SPECIAL GUEST LITERATURE REVIEW

Color Selection and Reproduction in Dentistry Part 2: Light Dynamics in Natural Teeth

Reproducción y selección del color en Odontología Parte 2: Dinámica de la luz sobre las piezas dentales

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ABSTRACT

In the first article of this trilogy, it was demonstrated the great importance of the light source in the chromatic procedures and also the chromatic characteristics of color communication proposed by *Munsell*. In this second article, the focus is in Geometric Attributes and Optical Properties of natural teeth. The main features of translucency, opalescence and fluorescence will be described. According to the interaction of light with natural dental tissues, the desired optical qualities of the esthetic restorative materials will be associated.

KEYWORDS

Color; Translucency; Chroma; Opalescense; Fluorescense.

RESUMEN

En el primer artículo de esta trilogía, se demostró la gran importancia de la fuente de luz en los procedimientos cromáticos y también sobre las características cromáticas del color propuestas por *Munsell*. En este segundo artículo, la atención se centra en los atributos geométricos y las propiedades ópticas de los dientes naturales. Se describirán las principales características de translucidez, opalescencia y fluorescencia. Según la interacción de la luz con los tejidos dentales naturales se pueden asociar las cualidades ópticas deseadas de los materiales de restauración estética.

PALABRAS CLAVE

Color; Croma; Translucidez, Opalescencia; Fluorescencia.

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TRANSLUCENCY OF NATURAL TEETH

Enamel and dentin have different structural characteristics and, consequently, they exhibit different light wave interaction characteristics. Due to its highly mineralized prismatic structure, low organic content and a small amount of water, enamel has a higher transmission of light than dentin; dentin has the less mineral content, an organic tubular structure, higher water content and is less translucent (Figs. 1 e 2) (1). Differences in translucency of dental tissues can be better understanding with the aid of polarizing filters (Fig. 3 e 4).

Defined as the relative amount of light transmitted through a material, the translucency can be understood as an intermediate situation between total blockage of light rays (opacity) and overall transmission of rays (transparency). Therefore, the translucent objects allow light to pass through, varying this passage to a greater or lesser degree (2-3). The chromatic evaluation in translucent bodies is more complex than in opaque bodies. Hue, chroma and value are parameters considered insufficient to accurately describe the optical effects observed in objects that allow light transmission. For this reason, the translucency is considered the fourth chromatic dimension applied in restorative dentistry. In this four-dimensional concept, the value is the most important dimension of color with the translucency coming in second place (4).

Generally, the translucency of resin composites and ceramic systems is directly related to its thickness. Several authors described that the increase of thickness of restorative materials results in a decrease of its translucency (Fig. 5). It is very important to discover what is the thickness required by each material to block the influence of the background contrast, an essential condition to evaluate the inherent color of the material (2,5-7).

The maximum thickness of 4.0 mm was described on a study by Kamishima and colleagues, who reported that enamel composite resins were not influenced by the background contrast at this thickness (5). To match tooth color, various shades of yellow and gray pigments are blended to white base material of traditional resin composites. In darker shades (low lightness or high chroma shade), more pigments might be incorporated, which may influence the translucency of the shade. Yu and Lee analyzed the influence of color parameters of resin composites on their translucency using a reflection spectrophotometer. The results indicated a high correlation between translucency and Value, with darker shades presenting lower translucency (7).

Besides the thickness, another factor that influences the translucency of the teeth is the surface texture. It relates to the appearance of the surface of objects, and in general, we can define it into macro-and micro-textures. The macro-textures are topographical variations found on the surface of the enamel, such as the grooves of development. The macro-textures are responsible for large areas of light reflection. The micro-textures are formed by tiny changes of enamel surface, occurring by deposition of hydroxyapatite crystals by ameloblasts during tooth germ formation, resulting in small oriented parallel grooves. A rich parallel groove surface is responsible for the creation of areas of diffuse reflection on the tooth surface, thereby, decreasing the translucency (Fig. 6) (8-9).

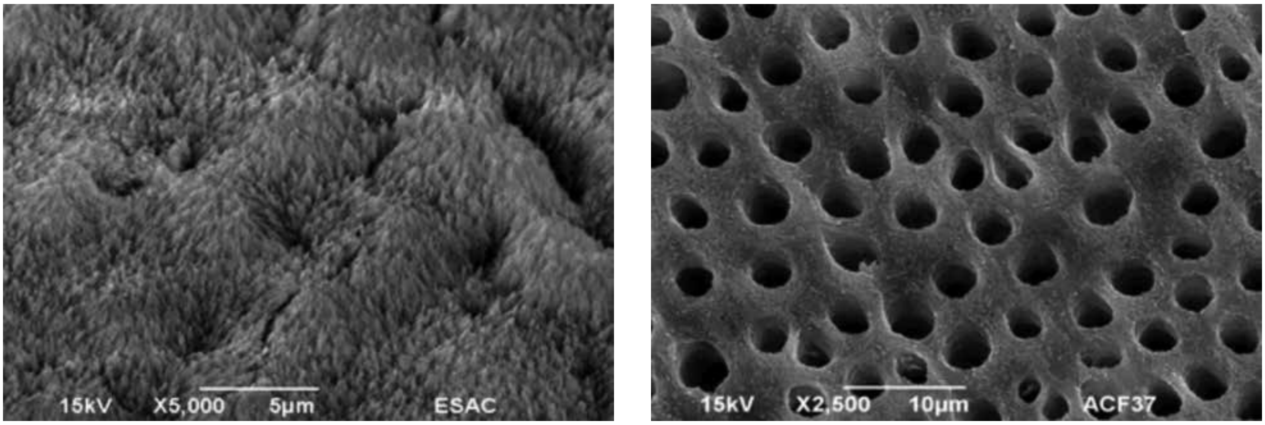

Figure 1 and 2. Note the different structural characteristics between enamel (left image) and dentin (right image).

