discoloration. This is due to the possibility of tannins forming complexes with naturally occurring metal ions in dental plaque and saliva, such as iron and aluminum. These complexes can discolor the teeth, turning them yellow or brown.

Tannins can make dental enamel more permeable, which makes it simpler for other substances to discolor teeth.(17)

Moreover, Coca-Cola is a carbonated soft drink. Coca-Cola is acidic and can erode tooth enamel, leaving teeth more susceptible to discoloration. Furthermore, Coca-Cola includes chromogens, which are highly colored chemicals that might cause tooth discoloration.(21)
It is important to note that dental hygiene practices, genetics, and lifestyle choices like smoking can all have a significant impact on how much tannins stain. Proper oral hygiene routines can also aid in eradicating the tannin-rich plaque and avoiding staining.

1.3. COLOR ANALYSIS

When it comes to dentistry and particularly teeth whitening, it cannot be pursued without the use of tooth color analysis, that can be evaluated thanks to a different and wide range of means and methods. The overall color is obtained thanks to a combination of light that is reflected by the tooth. (22)

A well-known experiment in science that helped to explain the characteristics of light and the phenomenon of color is Isaac Newton's prism experiment.

In 1666, Isaac Newton developed an interest in the properties of light and how it moved through prisms. In his experiment, he shone a beam of sunlight through a glass prism and saw that the beam was split into a spectrum of hues, including red, orange, yellow, green, blue, indigo, and violet.

According to the light's wavelength, Newton found that the prism refracted or bent the light at various angles. Light with longer wavelengths, like red, was bent less than light with shorter wavelengths, like violet. As a result, he was given the color spectrum.(23)

A tooth color can depend on many factors, there is a lot of different criteria making it multidimensional.
Notably the System of Munsell which is based on a tridimensional approach where the variables will be the value or brightness, the saturation or chroma and the hue or tonality, with this method we will determine first the value, then the saturation and finally the hue.(24)

Value: The volume of light emitted by an item is its brightness. Value was characterized by Munsell as a white to black grayscale. Low-value items have grayer and will look darker than bright objects, which have less gray. A crown's brightness may often be raised in one of two ways: either by reducing chroma or by raising the surface's reflectivity. A lower number indicates that less light is reflected back from the illuminated item and that the light that is still present is being absorbed or dispersed.(22,25)

Saturation: It is the intensity of a tone. It can be changed by adding lighter or darker tone. Value decreases as chroma increases; chroma and value are negatively correlated.

Hue: The characteristic that sets one color family apart from another is called "hue." Even if the precise wavelength of the observed color may not be present, it is characterized as the dominating range of wavelengths in the visible spectrum that produce the color. A total of wavelengths' physiological and psychological interpretation is given by hue.

However other optical phenomenon which are very important in order to find the perfect tint such as translucency: there are many levels of translucency in human teeth. Angle of incidence, surface luster, wavelength, and degree of dehydration all affect how translucent enamel is.

Opalescence: is a phenomenon where a substance seems to have a color when light reflects off of it and a different color when light passes through it. The teeth are made brighter and has visual depth and liveliness thanks to the opalescent properties of enamel. (26)

Fluorescence: is the natural emission of light with a larger wavelength after a substance absorbs light. Due to the increased proportion of organic material in the dentin of a normal tooth, it mostly happens there.

Metamerism: is the phenomena of two colors that, while having differing spectral reflectance, appear to match under a certain lighting circumstance. By choosing a shade and verifying it in various lighting situations, such as natural daylight and fluorescent light, the issue of metamerism may be avoided.
Moreover, the human eye and brain that will influence the overall perception of tooth color. (22)

We can find a tooth color visually thanks to shade guides such as Vita Classic Shade Guide and we can as well easily classify the different tones. It exists instruments that can also help classify a tooth shade such as colorimetry, spectrophotometry and digital image analysis done by a computer.
To unbiasedly assess the color of teeth, dental restorations, and other dental materials, dentists employ the CIE-LAB colorimetric system proposed by the International Commission on Illumination (CIE) in 1976. “L*” stands for the vertical axis of lightness the “a*” is for the changes of redness to greenness it goes from [-a* to +a*] and “b*” for the variations from yellowness to blueness in this system it goes from [-b* to +b*]. (27)

A vertical axis, or L* axis, is used to organize the value or luminosity, with values ranging from 0 to 100, or from perfect black to perfect white. The subtleties are represented by the a* and b* axes. The quantity of purple red is represented by the positive axis a*, while the amount of green is represented by the negative axis a*. The quantity of yellow is represented by the positive b* axis, while the amount of blue is represented by the negative b* axis.
Each color inside the sphere may be defined by L*a*b* using these three parameters and the positions it occupies on each axis.

The most comprehensive color model is this one. It is frequently used to refer to every hue that the human eye can see. We are able to assess the color distinctions among two colors objectively thanks to mathematical formula. The CIE76 delta-E value (E) represents this discrepancy. (26)

ΔE = ((ΔL) ^2 + (Δa) ^2 + (Δb) ^2) ^ (1/2)

This formula calculates the Euclidian distance between two points.

