Direct Esthetic Restorations Based on Translucency and Opacity of Composite Resins

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ABSTRACT

Light dynamics is a relevant phenomenon with respect to esthetic restorations, as incorrect analysis of the optical behavior of natural dentition may lead to potential clinical failures. The nature of incident light plays a major role in determining the amount of light transmission or reflection, and how an object is perceived depends on the nature of the light source. Natural teeth demonstrate translucency, opalescence, and fluorescence, all of which must be replicated by restorative materials in order to achieve clinical success. Translucency is the intermediary between complete opacity and complete transparency, making its analysis highly subjective. In nature, the translucency of dental enamel varies from tooth to tooth, and from individual to individual. Therefore, four important factors must be considered when appraising translucency. Presence or absence of color, thickness of the enamel, degree of translucency, and surface texture are essential components when determining translucency. State-of-the-art resin composites provide varying shades and opacities that deliver a more faithful reproduction of the chromaticity and translucency/opacity of enamel and dentin. This enables the attainment of individualized and customized composite restorations. The objective of this article is to provide a review of the phenomena of translucency and opacity in the natural dentition and composite resins, under the scope of optics, and to describe how to implement these concepts in the clinical setting.

CLINICAL SIGNIFICANCE

Choosing composite resins, based on optical properties alone, in order to mimic the properties of natural tooth structures, does not necessarily provide a satisfactory esthetic outcome. In many instances, failure ensues from incorrect analysis of the optical behaviors of the natural dentition as well as the improper use of restorative materials. Therefore, it is necessary to implement a technique that enables a restorative material to be utilized to its full potential to correctly replicate the natural teeth.

(*J Esthet Restor Dent* 23:73–88, 2011)

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INTRODUCTION

The dental marketplace offers great diversity in new direct resin systems, bringing new options, along with new doubts, regarding which choice of material to use. Given the importance of a fully integrated tooth restoration that fulfills both functional and esthetic requirements, a complete knowledge of the behavior of dental tissues and the relationship of restorative materials with the physical and optical phenomena of light is required.

The esthetic requirements of composite resins are intimately related to the optical interactions of light with matter. Light is the form of electromagnetic energy that is visible to the human eye. It is also the major element that allows perception of the color of an object. Perception of light occurs not only because of color but also because of physical and optical properties that are inherent to the electromagnetic waves. Those properties are directly related to the environment and the presence of light on the object. Considering that every substance capable of transmitting light is composed of matter, the tissues that compose the dental area are also capable of transmitting light. Just as it happens with other mediums, when light is dispersed on the surface of the tooth, it can be

reflected, absorbed, refracted, and diffused.¹

The Nature of Light

To understand how restorative materials will present their esthetic values, it is necessary to first understand the physical properties and characteristics of light. Particles named photons comprise what we see and experience as "light." These particles are represented by the different lengths of electromagnetic waves. Human perception of light begins at electromagnetic wave lengths between 400 and 700 nanometers.² Visible light, however, is a mix of different wavelengths and is called white light. In contrast, monochromatic light is produced by the luminous energy of short span of wavelengths, displaying as a single color or single wave of light.³ When light collides with an object, it creates phenomena such as absorption, transmission, or reflection. The interaction of light with matter typically results in the union of two or more phenomena.² The trajectory of the rays that interact with matter can be regular, diffuse, or a combination of both.

When these optical phenomena occur, light beams interact with an object and may be detoured, or deflected, in another direction. The way in which this occurs depends on the type of surface the light particles collide with, and on the angle they form with the surface.⁴ When light collides with the correct surface and the angle formed with the surface is correct, reflection occurs.

The reflection of light on a flat surface is called specular, or regular, reflection. This is because of the angle of light breakup and is equal to the angle of reflection. In rough surfaces, the reaction of the light is termed diffuse reflection, as the surface behaves as an infinity of tiny surfaces disposed irregularly, reflecting the rays in several directions, not as a parallel group.^{1,5} The appearance of diffuse reflection is because of the different angles at which the light travels after colliding with a rough surface. Semi-specular, or mixed, reflection occurs when light breaks up on a flat surface and is reflected at slightly different angles but still in the same direction. This generates an intermediate reflection that is both specular and diffuse.⁵ Because light can be reflected by certain surfaces, it also has the ability to refract.