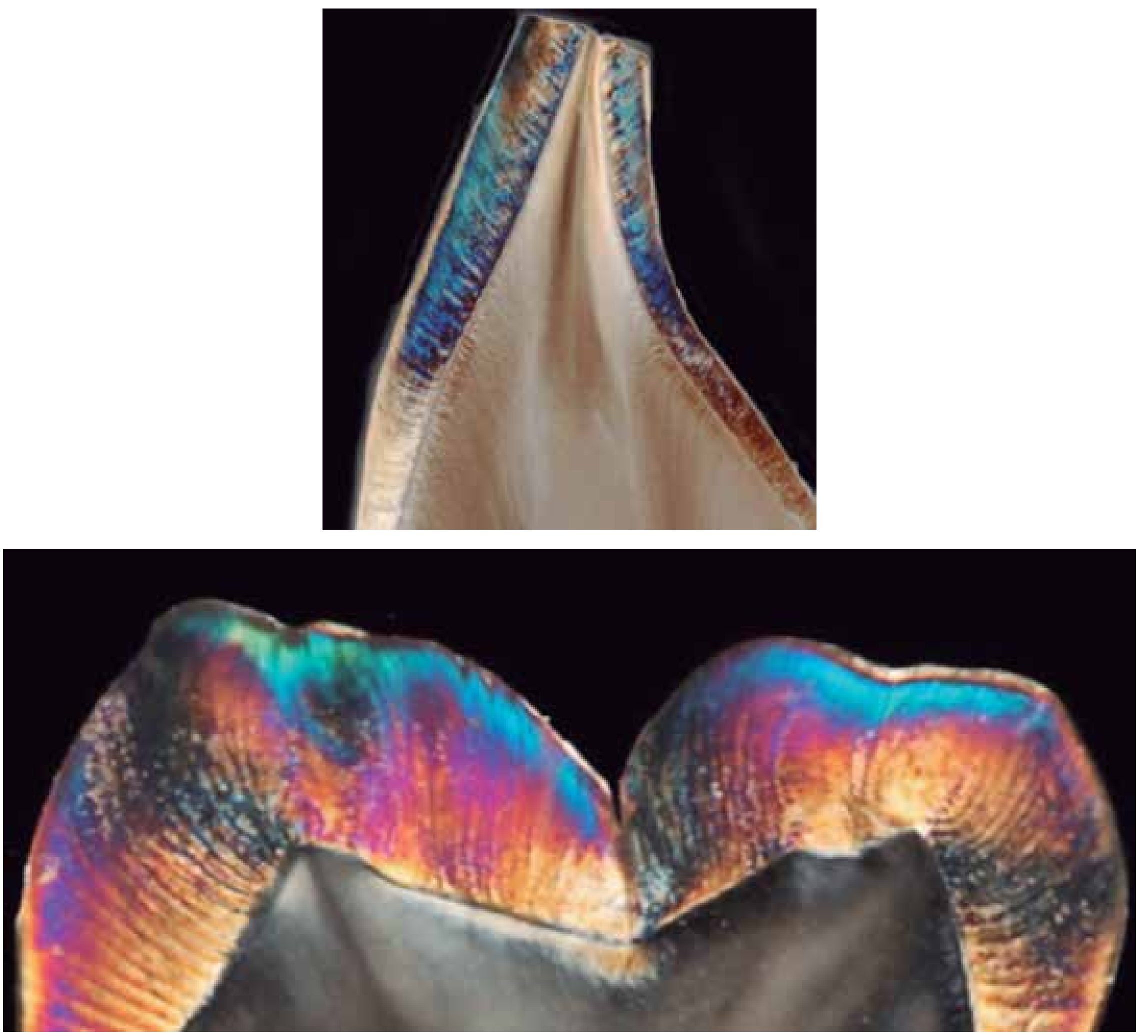

Figure 3 and 4. The translucency differences of dental tissues can be better understanding with the aid of polarized filters. Note that enamels acts like an optical fiber transmitting the light energy to dentin.

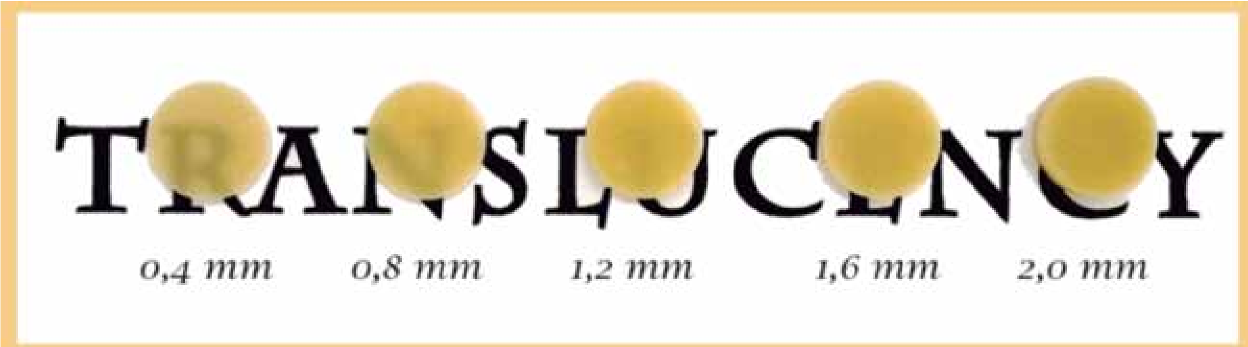

Figure 5. The opacity of esthetic dental materials is directly related to its thickness where a larger thickness corresponds to high opacity.

In a study of the translucency of enamel, some authors have shown that this property is strongly influenced by the degree of hydration of this tissue. In this study, the dehydration of the enamel was evaluated instrumentally after applying a jet of air for 10 seconds and resulted in 82% decrease in the values of translucency. This decrease was due to the increase of the refractive index of enamel caused by the water outflow and air intake on the outskirts of the prisms (Fig. 7) (10).