If our result is a positive value: ΔL* it signifies that the second color is lighter than the first color however if: ΔL* is a negative value, it implies that the second color is darker than the first color.

If we present a positive Δa*values the sample will be redder but if we have a negative Δa* value, the sample will be greener.

A positive Δb* will be because the sample is too yellow, furthermore, negative Δb* it's because the sample is too blue.

However, a more complex formula has been developed in order to solve some flaws of the CIE76 ΔE formula. It takes into consideration for the non-uniformity of the human eye as well as the fact that various colors have varying degrees of perceived difference. It also takes into account parameters like chroma and hue angle, which somewhat can have a considerable influence on perceived color difference.

It is represented by the following equation: (22,25,26)

ΔE=((ΔL') ^2 + (ΔC') ^2 + (ΔH') ^2 + R_T * (ΔC') * (ΔH') ^ (1/2)) ^ (1/2)

The ISO 12647-2 standard discusses the tolerance thresholds for chromatic deviations.

We can state that if ΔE is more than two, the color difference is becoming increasingly noticeable. Thus, an ΔE less than 1 is imperceptible to the human eye, between 1and 2 it is considerate slightly visible an ΔE between 2 and 3 is visible but still pleasant and

perceptible, and an ΔE between 3 and 4 implies a clear color difference. The upper limit of permissible E is 4, and ΔE more than 5 is not taken into account. (25,26,28)

Moreover, we must take into account that the type of color has an impact on the perception as well. For instance, the human eye is considerably more sensitive to variations in the levels of gray and midtones, which are more than obvious at a ΔE of 3, yet for the same value in green, we wouldn't really notice a difference. In other words, the human eye is better able to detect changes in brightness (ΔL*) than in hue (Δa* and Δb*). This is caused by the large number of rods who give the Scotopic vision that permit to see at low lights and cones who allow the Photopic vison giving rise of color vision and high special acuity who are present in the eyes.(27,29)

Dental professionals can assess these values with a spectrophotometer and use them to choose the proper shade of dental material or suit the color of a restoration to the neighboring teeth, in order to create dental restorations that are aesthetically acceptable and smoothly merge with the natural dentition, it is essential to achieve exact and reliable color matching, and that is possible with the help of the "L* a* b*" system.(29)

The aim of our study is to select a small sample of teeth that will went through the full treatment and to see if the staining beverages consumption will change the results that was given thanks to the tooth bleaching.
Therefore, in this pilot study we are going to evaluate the way of action of staining beverages on the color of teeth that had a tooth bleaching at home.

2. OBJECTIVES

The aim of this pilot study is to evaluate the influence of beverages that are known to have staining properties on tooth after a tooth bleaching at home. It is a small-scale study conducted in order to evaluate the feasibility as well as the techniques in order to perform in the future a full-scale study.

It begs the question:

What are the effects of staining beverages on the color of the tooth after a at home bleaching procedure?

Thus, was establish the following hypothesis (H0) of this study:

If the consummation of staining beverages after a at home tooth bleaching influence the outcome of the treatment than color changes can happen.

In addition, the following objectives were established:

1. Evaluate the results of a at home tooth bleaching conducted during two weeks for six hours every night.
2. Estimate if consuming only water after a at home tooth bleaching is the best option in order to maintain the color changeset provided by the bleaching product.

3. MATERIALS AND METHODS

3.1. THE RESSOURCES:

In order to perform this research, several scientifical articles from PubMed, Medline and Goggle Scholars that were related to this subject were chosen, in order to inform myself on the way I need to perform my protocol. These articles and data allowed the elaboration of a protocol.

3.2. DESIGN OF THE PROTOCOL

In order to answer the research question, an in vitro study was performed, therefore twenty-five extracted anterior teeth given by dentist from Spanish and French clinics were selected and placed into distilled water that was renewed daily to keep them hydrated as much as possible in order to try to mimic as much as possible the behavior of natural teeth inside the oral cavity.

The criteria of selection were simple: the crowns needed to be in perfect or in very good conditions we tolerated only minimal restoration performed on them.

These twenty-five teeth were divided randomly into five different groups, that corresponds to five teeth per groups. This groups of samples were given the name of the beverages they will be plunged into later in this study.

Group 1: Water which is going to be the control group.

Group 2: Coffee

Group 3: Tea

Group 4: Red Wine

Group 5: Soda

Each tooth was given the first letter of the group it is part off and a number from one to five.

Group 1: W1/W27W3/W4/W5

Group 2: C1/C2/C3/C4/C5

Group 3 : T1/T2/T3/T4/T5

Group 4: R1/R2/R3/R4/R5

Group 5: S1/S2/S3/S4/S5

3.3. PROTOCOL

3.3.1. PHOTOGRAPHS BEFORE AT HOME TOOTH BLEACHING

In order to assess the color of each group sample and to be able to perform the tooth bleaching at home, we used putty silicone in order to create socle to have each tooth standing the root inside the silicon and the crown facing us mimicking a mouth. Which makes easier the bleaching as well as taking pictures of the teeth.