The refraction phenomena is produced by the directional change that the luminous rays incur when passing from one medium to another, at varying speeds, while changing its value.^{2,5} Thus, if a brush of light disperses on the surface of a translucent body, part of it is reflected and the other part is refracted. Specifically, the light penetrates the translucent body while changing the direction of its motion.⁶

The refractive index, or the relationship between the speed of the light in a vacuum and in a concrete body, is a distinctive property of matter typically used for identifying materials.^{2,5} When the refractive index of light in the vacuum coincides with the index in the medium, without path modification, the medium is called transparent. If, however, the refractive indexes are different, the medium will present distinct translucent or opaque characteristics.^{5,6}

Light, aside from being refracted or reflected, can also be absorbed by matter. This absorption is caused by the decrease of energy of luminous radiations when colliding with an opaque body or across transparent surfaces.⁵ Absorption techniques consist of capturing the different wavelengths that compose white light. In general, bodies do not absorb all of the frequencies of the light spectrum with equal intensity. Therefore, a selective absorption is produced.³

Transmission, another property of light, is considered double refraction.⁶ When looking at a crystal, it is possible to see light undergoing an initial refraction as it passes from the air to the glass. It then

follows its way through the glass and refracts again once it reaches the air.^{2,5} After this process, if the light ray is not diverted from its path, light transmission is said to be regular, as in transparent glass.⁴ If the light is diffused in all directions, diffuse transmission occurs, a typical property of translucent glass. If one direction prevails over the others, there will be mixed transmission, as in organic glass and crystals with rugged surfaces.⁵ Therefore, it is understood that the optical behavior of each medium is determined by not one, but rather many different factors, including the degree of dispersion, refraction, transmission, and absorption of light rays.⁵

Optical Phenomena of Color Perception

Under natural conditions, the light that illuminates an object is white light, which is the result of the mixture of all colors in the spectrum.³ An object presents itself as "colorful" when its surface is capable of absorbing specific wavelengths of incident light. When one or more wavelengths are reflected, an object is recognized as being a specific color.

For example, an object is white when it is capable of reflecting all wavelengths of which light is composed. An object is considered red when it absorbs all wavelengths, including violet, blue, green, orange, and yellow, and reflects red. When an object completely absorbs all wavelengths of light, it is considered to be black.^{3,4} These definitions lead to the conclusion that an object will show color more proportionally to its opacity, rather than its ability to absorb and reflect light. According to this principle, a translucent body presents color in an inversely proportionate manner to the level of its translucency.

Similarly, the capability of a body to allow light passage through its interior is called the concept of light transmission. A transmitting medium can be classified into three categories that include opaque, transparent, and translucent. These characteristics are dependent upon how a specific material or body reacts to incident light.^{2,4,5} Bodies and materials either have the ability to transmit light or not transmit light. If a specific kind of matter allows the passage of light, it is called transparent or translucent. When matter is unable to allow passage of light, it is considered opaque.

Matter is considered to be opaque when it only absorbs and/or reflects light but does not have the ability to transmit it.² Opacity is typically observed in materials that do not transmit light. Oftentimes, it is used to describe materials that absorb or reflect all light by not



Figure 1. Properties of transparent bodies (A), *translucent* (B), *and opaque* (C).

allowing its passage. In this particular case, the property is termed total opacity (Figure 1C).⁴

Differing significantly from opaque matter, a transparent medium allows light passage through its interior, without suffering any modifications in its path. When a material is transparent, an observer can see through it without distortion of objects and shapes on the other side (Figure 1A). Transparent mediums may present with achromatic or chromatic properties. When the medium is achromatic, it will not influence the perception of the object's color when looking through it. Chromatic mediums, however, will affect the color of the observed object when viewing it through the medium.

In comparison with transparent materials, translucent bodies and materials are distinguished by their ability to allow the passage of incident light through their interior. Where transparency differs from translucency is through the modification of direction, which does not allow clear observation of objects behind translucent bodies (Figure 1B).^{2,4} In discussing translucent materials, there are four important factors that determine whether the material is achromatic or chromatic, including presence or absence of color, thickness of material, degree of translucency, and surface texture.

Color, or absence thereof, is a property that applies to both achromatic and chromatic translucent bodies.² Typically, a body is called achromatic-translucent when it allows passage of light by dispersing it through its interior and out the other side. In an achromatic translucent material, this occurs without presenting any color variation. This can be attributed to the transmission of all wavelengths of light through the body.