In aesthetic dentistry, the importance of translucency becomes evident when we observe the variation of the color of teeth according to background contrast (11). The same tooth observed in a white background and a dark background, will show different colors to due to absorption and selective reflection of certain wavelengths. Throughout this chapter we demonstrate the influence of the background contrast in the color of natural teeth with special attention in the incisal region of the anterior teeth.

THE DYNAMICS OF COLOR IN RELATED TO AGE

A basic factor when studying tooth color is the variation in thickness of these tissues due to aging. In natural teeth, the value is characteristic for the enamel, while the chroma and hue characterize dentine. The younger individuals, less exposed to the wear caused by the acids in the diet and brushing, present enamel thicker than older individuals, and consequently lighter teeth. As wear is accentuated and the thickness of the enamel layer decreases, the translucency of the enamel increase, enabling chroma and hue, characteristics concerning the dentine, become more obvious. Thus, during the process of interaction of light with the dental tissues, enamel plays an important role in acting as a filter, whose greater or less thickness accounts for teeth brighter or less bright (Fig. 8) (12-13).

These characteristics can also be proven by observing the color variation that exists in a single tooth. Thus, at the cervical region, where enamel is thin, the color is only attenuated and chroma is high. In the middle third, which is more thick, the enamel is able to filter significantly the characteristics of dentin, making this region with high brightness and low saturation in the incisor region where there is little or even absent dentine, hue and chroma are replaced by tooth translucency and opalescence effect that will be discussed below.

OPTICAL PROPERTIES OF DENTAL TISSUES

In addition to presenting different degrees of translucency, enamel and dentin also have different optical properties that give teeth unique beauty, highlighting respectively the opalescence and fluorescence.

OPALESCENCE

Opalescence is an optical property that gets its name because it was first observed in opal stones (Fig. 9) (14). It happens by scattering of smaller wavelengths of the visible spectrum, making the opalescent objects more bluish when viewed under reflected light and more orange when viewed in transmitted light (15). All teeth that are naturally covered by the enamel present opalescence (Figs. 10 e 11). However, this property can be better observed in the upper central incisors, in the form of a blue band, located near to the incisal edge called opalescent halo (16-17). Besides opalescent halo, the opalescence also gives rise to another optical phenomenon called counter-opalescence, (17-18) responsible for orange appearance that can be observed in the region of the mamelons tip of anterior teeth. It happens when the greater wavelengths, which are usually transmitted through the enamel, reach structures capable to reflect them. When the light performs inverse path through the enamel, the blue wavelength still being spread while larger lengths are transmitted, making the dentin more orange (Fig. 12).

Due to its great aesthetic importance, the opalescence was considered by some authors as a chromatic scale can be recognized by four different types of presentation (18).

- Type 1: Found in incisal edges that have opalescent halo closely related to the dentinal mamelons. It kind of opalescence presented by 58% of individuals (Fig. 13).
- Type 2: In this type of opalescent halo mamelons not penetrate between the dentin, extending over the incisal edge. It kind of opalescence presented por17% of individuals (Fig.14).
- Type 3: Found in incisal edges showing diffuse halo opalescent, distributed randomly throughout the incisal edge. It kind of opalescence presented by 4% of subjects (Fig. 15).
- Type 4: In this type of opalescence opalescent halo presents mixed with some kind of pigmentation or characterization. It kind of opalescence presented by 25% of subjects.

Baratieri, Araujo, Monteiro JR (2005), demonstrated that removing the vestibular enamel of central incisors extracted, the of mamelon tip showed white opaque color than the original orange color, showing the influence of the counter-opalescence in the appearance of the tooth (19). By understanding the role and importance of opalescence and counter-opalescent we realize that the enamel contributes decisively in the expression of subtle variations of hue observed in natural teeth.

In ceramic systems, opalescence has been responsible to solve aesthetic problems related to value and translucency, making possible to produce unnoticeable restorations (20-21). It has been demonstrated that the opalescence helps on the masking effect when the resins present similar translucencies. However, when the composite resins present different translucency degrees, the translucency is predominant (22). When these results are extrapolated to enamel, it means that in spite of the opalescence decrease, it is more important to evaluate changes of translucency than of opalescence to determine the potential of masking effect of this tissue. The correct reproduction of opalescence with composite resins involves careful observation of adjacent teeth and the selection and application of opalescent resins in appropriate locations. The correct reproduction of opalescence with ceramic systems also involves careful observation and the use of opalescent ceramic, however, this information should be forwarded to the technician who performs the restoration.

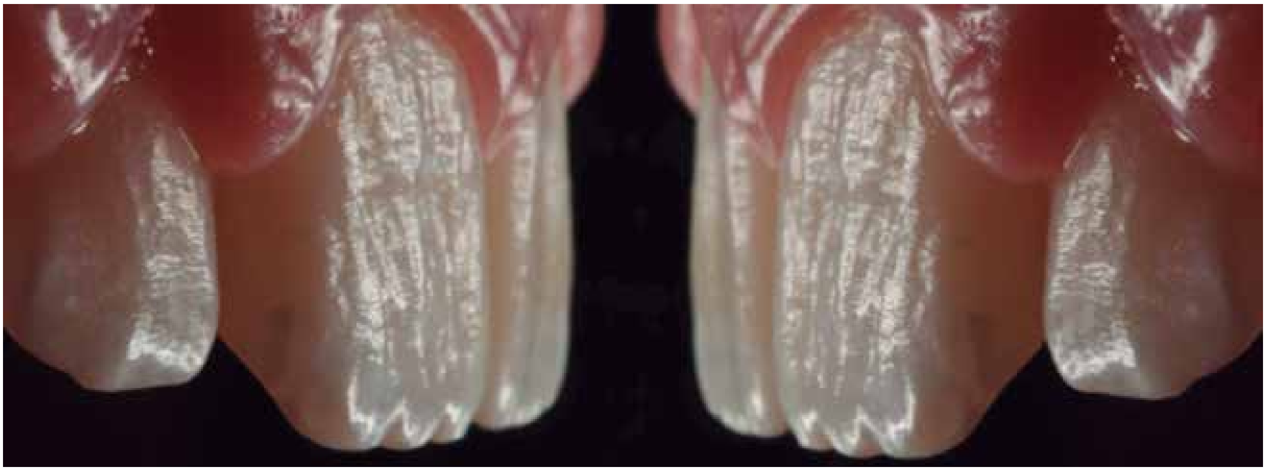

Figure 6. Surface texture of the upper central incisors. Note the large vertical elevations and depressions that are present on the tooth surface as well as the smaller horizontal grooves that can be observed, mainly in younger individuals.