In order to estimate the color of each tooth from each sample pictures were taken with a Camera Reflex (Figure 1) from the brand Canon model: EOS 700D who was equipped with a Canon camera MACRO LENS EF 100mm. The sharpness, clarity, and overall quality of the captured image are significantly influenced by the lens quality of the camera.

Figure 1: Camera and Settings used for this study.

Moreover, a neutral grey polarizing filter allowing minimal changes of the colors temperatures as well as a maximal transmission was putted in front of the camera lens in order to increase the color saturation of the images that are going to be photographed

as well as to reduce possible reflections and the atmospheric haze. In fact, these combined with the flash help elimination of the high reflectance propriety of the enamel.(30)

The camera was also arranged with a ring flash (Figure 2), indeed without this equipment we would have dark photos in which we would be unable to appreciate anything. Electronic flashes provide light with a neutral, sufficient, and consistent color temperature, allowing for proper exposure. The ring flash emits a burst of light throughout the whole optical axis and is generally placed directly in front of the lens to eradicate any shadows. (30)

Figure 2 : Ring Flash

The power of the flash was set to 1/1. The F number: Focal length/ Aperture selected was F8.0 it corresponds to the size of the hole that lets light into the device. The camera diaphragm was set between two and three. (Figure 3)

Figure 3: Camera Settings

The photos were all taken inside the laboratory of Prosthesis of the Universidad Europea de Madrid.

A metric and colorimetric witness who looks like a grey card (Figure 4) was used with each sample for each photo. On this card we can see values who follows the CIE colorimetric system. The values were: L*79; a*0; b*0 because it was decided to perform the color analysis following CIE-Lab* System.

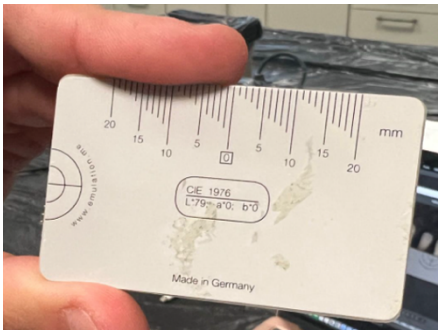

Figure 4 : Colorimetric witness

The values collected were following the CIE L*a*b* Color System therefor, were collected: L*, a*, b values for each tooth from each sample group.

When all the samples were photographed (Figure 5.1; 5.2; 5.3; 5.4; 5.5) we used Photoshop in order to estimate the colors of each tooth before the at home tooth bleaching.

Figure 5.1: Control group sample before bleaching.

Figure 5.2: Coffee group sample before bleaching.

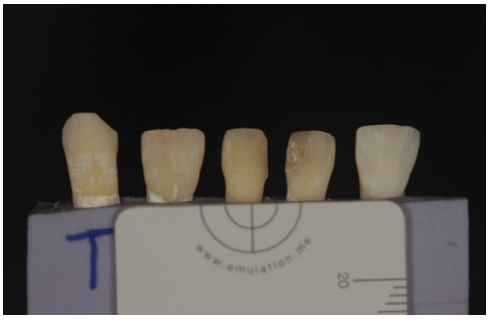

Figure 5.3: Tea group sample before bleaching.

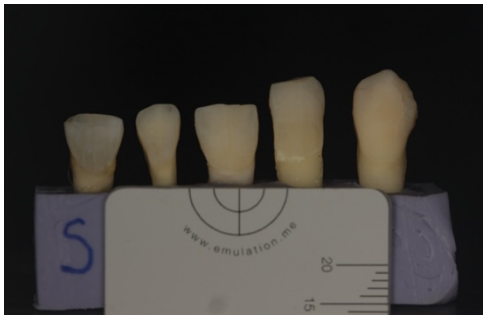

Figure 5.4: Soda group sample before bleaching.

Figure 5.5: Red Wine group sample before bleaching.

3.3.2. COLOR ANALYSIS FOLLOWING CIE-L*a*b* SYSTEM BEFORE TOOTH BLEACHING

To perform this color analysis, we changed the setting from RBG to CIE-L*, a*, b*.

In order to have appropriate values we changed parameters such as the exposition, the hue as well as the temperature with the help of the values presented on the colorimetric witness.

When the values correspond to l:79; a:0; b:0 coordinates on a given point on the colorimetric witness, the color analysis of each tooth was performed.

A point was selected on each tooth making sure it was not composite or fracture but in good state enamel, then the L*, a*, b* values coordinate for each tooth were collected on the point.

All the data collected were written inside a table.