A material, substance, or object is called chromatic-translucent when it allows the passage of light by dispersing it through its interior but reflecting only one wavelength.⁵ This single wavelength provides color to the otherwise translucent body (Figure 2).² Therefore, the perception of an object through an achromatic translucent body is very different from the perception of the color of the same object through a chromatic translucent body. In the latter, the perception of the object is influenced by the color of the interposed medium.

In the field of dentistry, dentin presents a chromatic translucency, with its saturation increasing over time (Figure 3). Enamel, however, has the ability to present either chromatic or achromatic translucency. Although it is often colorless, enamel can gradually become achromatically translucent (Figure 4).⁷⁻⁹ According to many experts in this field, enamel tends to have a yellowish-white or gravish-white aspect. When applied to composite resins, this concept abides by the same principles, as enamel resins can be pigmented, presenting chromatic and achromatic translucencies. The choice of material and pigment is then very



Figure 2. Properties of achromatic and chromatic translucent glass (A), (B), on different colored backgrounds.



Figure 3. Different saturations of the dentin; age enhances saturation.

important, because color perception of the dentin composite resin is influenced by the enamel composite resin selected (Figure 5).

When dealing with these types of translucent substances, the variation in the refractive index is also an important consideration, as it is directly related to the thickness of the material.^{1,5} When light is diffused in the interior, the material becomes translucent. The translucency of the substance may also vary because of the thickness of the material. For example, if there are three bodies of the same material with three different thicknesses (i.e., 0.5, 1, 2 mm), the one with the greatest thickness will be the least translucent (Figure 6).¹⁰

In natural teeth, the thickness of the enamel varies greatly and is greater at the incisal one-third, decreasing gradually toward the cervical one-third.^{8,11} Therefore, translucency in the cervical region is greater when compared with the incisal region, allowing for a clearer perception of the dentin (Figure 7). The same principle applies to tooth age, whereby younger teeth present more enamel than in older teeth.¹¹

Young teeth present a high color value, with typically no translucency whatsoever. This is because of the high quantity of enamel present, as the enamel of older teeth becomes thinner and more translucent over time, sometimes presenting as nearly transparent (Figure 8A and B). Older teeth also present a much lower color value than that which is seen in younger teeth. When this principle is applied to composite resins, especially to those used to restore missing natural enamel, the thickness chosen is critical. This is important because a small thickness increase may significantly change the color value of the restoration, thereby altering the perception of the color beneath it (Figure 9).

The degree of translucency of a material is an inherent property.² Light does not always pass through matter with the same incidence and direction.¹ Many times, a major fraction is deflected by the action of particles or anomalies within the object.⁵ As previously mentioned, translucency is directly related to the diffusion of light, and both concepts depend on the refraction index of the material.¹ The larger this index, the larger the degree of light dispersion and,



Figure 4. A side-by-side comparison was made to colorless young enamel and older enamel, which is achromatically translucent.



Figure 5. Interaction of chromatic and achromatic enamel resins, which modify the perception of the dentin resin.

consequently, the lower the degree of translucency.^{2,5}

Surface texture is also an important characteristic of an object that can significantly change the perceived translucency of an object. The more a surface reflects light, the less selective absorption is observed. If surface conditions enhance light reflection, transmission is proportionally reduced.¹² When light reflection is increased, the color of the object tends to be more luminous and of a higher value. In objects with a certain degree of light transmission, reflection of the surface reduces the amount of light that crosses the object. For example (Figure 10), translucency of a sandblasted glass is greatly reduced as a result of reflection on its irregular surface. The glass therefore becomes more luminous, as it is more reflective.

The glass also becomes opaque on the surface at this time because of the reflection limits on translucency and light transmission. This surface does not only modify color perception but also the perception of the translucency and opacity.

Depth and Translucency

An important as well as critical challenge in the clinical setting is restoring the natural shape of a tooth. This involves rendering proper anatomy, depth, and translucency in the typical adverse conditions encountered in dental restorations. Clinicians must achieve perfect rendering and contouring in an area that presents a lack of space, little material thickness, and the need to employ opaque materials under thin outer layers. If done incorrectly, the result may be inexpressive, lifeless restorations because translucency

and depth are important characteristics when attempting to replicate what was created naturally.