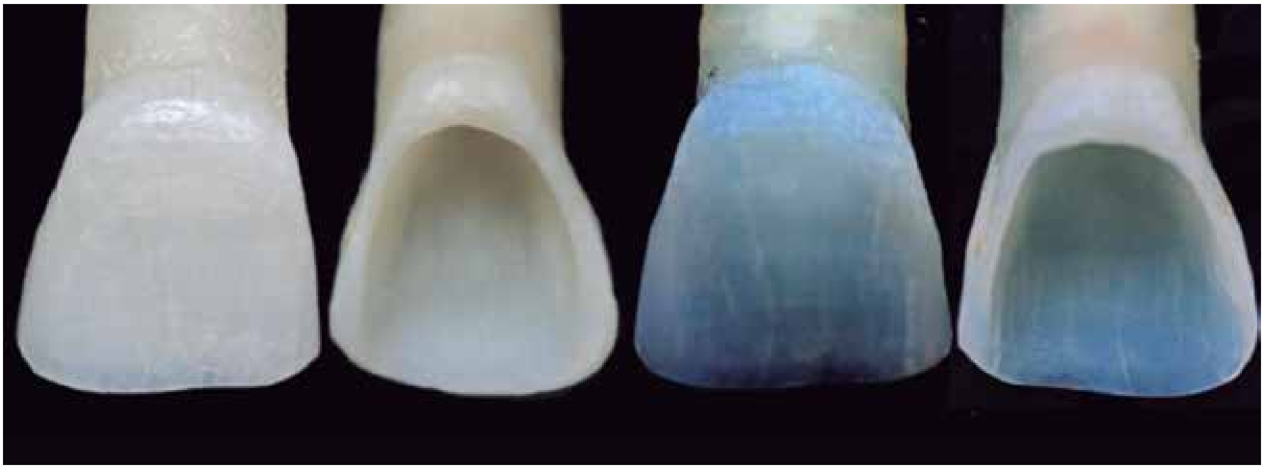

Figure 7. The enamel is strongly influenced by the degree of hydration. The left incisors were dehydrated allong 24 hours and became with an white-opaque color (note that we can't see the black background contrast through it). The right incisors are observed after 5 minutes under the water. Note the increase of translucency and the influence of the background contrast through hydrated enamel.

Figure 8. The dynamics of color natural teeth related to age.

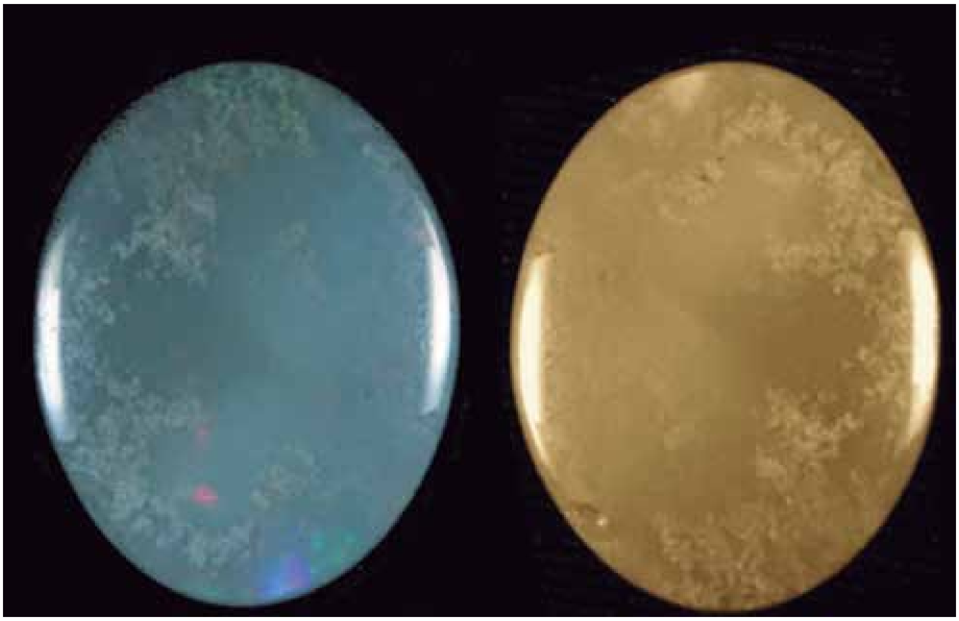

Figure 9. Opal stone observed under direct reflected light (left) and transmitted light. Note the blue shade under reflected light and the orange shade under transmitted light.

Figure 10. Central incisor slices observed under reflected and transmitted light in black background.. Under reflected light (left) we could see bluish shades on enamel. Under transmitted light, enamel also shows an orange color.

Figure 11. For esthetic reasons, the anterior teeth are the most used examples to present opalescence. Nevertheless, opalescence is present in all teeth. Observe that under transmitted light dentin also shows an orange color. This fact confirms the influence of translucency on opalescence. Clinically we can confirm this affirmation observing the oranfe effect on tips of mamellons.