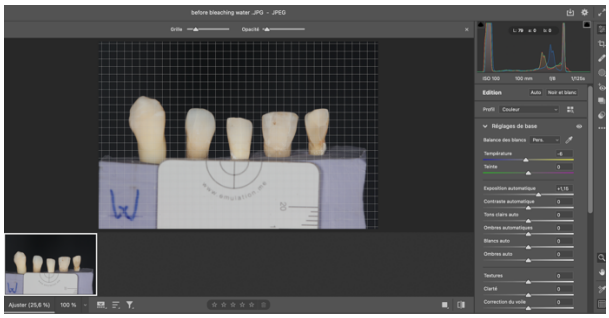

Figure 6: Screenshot of the work set up used. Coordinate selected always in the same point

3.3.3. THIRD STEP: AT HOME TOOTH BLEACHING

Thanks to a dental laboratory mouthguard in acrylics were made in order to perform the tooth bleaching.

The product used for the tooth bleaching is from the brand Ultradent the name of the product is Opalescence with the concentration of 16% of peroxide carbamide which correspond to a concentration between 3.6 to 5.8 of hydrogen peroxide. The gel was inside syringes. The gel was flavorless.

The product was inserted every night inside the mouthguard for two weeks. A small amount of product was filed only on the buccal side. In total, three syringes of tooth bleaching product were used to conduct this study.(31)

These substances enter the enamel and dentin layers of the teeth when they are administered, reacting with the colored compounds to produce discoloration. These substances are oxidized by peroxide or carbamide peroxide, which reduces them to less noticeable, smaller particles that are simple to remove.(5,31)

As greater quantities of the discolored compounds are decomposed down and eliminated from the teeth, the teeth will gradually seem lighter and brighter. To maintain the whitening benefits, it's crucial to use these products as recommended.

Every morning after removing the mouthguards filed with bleaching products all the teeth were rinsed and then kept inside distillated water to let them be hydrated as much as possible.
The tooth bleaching was performed for fourteen days during six hours.

Before taking pictures of the teeth post tooth bleaching the tooth were kept for two days inside distilled water to let the color stabilize.

3.3.4. PHOTOGRAPHS AND COLOR ANALYSIS POST TOOTH BLEACHING

After the color stabilization other photos (Figure 7.1; 7.2; 7.3;7.4; 7.5) of each group sample with the same metric and colorimetric witness were taken under the same conditions as before.

Figure 7.1: Control group sample after bleaching.

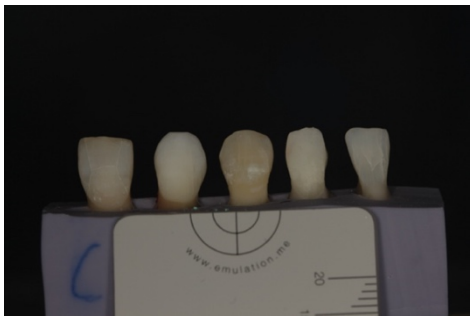

Figure 7.2: Coffee group sample after bleaching.

Figure 7.3: Tea group sample after bleaching.

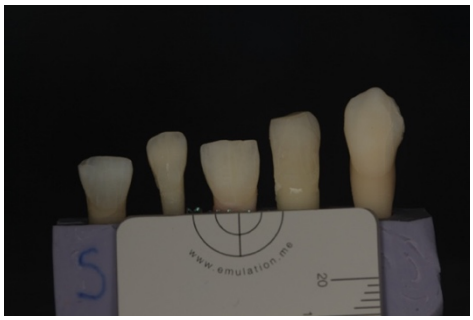

Figure 7.4: Soda group sample after bleaching.

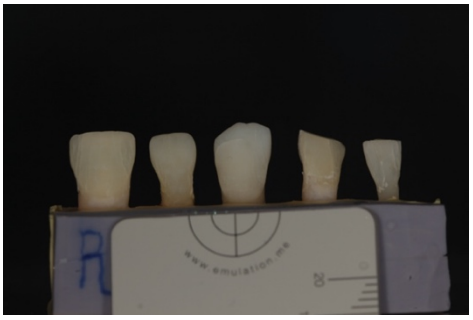

Figure 7.5: Red wine group sample after bleaching.

Then, the color analysis was performed with Photoshop under the exact same conditions as the first time. The values were selected on the same position as the color selected the first time.

The L*,a*, b* values were collected and written inside a table.

Delta E was calculated and collected by comparing the L*, a*, b* values gathered of each tooth from all the samples before the at home tooth bleaching procedure to the one who just went through the at home tooth bleaching procedure. (22,27–29)

Two Delta E values were taken into account.

First CIE76 ΔE corresponding to this formula:

ΔE = ((ΔL) ^2 + (Δa) ^2 + (Δb) ^2) ^ (1/2)

The color difference ΔE is calculated between two shades by comparing their coordinates.

Secondly CIE00 ΔE which is more precise because it considers chroma and hue corresponding to this equation:

ΔE=((ΔL') ^2 + (ΔC') ^2 + (ΔH') ^2 + R_T * (ΔC') * (ΔH') ^ (1/2))^(1/2)

The color difference ΔE is calculated between two shades by comparing their coordinates but also with this newest equation is taken into account other values such as hue and chroma.

ΔE below 1 means no color changes, between 1 and 2 it is stated that it implies small changes of color but not easily seen with the naked eye.