When dealing with depth, or "depth effect," a challenge often faced is the distance between the extreme positions of a screen, over which an optical system can chart images. This is the result of the different levels of translucency that a structure may present.¹² It is necessary to note that translucency and depth are intertwined and are responsible for the simultaneous perception of various special situations, such as "close and far" and "front or back."

In applying this concept to natural dentition, depth is said to be all structures that are part of the tooth. This is attributed to the different levels of translucency and depth that the enamel and dentin







Figure 7. Enamel presents itself with different translucencies.



Figure 8. A side-by-side comparison was made to young (A) and old teeth (B).

present, which also contribute to the natural appearance of the dentition.

Translucency and Opacity of Dental Structures

The analysis of the interaction of light and dental structures is immensely important, as it is necessary to understand the optical properties of teeth. Regarding this interaction, it can be said that dentin is the color and enamel is the color modifier.^{11,13,14} Although there are variations of composition and mineralization, it is known that enamel allows a 70.1% average light passage, whereas 52.6% of light can be transmitted through the dentin structure.^{15,16} There are few reports in the literature that study teeth as a whole, yet for correct understanding of the phenomena that occur in enamel and dentin, they should be studied separately.

Enamel

In dealing with enamel, the rods that comprise the basic structure of

the enamel generally rise at a right angle from the dentin surface. In cervical areas, the rods divert from horizontal orientation and lean apically. Near the incisal or cusp tip, the rods change direction gradually, becoming oblique and nearly vertical over the edges.¹⁷ Rod groups can present wrinkling, referred to as Hunter–Schreger bands, throughout their course of movement. Because of this orientation change, less light is transmitted, which decreases the translucency of the enamel.⁹

The translucency of the enamel is often expressed by the transmission coefficient, or the relative amount of light that passes through a certain thickness. The transmission coefficient of enamel is dependent upon the wavelength of incident light, as the total transmission of light through human enamel







Figure 10. An image showing translucent glass at various levels of sandblasting.

increases as the wavelength increases. This effect causes the enamel to become more translucent under larger wavelengths. The correlation between wavelength size and transmission of light is of paramount importance during shade selection because the nature of the light source also influences the outcome of translucency and esthetics.¹⁸

Enamel also modifies the chromatic aspects of the teeth because of phenomena such as reflection, transmission, refraction, thickness, and surface texture. It is also important to note that enamel has the ability to attenuate underlying colors, which can affect the chromatic aspects of the teeth.¹⁹ Therefore, properties of light reflection, or transmission of enamel, are dependent on its texture, orientation of enamel rods, and its ability to refract light, in addition to histological characteristics. However, when unreflected, luminous radiation passes through matter and reaches prisms of diverse orientation, additional refraction then occurs. This refraction determines the varying degrees of translucency and opacity present. These situations occur when light passes through a multicrystalline structure, such as dental enamel. Relative translucency of the enamel also depends on the light reflection and/or transmission properties of the enamel. Enamel translucency may also be attributed to variations in calcification levels, because the more porous and less mineralized the enamel, the larger the dispersion index.^{8,20}

This variation occurs in young teeth, as they reflect more light and are brighter because of their higher color value. Young teeth also tend to exhibit a milkier and less translucent appearance. Younger patients typically display thicker and more luminous enamel, attenuating the color of the dentin. Conversely, more mineralized and less porous enamel becomes more translucent and has a reduced color value. All achromatic translucent matter overlaying an object produces more grayish tones because the less light that is reflected, the less the object illuminates. Therefore, translucent enamel imparts a grayish color to the tooth, whereas opaque enamel presents itself as whiter, more reflective, and luminous because of its high value.

Older patients, however, display enamel that may be slightly thinner and translucent as a result of permanent wear. This type of wear promotes an enhancement of dentinal chroma toward the cervical one-third. Both incisal and proximal enamels are also highly translucent. Between the incisal area of the enamel and the incisal portion of the dentin, there is an



Figure 11. View of the area of transition between the enamel and dentin.

intermediate zone of marked translucency. Typically, this is more visible in young teeth, whereas practically nonexistent in older teeth because of incisal wear and lack of sufficient enamel thickness. This intermediate zone relates to the opalescence phenomenon of natural teeth. Incisal bluish-gray translucency rarely presents itself in a continuous and uniform manner, normally showing different patterns, depending on the shape of dentin mamelons.²¹