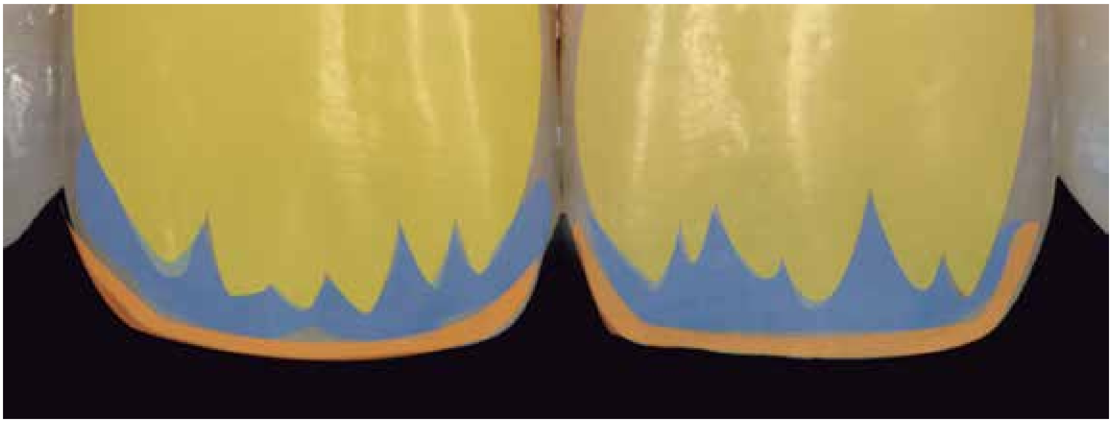

Figure 12. Schematic image of opaque halo (in the edge of incisal board- Orange color), opalescent halo (between opaque halo and dentin mamelons -blue color) and dentin mamelons At the center of tooth -yellow color.

Figure 13. Opalesccnce type 1.

Figure 14. Opalescenve type 2.

Figure 15. Opalescence type 3.

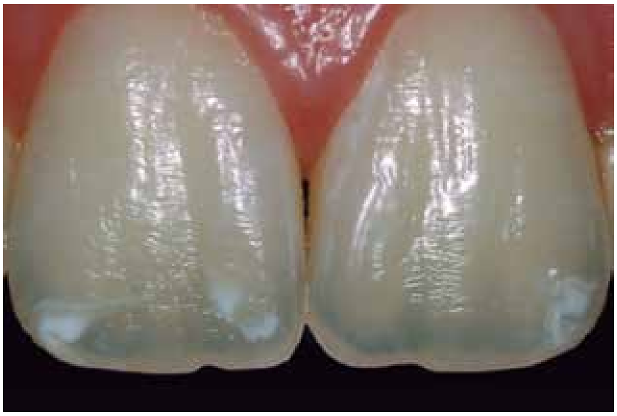

Figure 16. Opalescence type 4.

Figure 17. Influence of background contrast on opalescence and counter-opalescence.

Figure 18. Removing the vestibular enamel of central incisors extracted, the of mamelon tip showed white opaque color than the original orange color, showing the influence of the counter-opalescence.

Figure 19. The correct reproduction of opalescence with composite resins involves careful observation of adjacent teeth and the selection and application of opalescent resins in appropriate locations.

FLUORESCENCE

Fluorescence is a luminescence phenomenon, which means that it causes spontaneous light emission by a process other than heating (23). To better understand fluorescence, clinicians must remember that all visible light is situated in a narrow band of the electromagnetic field, limited at the lower end by ultraviolet (UV) radiation and at the upper end by infrared (IR) radiation. Both radiations are invisible to the human eye. This range is called the visible spectrum (24). While most objects dissipate the absorbed light energy as heat, fluorescent objects re-emit this energy in a longer, visible wavelength at a speed faster than 10-8 seconds (25-26). Although there is evidence that dentin and cementum exhibit a red color when they intercept the incidence of green light, (27) tooth fluorescence is usually associated with a blue-white chromatic appearance (Fig. 20) caused by the incidence of the UV wavelength, as is emitted by the black light present in most nightclubs (28).

In this environment, the incidence of UV wavelengths in a tooth restored with nonfluorescent material causes metameric failure and is responsible for highlighting the restorative material (29-30). Fluorescence is present in both enamel and dentin; however, because it is associated with the amount of organic matter, it presents three times greater intensity in dentin than in enamel (Figs 21 e 22) (31). This difference results from the presence of collagen fibers (32) and specifically the amino acids that help to compose those fibers, including tryptophan, pyrimidine, (33-34) and pyridinoline (35). Under natural light, fluorescence makes teeth more luminous and shiny, giving them an internal luminescence (36). Fluorescence must be present in restorative materials to obtain natural-looking results. Indirect materials were the first to show fluorescence. Currently, direct composite resin and adhesive systems, which can be used even for extensive Class III or IV restorations, offer the potential for suitably fluorescent results. Based on the fluorescence observed in natural teeth, the fluorescence of composite resins can be classified as low, suitable, or excessive (Fig.23) (29-30). When composite resin disks, of the same color but different thicknesses, were compared they all showed similar fluorescence (30, 37).

The different fluorescent properties of composite resins can be better observed when compared to a natural tooth (Fig 24). Observation of the fluorescence of enamel has been described as an effective alternative method for the initial diagnosis of caries due to the low fluorescence of decayed enamel compared to sound enamel.39 When human dentin was irradiated with light in the range of 365 nm, fluorescence was observed with a peak located at 440 ± 10 nm. (38).

Although dentin is primarily responsible for the fluorescence of natural teeth, several authors have suggested that the enamel composite resin layer is more responsible for fluorescence of a restoration. Thus, if the dentin layer comprises highly fluorescent resin and the enamel layer comprises nonfluorescent resin, the result will be a nonfluorescent restoration. Conversely, if the enamel layer exhibits high fluorescence and the dentin resin layer does not, the result will be a fluorescent restoration (Fig 25) (29-30, 38). The correct reproduction of fluorescence with composite resins involves the correct selection and application of fluorescent resins in appropriate layer technique.