An ΔE between 2 and 3 is apparent but still pleasant and observable, whereas an ΔE between 3 and 4 suggests a distinct color variation. The top limit of allowable E is 4, and ΔE larger than 5 is ignored since a delta E value greater than 5 in dentistry implies a considerable variation in color that is easily detected by the human eye. However, in this study, ΔE E greater than 5 were not excluded.

3.3.5. STAINING PROCEDURE

For fourteen days each sample was soaked inside the corresponding beverages it means that every day for two weeks, the soda sample was soaked inside coca cola, the red wine sample was soaked in red wine, the tea sample was soaked in black tea, the coffee one was soaked in soluble coffee and the control sample was the only one only soaked in water.

To keep the teeth as much as hydrated as possible they were kept inside distilled water and removed from the distilled water only fifteen minutes the time of the experience.

After being submerged into those beverages, the teeth were rinsed.

Over the days, variations have been visible.

After two weeks, new photos figure (8.1; 8.2; 8.3; 8.4; 8.5) were taken under the same conditions as the two first times using the same camera, same values and flash and the same colorimetric and metric witness.

Figure 8.1: Control group sample after soaking only in water.

Figure 8.2: Coffee group sample after soaking into coffee.

Figure 8.3: Tea group sample after soaking into tea.

Figure 8.4: Soda group after soaking into Coca Cola.

Figure 8.5: Red Wine groupe sample after soaking into red wine.

A new color analysis using Photoshop the same way as the two other time was performed using the same location point on every tooth.

Thanks to these new L*, a*, b* values collected and written down a table it was possible thanks to same formula that was used before to calculate the CIE76 and CIE00 Delta E between the values recorded after the bleaching procedure to the one recorded after the staining beverages damping. All the Delta E of this research were calculated thanks to a Delta E calculator on the website "BruceLindBloom.com". (Figure 9)

".

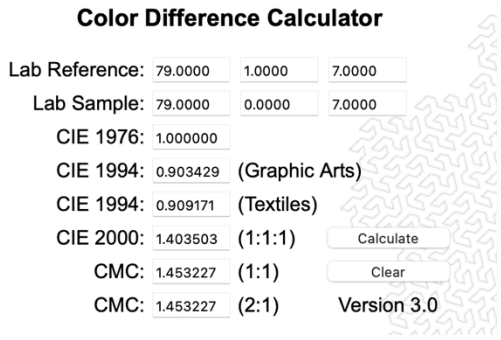

Figure 9: Delta E Calculator by" BruceLindBloom.com"

All the results were recorded, Microsoft Excel was used in order to enter all the data collected.

The results were then analyzed and compared.

4. RESULTS

4.1.Tables of CIE-L*a*b*values before at-home tooth bleaching

Tables filled with the data from all the samples before the at home tooth bleaching were made for each sample following the standard measures of CIE L*a*b*. The L* value reflects brightness in this color space, with larger values suggesting lighter shades, while the a* and b* values correspond to the red-green and yellow-blue color components, respectively.

The first table represents the CIE-L*a*b*values of the Control (Water) group sample before the at home tooth bleaching procedure:

CIE L*a*b* values	W1	W2	W3	W4	W5
L*	77	77	79	69	66
a*	1	1	0	4	4
b*	9	9	9	18	18

*Table 1: the Control (Water) group sample CIE-L*a*b* values before the at home tooth bleaching.*

These second table gathered the CIE-L*a*b* values of the Coffee group sample before the at home tooth bleaching procedure:

CIE L*a*b* Values	C1	C2	C3	C4	C5
L*	75	80	70	79	75
a*	2	0	3	0	0
b*	8	6	16	5	6

*Table 2: Coffee group sample CIE-L*a*b* values before the at home tooth bleaching.*

These third table is made of the CIE-L*a*b* values of the Tea group sample before the at home tooth bleaching procedure:

CIE L*a*b* values	T1	T2	T3	T4	T5
L*	73	71	71	74	77
a*	3	3	5	2	1
b*	14	14	12	13	6

*Table 3: Tea group sample CIE-L*a*b* values before the at home tooth bleaching.*

These table represent the CIE-L*a*b* values of the Soda (Coca Cola) group sample before the at home tooth bleaching procedure:

CIE L*a*b* values	S1	S2	S3	S4	S5
L*	69	75	77	76	78
a*	0	0	1	0	1
b*	4	10	11	10	8

*Table 4: Soda/Coca Cola group sample CIE-L*a*b* values before the at home tooth bleaching.*

This fifth table represent the CIE-L*a*b* values collected on the Red Wine group sample before the at home tooth bleaching procedure:

CIE L*a*b* values	R1	R2	R3	R4	R5
L*	76	76	78	76	74
a*	1	1	1	2	1
b*	8	9	6	11	7

*Table 5: Red Wine group sample CIE-L*a*b* values before the at home tooth bleaching.*

4.2.Tables of CIE-L*a*b* values post at-home tooth bleaching.