Reflected and refracted light highlights a high-translucency area between the enamel and the dentin, known as the "glass layer" or "high diffusion layer."²¹ This layer is visible in the stereomicroscope trans-illuminated sections as a grayish-white line that can be histologically identified as an area of high protein concentration in the matrix. This matrix, likely composed of enamelines or amelogenines, usually becomes degraded over time, even though a few teeth may still preserve features of strong light refraction and diffusion (Figure 11).¹³

Dentin

Dentin, however, can be considered the dental tissue of higher relevance when concerned with color.9,13 From an optical point of view, dentin is a low-translucency structure with various chroma and saturation variations. Dentin tubules are cylindrical structures that are spread throughout the entire depth of the dentin. Their course on the coronal portion commonly assumes the smooth curved shape of an italic "S," becoming even smoother near the root. The first convex curvature of this double-bent course begins at a right angle with the pulp surface and is oriented toward the tooth apex.

These tubules achieve an ending point at the dento-enamel junction. Near the incisal and cusp edges, the tubules are nearly straight. Throughout their length, they present relatively regular small secondary bending, with sinusoidal shaping.^{8,9} This dentin tubule arrangement enables the dentin to demonstrate selective light diffraction, as certain rays are reflected whereas others are absorbed. This phenomenon produces relative opacity, which is a special property of the dentin.⁸

As age increases, primary dentin begins to evolve or change. Originating secondary and tertiary dentins, which have different structures and compositions, affect the tissue's optical properties.⁴ In elderly patients, the reduction in the diameter of the dentin tubules causes progressive dentin sclerosis and high saturation.

These properties are influenced by hydration levels and orientation as well as the number and diameter of existing tubules (Figure 12). A cross-section of a tooth depicts a great amount of highamplitude dentin tubules oriented downrightly to the section frame. If light is directed straight into the center of a horizontal cut of the occlusal third, the light inside the dentin tubules will be traveling in the same direction, which will determine its translucency.¹²



Figure 12. Evidence of translucency/opacity of different thicknesses of dentin: 0.5 mm (A), 2 mm (B).

Further from the middle of the cut, the tubules change direction and reach the edge of the cut at nearly a right angle to the incidence of light, thereby decreasing its translucency. On a longitudinal section, their displacement will differ. Therefore, the perception of translucency will be changed. Thus, the orientation of the cross-section highly influences the study of the effect of light transmission through the dentin.

DISCUSSION

Translucency and Opacity of Composite Resins

Translucency may be one of the optical characteristics that is hardest to quantify in natural dentition, as it varies from individual to individual, many times even varying within the same person. Within the scope of composite resins, there are basically three variations that are divided by translucency and opacity levels. This allows the resins to perform a specific role during the layering process.²² Modern composite resins have different hues and opacities that imitate the chromaticity and translucency of enamel, as well as dentin, in the best possible manner.²³

Among commercial brands, there is no general agreement on translucency and opacity levels of composite resins, or their designations. This is also true regarding the literature on the topic, because there is no report to date of a terminology that standardizes these materials. Additionally, manufacturers provide very little or no information at all on the topic.²⁴

There are, however, terms such as "artificial dentin" and "opaque" that are typically used as synonyms

for high-opacity composite resins that present opacity and translucency close to that of natural dentin.²⁵ Other terms like "artificial enamel" or "body" are used to denote composite resins that present translucency and opacity, as well as chromaticity, similar to that of natural dental enamel.²⁵ There are also composite enamel resins, called translucent or incisal, which display higher than normal translucencies to help match hightranslucency areas in restorations. Recently, value-changing composite resins were developed to alter the luminosity of restorations.²⁶

Conversely, some authors categorize "body" resins as those that have intermediate translucency and opacity between the enamel and dentin. This allows clinicians to substitute both enamel and dentin in only one layer.²⁷ Therefore, the concepts of "artificial enamel" and "artificial dentin" refer to composite resins designed to replace the physical and mechanical, as well as the color and optical properties, of the tooth.²⁵ The greatest difficulties appear, however, when designating "artificial enamel" resins, as each variation displays specific individualized properties. These resins are usually designed to fulfill only a special area within the restoration. The following describes a classification of this group:

- 1. Artificial body enamel resins: keyed to the Vita shade guide, provide a chromatic basis to the restoration, responsible for generating color hue
- 2. Artificial translucent effect enamel: provides translucency especially to deep areas throughout incisal and proximal edges
- 3. Artificial milky-white semitranslucent enamel: used for creating halos, which are high-value areas with white effects
- Artificial value-modifying enamel: used as final layers in specific areas of the labial aspect, in order to enhance, to decrease, or to corroborate the preexisting natural enamel color value.²⁶