CONCLUSION

After reading the second article of this trilogy we must comprehend the natural teeth as a dynamic mosaic influenced by the interaction of different variables, resulting in a unique and inconstant beauty. Indeed, to obtain optimal esthetic results, the restorative materials should present optical properties that are similar to those of the dental structure.

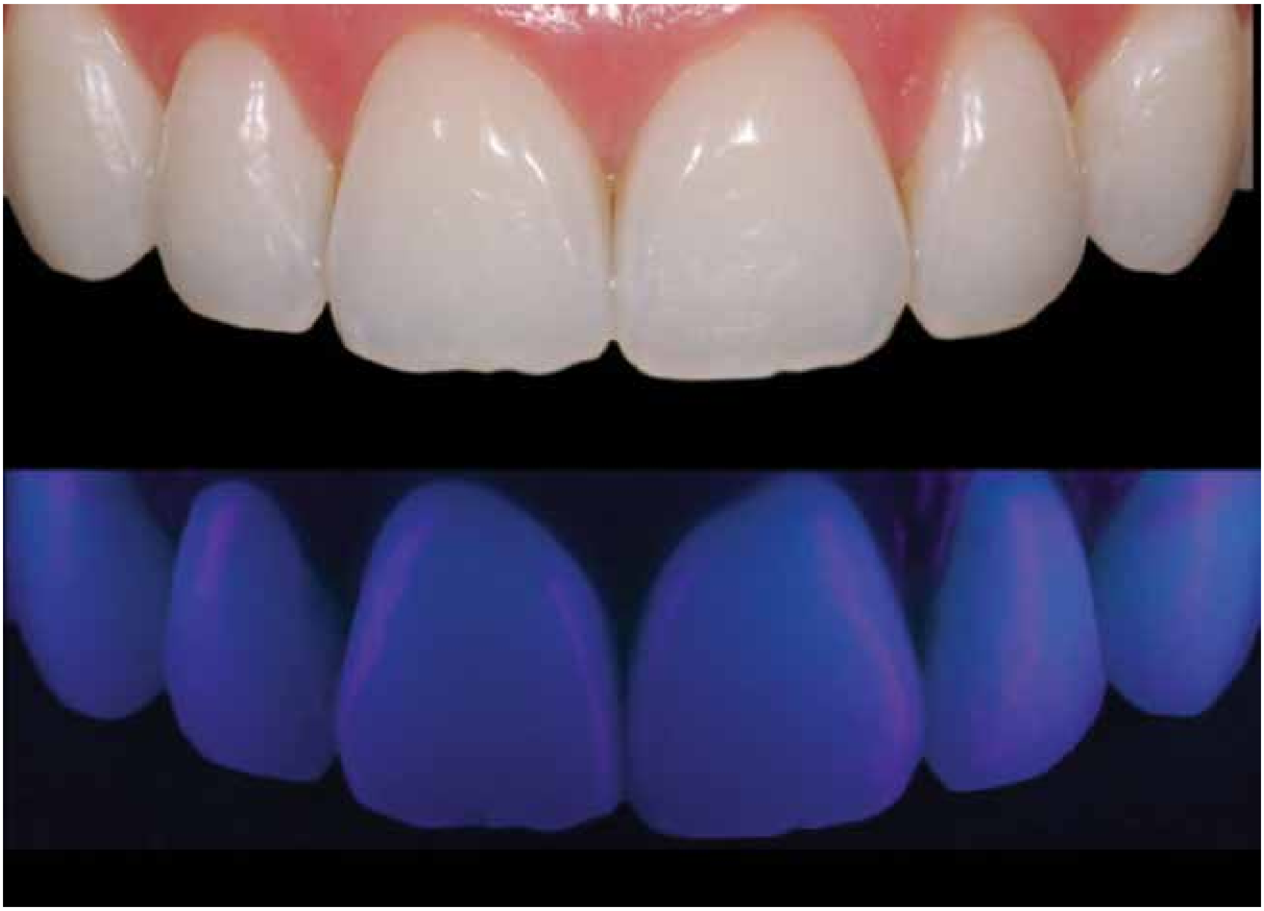

Figure 20. Natural teeth as observed in daylight and black light.

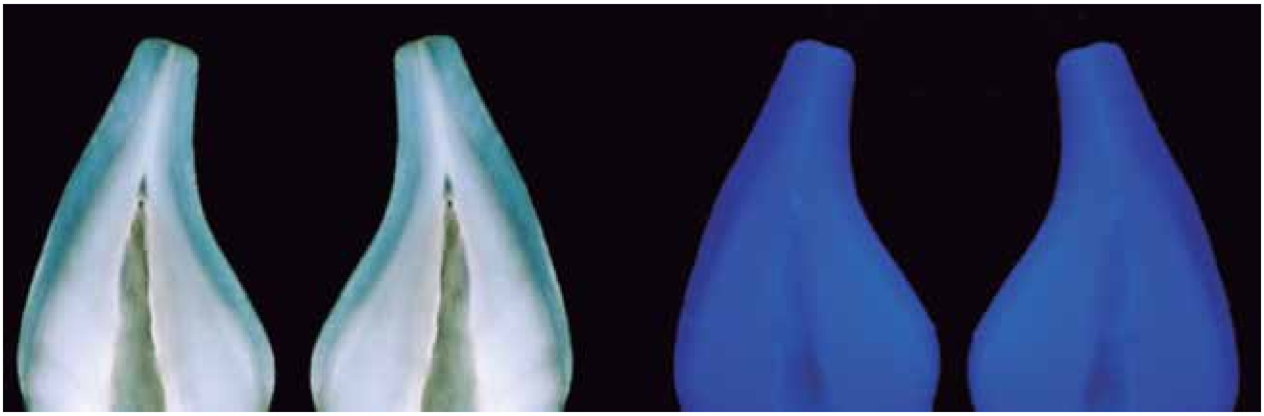

Figure 21. Fluorescence of central incisor slices under daylight and black light. Because it is associated with the amount of organic matter, note (under black light) that it presents three times greater intensity in dentin than in enamel.