After the at home tooth bleaching that was performed for two weeks during 6 hours at night, new values were collected the same way as the first time.
Tables of CIE-L*a*b* new values post at home tooth bleaching were made for each sample:

CIE L*a*b* values	W1	W2	W3	W4	W5
L*	79	77	77	69	66
a*	1	1	0	2	2
b*	7	6	7	15	15

*Table 6: Control Sample CIE-L*a*b* values post at home tooth bleaching.*

CIE L*a*b* values	C1	C2	C3	C4	C5
L*	74	81	73	80	75
a*	1	-1	2	-1	0
b*	5	4	14	3	3

*Table 7: Coffee Sample CIE- L*a*b* values post at home tooth bleaching.*

CIE L*a*b* values	T1	T2	T3	T4	T5
L*	74	72	72	75	77
a*	2	1	2	2	0
b*	11	11	10	10	3

*Table 8: Tea sample CIE-L*a*b* values post at home tooth bleaching.*

CIE L*a*b* values	S1	S2	S3	S4	S5
L*	71	73	79	77	79
a*	-1	0	0	0	0
b*	2	7	8	7	5

*Table 9: Soda sample CIE-L*a*b* values post at home tooth bleaching.*

CIE L*a*b* values	R1	R2	R3	R4	R5
L*	78	76	80	76	75
a*	0	0	0	1	0
b*	7	6	4	8	4

*Table 10: Red Wine sample CIE-L*a*b* values post at home tooth bleaching.*

We can see thanks to this table that the L*a*b* values are not the same before and after the tooth whitening procedure performed at home.

4.3. Tables collecting the CIE76 ΔE and CIE00 ΔE comparing values before and after tooth bleaching.

After this second color analysis we can observe that the values were not the same before and after the at home tooth bleaching in order to compare the color changes Delta E between each tooth of each sample were calculated giving us the CIE76 ΔE as well as the CIE00 ΔE pre and post the at home tooth bleaching. Delta E is a color difference measurement between two samples.

Tables collecting the CIE76 ΔE and CIE00 ΔE were made:

	W1	W2	W3	W4	W5
CIE76 ΔE	2.8284	3	2.8284	3.6065	3.0560
CIE00 ΔE	2.0462	2.2574	2.0399	2.6462	2.8260

Table 11: Delta E values of the Control Group sample comparing before and after at home bleaching.

It can be affirmed that the CIE76 ΔE of the water group sample are ranged between (2.8284-3.056) and for the and CIE00 ΔE are between (2.0399 to 2.8260)

	C1	C2	C3	C4	C5
CIE76 ΔE	3.3166	2.4495	3.7416	2.4495	3
CIE00 ΔE	2.6743	2.3166	2.7663	2.3715	2.4948

Table 12: Delta E values of the Coffee Group sample comparing before and after at home at home tooth bleaching.

The CIE76 ΔE of the coffee group sample are ranged between (2.4495 to 3.3166).
The CIE00 ΔE are between (2.3166 to 2.7663)

	T1	T2	T3	T4	T5
CIE76 ΔE	3.3166	3.7412	3.7417	3.1623	3.1623
CIE00 ΔE	2.2580	3.0823	3.7796	2.1409	2.8260

Table 13: Delta E values of the Tea Group sample comparing before and after home tooth bleaching.

The CIE76 ΔE of the tea group sample go from (3.1623 to 3.7417)
The CIE00 ΔE founded are ranged between (2.1409 to 3.7796)

	S1	S2	S3	S4	S5
CIE76 ΔE	3	3.6056	3.7412	3.1623	3.3166
CIE00 ΔE	2.2098	2.6250	2.8372	2.2980	2.7568

Table 14: Delta E values of the Soda Group sample comparing before and after at home tooth bleaching.

For the Soda group sample, the CIE76 ΔE are between (3 to 3.7412) and the CIE00 ΔE are from (2.2098 to 2.8372)

	R1	R2	R3	R4	R5
CIE76 ΔE	2.4495	3.1623	3	3.1623	3.3166
CIE00 ΔE	2.1180	2.25931	2.5425	2.3711	2.8397

Table 15: Delta E values of the Red Wine Group sample comparing before and after at home tooth bleaching.

Has you can see, the CIE76 ΔE of the red wine sample is ranged between (2.4495 to 3.1623). For the CIE00 ΔE the values are between (2.1180 to 2.8397).

4.4.Table collecting CIE-L*, a*, b*values after staining procedure.

The soaking in the staining beverages was performed during two weeks for fifteen minutes, new data and values were collected thanks to color analysis performed under the same condition as before using Photoshop.