Recent reports, based on the aforementioned classifications, have shown that an ideal material for replacing dentin should present features such as uniform hue and opacity as well as a wide range of saturations.²⁸ These principles are based on a colorimetric study of contrast rates (CR) of human enamel and dentin, making it unnecessary to choose colors for the dentin, apart from the Vita A (A1 to A4) and B (B1 to B3) scales. Contrast rate fluctuation, within the same group, does not support using different levels of translucency and opacity for dentin resins (translucent, regular, and opaque dentins).28,29

In the same study, colorimetric and CR values for the enamel vary according to dental age, so owning a wide range of enamel composite resins to replace dental tissue is a must. In the case of young enamel, the choice of resins should rely on a low-translucency, milky white color. In the case of adult enamel, the resins should have a neutral color and medium translucency. For older enamel, resins should have high translucency and a yellow hue.^{28,29}

After choosing the correct resins, it is important to consider the thickness of the material to be layered during the application of the composites because the perception of higher chroma and opacity is related to an increase in thickness.¹² The handling of these layers is crucial for obtaining the desired chromaticity, translucency, and opacity.²³ When using a tworesin system (e.g., bichromatic technique: "artificial enamel" layer + "artificial dentin" layer), the material with less translucency (more opacity) and higher chroma may be used for the dentin, whereas enamel can be replaced by a more translucent resin. Compared with dentin and enamel resins, polychromatic techniques require effect resins that impart a more natural appearance to the restoration. Similarly, tints allow greater characterization of the restoration.

In the incisal third area, the restorative challenge is even more complex, as the range of translucency and opalescence is greater.³⁰ This area, seen mainly in young teeth, tends to be highly translucent and spreads from the mamelon outline to the incisal opaque halo. Using an opalescent material is often insufficient to properly replicate this phenomenon in restorations. Rather, a detailed analysis of the opalescent pattern is necessary. Therefore, each case should be undertaken utilizing a special approach, because opalescence presents high variability.³¹ It is also advisable to use a translucent composite termed "incisal" (high translucency at the incisal region) between the dentin and enamel layers in order to fill the areas between the lobes and the incisal halo.32

This layer's thickness is closely related to the amount of translucency required for the type of effect required. The hightranslucency resin layer will increase the perception of depth and will allow the restoration to demonstrate a more natural look. High-translucency resins should not be placed on the surface of the final layer of the restoration, however, because they tend to reduce restoration value and may potentially modify the chroma to some extent.



Figure 13. The translucent resins are more sensitive to differences in background color (black and white), changing their final perception.

It is important to note that the final outcome of a restoration is dependent on the thickness as well as the varying degrees of translucency and opacity of the several layers of composite. In comparing two dentin composite resin discs (e.g., 1 and 2-mm thick, respectively), both covered with 1 mm of enamel resin. the thicker dentin resin disc will present higher opacity, chroma, and value. However, in comparing two 1-mm thick dentin composite resin discs (e.g., overlaid with 1 and 2 mm of enamel resin), the latter presents lower value and chroma. Thus, regarding the final enamel layer, it is important to stress that a certain thickness should not be overlooked, as restorations with excessively high-translucency resins may become gray and demonstrate a lower value.

It is also important to remember that the thickness of composite resins determines the limit between translucency and opacity. When thicknesses of translucent chromatic composite resins increase, value decreases and chroma increases. By increasing the thickness of opaque composite resins, both value and chroma increase.¹² Chromatic perceptions of translucent structures are also closely related to the background used for its observation. The same translucent body will present differently when placed against black and white surfaces separately because of the background's selective absorption and reflection of particular wavelengths.³¹

When comparing composite resins and different colored backgrounds, white backgrounds tend to be the best choice for visualizing how a restoration will appear, as white enhances saturation and value, compensating for any chromatic shortage.¹² Translucent composite resins are more sensitive to a white background than opaque resins, as value and chroma are enhanced (Figure 13). Highopacity resins, or white dyes, have the ability to act as opacifiers, masking an undesired chromatic substrate and enhancing value.33 For the same material in various thicknesses, a slimmer piece of material will exhibit far less saturation and present a higher translucency than a thicker piece of material, thereby increasing the perception of the background.