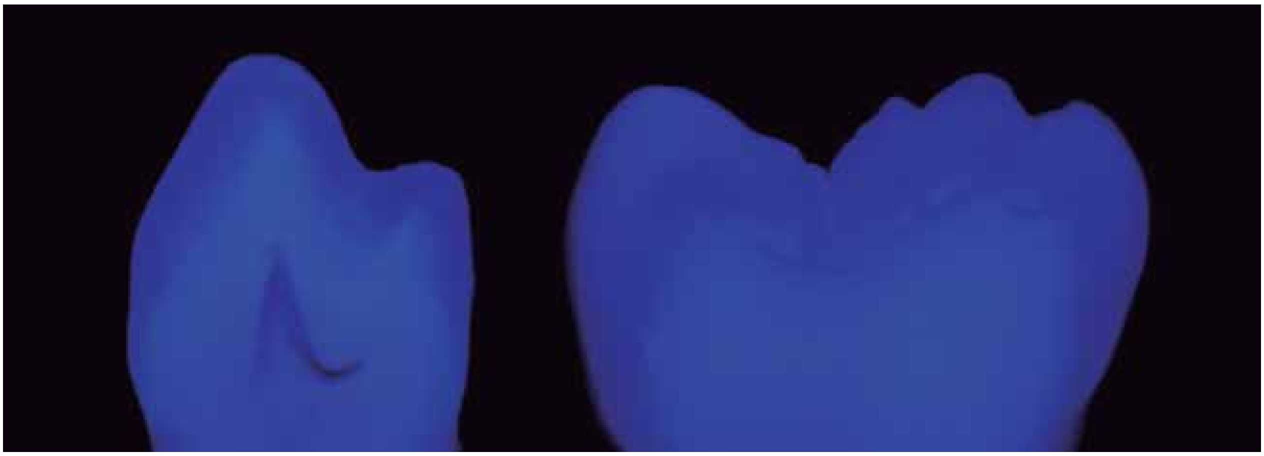

Figure 22. For esthetic reasons, the anterior teeth are the most used examples of fluorescence. Nevertheless, it is present the same characteristics in all teeth.

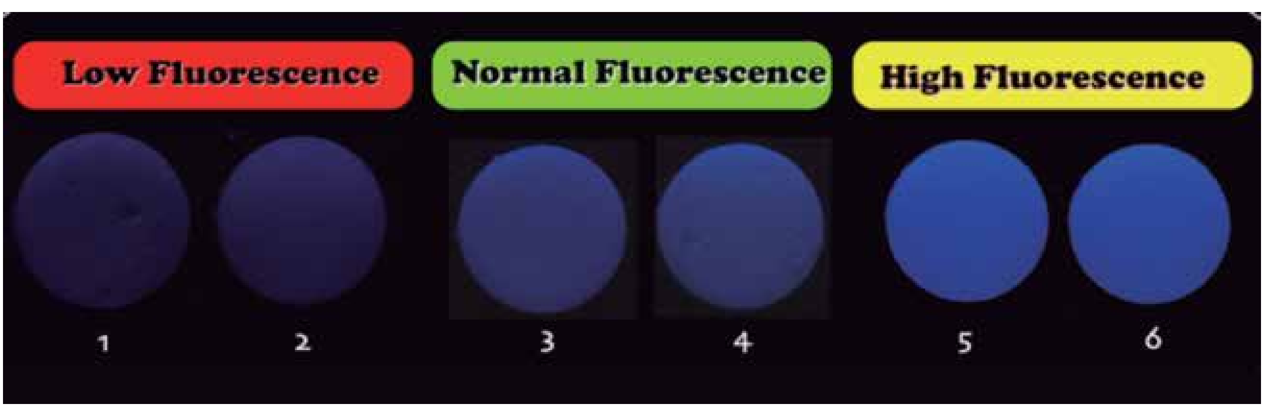

Figure 23. Based on the fluorescence observed in natural teeth, the fluorescence of composite resins can be classified as low, suitable, or excessive.

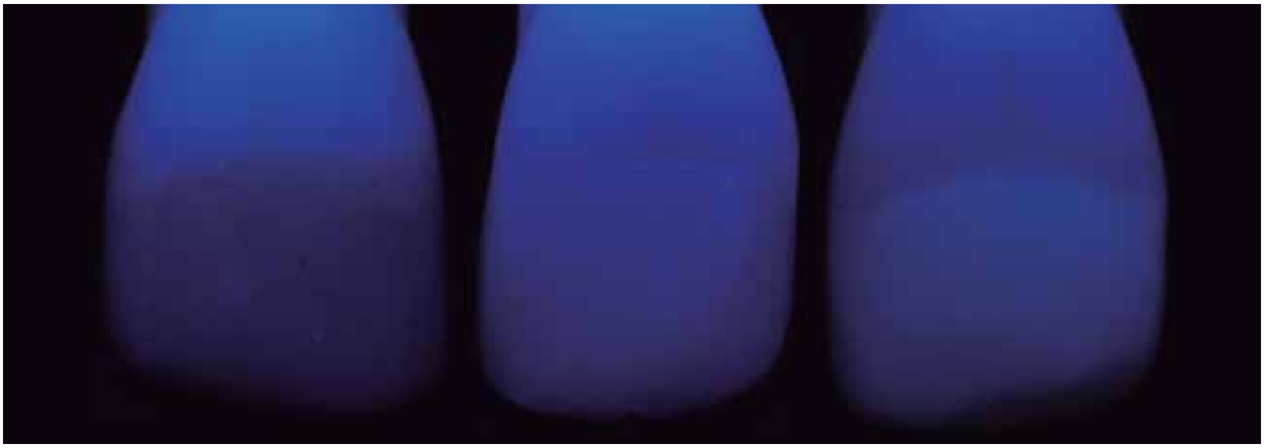

Figure 24. Differences in resin composite fluorescence compared to an natural extracted teeth.