CIE L*a*b* values	W1	W2	W3	W4	W5
L*	79	77	77	69	64
a*	0	0	0	3	2
b*	7	6	8	15	15

*Table 16: Control (Water) sample group CIE L*a*b* values after soaking only in water.*

CIE L*a*b* values	C1	C2	C3	C4	C5
L*	69	75	68	69	72
a*	2	-1	3	3	2
b*	9	4	12	8	8

*Table 17: Coffee sample group CIE L*a*b* values after soaking into coffee.*

CIE L*a*b* values	T1	T2	T3	T4	T5
L*	69	60	64	64	72
a*	6	6	2	6	2
b*	14	17	10	10	7

*Table 18: Tea sample group CIE L*a*b* values after soaking into tea.*

CIE L*a*b* values	S1	S2	S3	S4	S5
L*	54	55	60	57	66
a*	10	12	14	10	10
b*	21	33	27	22	21

*Table 19: Soda sample group CIE L*a*b* values after soaking into Coca Cola.*

CIE L*a*b* values	R1	R2	R3	R4	R5
L*	57	57	60	61	49
a*	8	6	9	5	11
b*	9	6	7	6	8

*Table 20: Red Wine sample group CIE L*a*b* values after soaking into red wine.*

4.5. Tables collecting the CIE76 ΔE and CIE00 ΔE comparing values after tooth bleaching and after staining procedure.

Thanks to all the values collected after the last part of this experiment it was possible to calculate the Delta E between the values gathered after the tooth bleaching with the one found after soaking them for 15 minutes for two weeks in the appropriate beverage for each sample group.

	W1	W2	W3	W4	W5
CIE76 ΔE	1	1	1	1	2
CIE00 ΔE	1.4035	1.4171	0.7476	1.2283	1.6010

Table 21: Delta E values of the Control Group sample after soaking only in water.

	C1	C2	C3	C4	C5
CIE76 ΔE	6.4807	6	5.4772	10.4881	6.1644
CIE00 ΔE	4.9749	4.2410	4.3223	8.1880	5.2222

Table 22: Delta E values of the Coffee Group sample after soaking in coffee.

	T1	T2	T3	T4	T5
CIE76 ΔE	7.0711	14	8	11.7047	6.7082
CIE00 ΔE	6.1089	11.6613	6.3390	9.9079	5.5432

Table 23: Delta E values of the Tea Group sample after soaking in tea.

	S1	S2	S3	S4	S5
CIE76 ΔE	27.7669	33.8231	30.2985	26.9528	22.9129
CIE00 ΔE	21.7948	21.8641	21.2182	20.5249	16.6979

Table 24: Delta E values of the Soda Group sample after soaking in Coca Cola.

	R1	R2	R3	R4	R5
CIE76 ΔE	22.5610	19.9249	22.1359	15.6525	28.5132
CIE00 ΔE	19.4045	17.2278	18.8399	13.1399	25.5304

Table 25: Delta E values of the Red Wine Group sample after soaking in red wine.

As shown in these tables, the Second CIE76 Delta E founded are ranged:
-for the control group sample between (1 to 2) Table (21)
-for the coffee group sample between (6 to 11.1803) Table (22)
-for the tea group between (6.7082 to 11.7047) Table (23)
-for the soda group between (22.9129 to 33.8231) Table (24)
-for the red wine group between (19.9249 to 28.5132) Table (25)

As for the Second CIE00 Delta E are:
-for the control group sample between (0.7476 to 1.6010) Table (21)
-for the coffee group sample between (4.2410 to 8.1880) Table (22)
-for the tea group between (5.5432 to 11.6613) Table (23)
-for the soda group between (16.6979 to 21.8641) Table (24)
-for the red wine group between (13.1399 to 25.5304). Table (25)

5. DISCUSSION

Thanks to all the tablets present in this study the results founded were analyzed in order to confirm or reject the hypothesis (H0): If the consummation of staining beverages after a at home tooth bleaching influence the outcome of the treatment than color changes can happen.

The values collected before the at home tooth bleaching have shown changes compared to the one founded after the procedure. In fact, it was possible to observe that all the tooth who undergone the bleaching treatment presented all changes in their CIE-L*, a*, b* values.
In this way, Delta E CIE76 and CIE00 were calculated for each tooth of each sample.

Delta E measures the apparent difference between two colors. A value equal to 0 indicates that the colors are same, but higher values indicate that the colors differ. A value lower than one is considered undetectable to the human eye, whereas values between one and two are minimal. Values greater than 2 imply that there is a discernible difference between hues. When the Delta E value is more than 3, the difference in the colors is regarded substantial and perceptible to most people.

However, CIE76 ΔE is the most widely used value it was therefore more appropriate to analyze even though CIE00 ΔE is more precise because it takes into account more criteria.
The CIE76 ΔE results are higher than the CIE00 ΔE. Nevertheless, CIE76 ΔE gives an excellent idea of the overall color difference between two items and is appropriate for many clinical situations. (26)

For the Control sample group, CIE76 ΔE of W1 and W3 are slightly above 3. Table (11)
CIE76 ΔE of W1 and W3 are of 2.8284.
However, CIE76 ΔE of W2 is equal to 3.

W4 and W5 are above 3.

These results show that the at home tooth bleaching worked on all the teeth of this sample group with noticeable results for W1, W2 and W3. Moreover, W4 and W5 the brightness and whiteness of these teeth is even more pronounced. Figure (7.1)

The CIE76 ΔE founded for the Coffee sample group were between 2.4495 to 3.7417 which signifies that the difference of color was noticeable for all the teeth presented in this group. Figure (7.2)

CIE76 ΔE of C2 and C4 were equal to 2.4495 corresponding to easily observable color improvement. Table (12)

CIE76 ΔE of C5 was of 3 with signifies there is moderate changes.