The level of polish of a surface also changes the chromatic perception of composite resins and is inversely proportional to luminosity.³⁴ The more polished the surface, the larger the light transmission and, consequently, the less luminosity.¹² Conversely, lack of polishing causes the surface to become more reflective, making the restoration appear more luminous.³⁵

Another important aspect that deserves attention is photopolymerization, as light-curing may create optical changes. Normally, microfill resins are more translucent and possess higher chroma before polymerization. Unpolymerized hybrid composite resin is more opaque and has a relatively less intense chroma. Once polymerized, chroma and translucency enhance, value decreases, and the composite



Figure 14. Intrinsic opacity and thickness of achromatic enamel shades play a fundamental role in the modulation of the perceived chroma and value.

becomes slightly grayer.³⁶ The same phenomenon occurs on wet surfaces.

Additionally, dentists should consider the color of the underlying dentin when using chromatic enamel composite resins in order to avoid unwanted chromatic variations. The stratification of translucent chromatic enamel resin composites on the dentin occurs following a subjective mixture of colors. The resulting phenomena of the interaction of light and matter are of great importance for esthetic restorations, as they allow a faithful reproduction of the properties of natural dentition. However, inadequate analysis of the optical behavior of natural dentition may lead to failure of the restorative procedures.

The logical use of the different composite resins available and the

many variations in natural dentition make the restorative process much more efficient and predictable. For example, achromatic enamels of different opacities and increasing thickness, layered over a resin composite dentin substrate of equal opacity and chroma, will allow the perception of varying chromas and values (Figure 14). As the thickness increases (e.g., from 0.3 to 1.5 mm), more light is reflected and scattered throughout the achromatic resin substrate, thereby blocking the perception of the underlying dentin in various degrees.

T and P shades of a commercially available composite resin (Vit-lescence, Ultradent, South Jordan, UT, USA) will appear to have almost the same translucency at 0.3 mm of thickness while displaying nearly the same chroma and value. As thickness increases, P shades will block the transmission of light to a greater extent than T shades. The resulting effect is a comparatively lower chroma and higher value for the P shades in relation to the T shades of the same thickness. The reported mean refractive indices for enamel and dentin are 1.631 and 1.540, respectively.³⁷ The refractive index for T and P shades is 1.52.³⁸

It should be expected that the use of artificial enamels of the same refractive index as natural enamel would account for an ideal reproduction of the optical characteristics found in nature. Unfortunately, having the correct refractive index is only one of the many components necessary for rendering a lifelike restoration. Choosing artificial dentin and enamel composites of the proper opacities, as well as determining the correct thickness of each layer, is of paramount importance and should be just as significant as the use of refractive indices (Figure 15).

FINAL CONSIDERATIONS

Of all dental structures, enamel seems to be the optical entity that is most difficult to imitate. There is a common trend among practitioners to layer artificial enamel and dentin composites according to the actual thickness of the missing natural enamel and dentin. This proves futile, however, because no known composite behaves exactly



Figure 15. A, View of a defective class IV restoration. B, The artificial value enamel was applied to establish a lingual shelf. C, The artificial dentin should reproduce the dentin mamelons. To achieve a natural opalescent effect at the incisal third, a high-translucency resin was used. D, A final enamel layer is applied on the proximal and buccal surfaces to complete the restoration. E, Finishing and polishing can be achieved with various instruments. F, Completed restoration after tooth rehydration.

as natural enamel or dentin. A restoration created according to the "anatomic approach" might seem awkward at first, but it is well worth it. By using composite resins to imitate dental enamel, and by pursuing anatomic and meaningful principles to mimic the tooth's chromatic variability, the definitive restoration will be esthetically pleasing.

Currently, composite resin manufacturers are seeking ways to improve their optical properties to better mimic the natural properties of human dentition. For that reason, many state-of-the-art composite resins demonstrate translucency similar to that of the natural teeth. However, with a thorough understanding of light behavior and the optical properties of the dental structures, as well as utilizing state-of-the-art composite resin restoratives, clinicians should be able to provide patients with life-like, seamless restorations.

DISCLOSURE

The authors do not have any financial interests in the products used in this manuscript.

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This article is accompanied by commentary, "Direct Esthetic Restorations Based on Translucency and Opacity of Composite Resins," André V. Ritter, DDS, MS, DOI 10.1111/j.1708-8240.2010.00393.x.

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