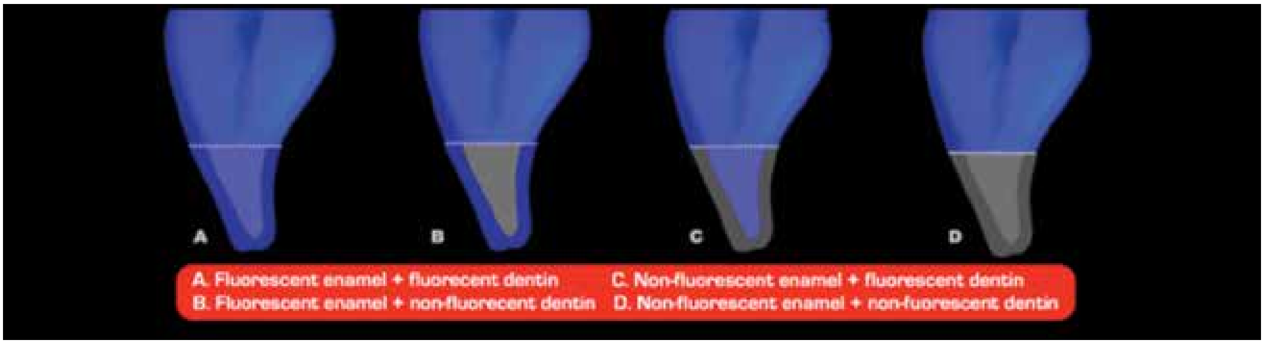

Figure 25. Schematic representation of the importance on the composite resin surface in fluorescence of restorations. Restoration A and restoration B show fluorescence, while restoration C and D do not.

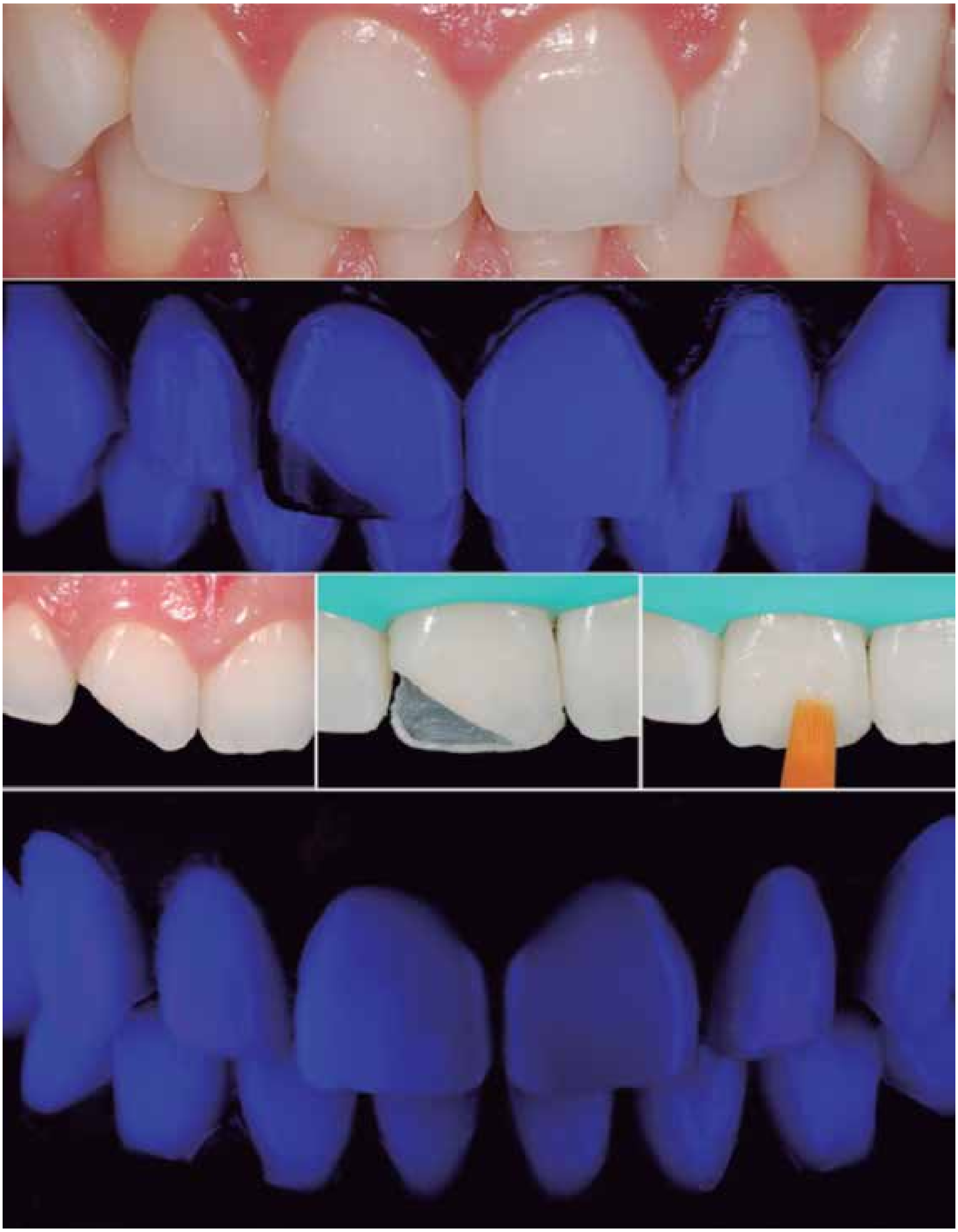

Figure 26. The correct reproduction of fluorescence with composite resins involves the correct selection and application of fluorescent resins in appropriate layer technique.

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