CIE76 ΔE of C1 and C5 were above 3 that means that the tooth shade improvement was even more dramatic.

In the same way the CIE76 ΔE founded within the tea sample group are arranged in only three results T1, T4, T5 representing 3.3166, T2 is equal to 3.7412 and T3 being of 3.7417 Table (13). The results look homogenous and because they are superior to 3 the color of the teeth from this group sample changed and it's highly noticeable with the human eye. The teeth in fact looked more appealing and brighter after the bleaching treatment. Moreover, T3 and T4 presented both composite restorations, a distinct color variation between the tooth and the material was observable on both teeth. Figure (7.3)

Regarding the Soda group sample the CIE 76 ΔE obtained presented a bigger range, results went from 3 being S1 to 3.7412 being S3 Table (14). All the teeth achieved considerable shade improvement easily noticeable to the human eye. Figure (7.4).

The Red wine group sample CIE76 ΔE of R1 was the only ΔE of this group sample to be between 2 and 3 the difference of color is therefore slightly improved, however CIE76 ΔE of R2, R4, R5 were above 3 and R3 is equal to 3 Table (15). These results provided justify the visible shade ameliorations. Figure (7.5)

The whitening procedure worked on all the teeth from all the samples since most of their CIE76 Delta E values were equal or above 3, then a lot were between 2 and 3, which explain why it was possible to observe visually brighter and whiter shades.

The Delta E value computed following a tooth whitening treatment might have varies based on several factors, including the starting shade of the teeth. However, in terms of tooth bleaching results, a Delta E value between 2 and 4 indicates that the procedure worked well since the goal of tooth bleaching is to brighten the tooth making them look whiter and still natural, it is necessary to keep in mind that the result can takes weeks to stabilize.

Regarding, the last part of the experiment which consisted in soaking the group sample inside the correspond beverages changes and alterations of color were visible to the naked eye for four out of the five group sample.

Indeed, the Control group who was soaked in water show CIE76 Delta E values very low:

W1, W2, W3, W4 have CIE76 Delta E values equal to 1. W5 have CIE76 Delta E is of 2 Table (21)

These results let suggest that even though they are changes in shade they are minimal and not discernable to the human eye. Figure (8.1)

Besides, the Coffee sample group after being soaked in coffee for two weeks presented CIE76 Delta E values higher than 4. Going from 5.4772 for C1 being the lowest to 10.4881 for C4 being the highest C2; C3; C5 are between 6 to 6.4807 Table (22). Values that high shows that in fact all the teeth suffered shade modification identifiable, in fact the teeth look yellower and less bright. (Figure 8.2)

Therewith, CIE76 Delta E values of the Tea sample group are much more heterogenous, T1 being of 7.0711, T2 of 14, T3 of 8 , T4 of 11.7047 and T5 is equal to 6.7082 Table(23)

These high values founded are the proof of a discernable alteration happened when the teeth were inserted for fifteen minutes inside a cup of tea. The shade of these teeth looked visually more yellow Figure (8.3).

Furthermore, values gathered after soaking the Soda group sample inside coca cola high color alterations were recorded, in fact the CIE76 Delta E values founded are all above 21 going from 22.9129 for S4 to 30.2985 Table (24). This justifies the high differences of shade observed at the end of the experiment. The teeth seem brownish and lose all their shininess and brightness. Figure (8.4).

Withal, Red wine group sample CIE76 Delta E values are go from 15.6525 for R4 to 28.5132 Table (25). Shade alterations and darkness leaning towards purple observed on the teeth of this group sample are consequently explained with these results that are very high. Figure (8.5).

6. CONCLUSION

By taking into account the limitations of this pilot study such as the small size of the sample, as well as the short duration of execution and potential bias, we can conclude that:

- Among the chosen staining beverages Coca Cola as well as Red Wine showed the biggest alterations of color and stains on the teeth surfaces that clearly showed that in their presence, the effects of the bleaching procedure disappear.
- Tea and Coffee were also responsible of stains, teeth after exposed to these beverages looked yellower however they were not as damaged as the one exposed to Coca Cola and Red Wine.
- Shade improvements were observed on all the teeth after the at-home bleaching treatment.
- The control group who soaked only in water is not showing stains or color alteration. Water exposition let the teeth's shade stabilize and does not produce discernable variation effect on the color obtained after the bleaching procedure. Therefore, it should be the only beverage consumed by patients who wants to obtain durable teeth shade improvement.

In a nutshell, patients should avoid consuming beverages other than water after an at home teeth bleaching, however, it seems that there are a few ways to bypass this restriction. Consuming only white or colorless food in a "White Diet"(11) should be considered as it would allow recently bleached enamel to solidify and prevent new stains from forming. Another option that is worth studying is using a straw to avoid dental contacts with staining beverages or limiting fluid intakes to water and milks (as their properties wouldn't alter the desired whiteness).

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