Visualizing the Natural Dentition

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We look, but do we really see? When we look at anterior teeth, do we form mental visual images? Are we trained to process and interpret what we see into visual terms?

This article describes a method for visualizing a final restoration before it is begun. Visualization of natural tooth forms comes with its own vocabulary, which will act as our guide and serve as our interpreter when we communicate with the dental laboratory technologist and the patient (Figure 1). The final challenge is to convert what has been seen in nature to dental restorations, which is best accomplished when the clinician has a “vision” of the final creation based on an understanding of nature’s variations.

A restoration of an anterior tooth must satisfy the requirements of form, function, phonetics, and esthetics. It must be biologically compatible with the adjacent hard and soft tissues, while satisfying the expectations and desires of the patient. Although esthetic dentistry provides the clinician with latitude and creativity in serving the needs of the patient, the concepts of esthetics in dentistry echo traditional restorative tenets, i.e., beautiful esthetics imply an inherent sense of realism when reproducing natural teeth (Figure 2).

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Figure 2. To understand the physical characteristics of the natural dentition, one must learn how to visualize form, color, value, relative translucencies, and surface attributes in order to create natural appearing restorations.
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We begin by focusing our attention on the physical characteristics of the natural dentition and learn how to see the subtle nuances of color, relative opacities and translucency, form or shape, surface texture, and luster. Once one learns how to visualize natural teeth, then one can analyze the smile, facial make up, character of the patient, and psychological factors, all of which are essential to successful completion of esthetic restorations.

OPTICAL PROPERTIES OF THE NATURAL DENTITION

Natural teeth are translucent. Incident light is reflected off them, absorbed into them, and some is transmitted through them (Figure 3). All light entering a tooth is scattered or refracted, unlike window glass, which is transparent and allows light to pass through with little change. Opaque materials are impenetrable to light (i.e., the light that is not absorbed is reflected and scattered directly off the surface).

Translucency complicates our understanding of how to reproduce natural teeth, because it interacts with color, light and shadow, opacities, surface textures, and luster, both on and within the tooth. The degree of translucency depends on the structure and thickness of the enamel and dentin. Translucency alters the quantity and quality of the light that is reflected back to our eyes.

Translucency in teeth is influenced by the way light is reflected and refracted by the enamel rods and the condition of the dentin. Enamel and dentin have different optical densities; enamel is more than twice as translucent as dentin. When light passes through enamel and strikes an optically denser dentin, more light is reflected back. The color saturation and brightness of the dentin also influence the amount of light reflected (Figure 4).

Figure 3. When incident light strikes a tooth, a fraction of the light is reflected off the surface (specular and diffuse reflection) determining the degree of luster or gloss. The remaining light is absorbed, diffusely reflected, or diffusely transmitted through the tooth.

Figure 4. A longitudinal section of a maxillary central incisor. The dentin is three to four times as thick as the enamel and optically denser. The incremental lines of Retzius are apparent in the enamel.
Because dental porcelains do not have hydroxyapatite crystals, enamel rods, or dentinal tubules, the final ceramic restoration is an illusion of the way light is reflected, refracted, absorbed, and transmitted by a multi-layered, complex tooth structure (Figure 5).

COLOR PERCEPTION

The source of all color is white light. Light is electromagnetic radiation capable of stimulating the retina. The eye responds to light wavelengths between 380 and 760 nm. When an object reflects some wavelengths and absorbs others, the nature of the reflected rays determines the stimulus to the eye and the brain, and a color is perceived. If an object absorbs all light, it will appear black. If it reflects all light, it will appear white, provided a full spectrum of light is incident upon it.

The way in which tooth color is perceived depends on the following factors:

1. The quantity of light incident to it.
2. The spectral energy distribution of the light source (i.e., daylight or artificial light).
3. The sensitivity of the eye.
4. The visual interpretation of the perceived color.
5. The particular reflective, absorptive, and transmissive optical properties from different levels within the teeth.
6. The conditions under which the tooth is being viewed (i.e., in the oral cavity, wet or dry, angle and intensity of illumination, and the colors of the surrounding objects).

In teeth, the dominant wavelengths reflected are in the yellow-orange range.

Eye

The retina is the photosensitive layer in the human eye. It is the contact point between the light and the brain. The retina reacts to very minimal light impulses and can differentiate fine nuances of brightness and color.

The cell layer, which reacts to light stimulus, is made of rods and cones. The rods register the varying intensity of the light (i.e., they differentiate between brightness and darkness [value]). The cones react to the varying spectral compositions of light (i.e., they differentiate colors [hue and chroma]). The eye can differentiate up to 300 spectral colors. The cones require considerably more light to be activated compared to the minimal stimulus required by the rods. An eye contains approximately 100 million rods and 6 million cones.
Light and Shadow
Light is necessary to reflect color from a tooth; the less light, the less color. Light and shadow differ from each other not only in terms of brightness and darkness, but also in reflected color. When the lip covers the teeth, there will be changes in perceived brightness and color.

A dark or shadowed oral cavity creates sharp contrast to natural teeth and accentuates their brightness and form. The silhouette of the incisal edge and incisal embrasures are highlighted in front of a darkened mouth. The light reflecting off the heights of contours of teeth and the corresponding slight shadowing interproximally creates depth and enhances a 3-dimensional form.

Therefore, recognition of color is determined by the stimulus, the receptor cells of the eye, and the subjective response by the brain. Any distortion of the stimulus, receptor, or interpretation results in a misunderstanding of the real color. Color must be perceived, not merely seen.

It is an objective of tooth reproduction to control the external factors, such as the quality and quantity of incident light, as well as the conditions under which the tooth is being viewed. Training the eyes and brains of the entire dental team will result in predictable color reproductions for your patients.

QUANTIFYING COLOR
In 1898, A.H. Munsell quantified the three dimensions of color into hue, chroma, and value, which applies best to opaque, nontranslucent colors. This often creates much confusion when relating these dimensions to translucent teeth, especially concerning value (Figures 6 to 10).

Hue
Hue is determined by the wavelength of the stimulus and is designated by the convenient family of names we all recognize. The shortest wavelengths are called violet, and the longest are red. The sequence dictated by wavelength, from shortest to longest, is violet, blue, green, yellow, orange, and red.
A 38-year-old female patient. Notice the chroma and value changes within each tooth, as well as from tooth to tooth. The mandibular anterior teeth exhibit the same characteristics as the maxillary teeth.

**Chroma**
Chroma is the intensity, concentration, strength, or saturation of the hue. A change in chroma has a corresponding change in value. As the chroma intensifies the value decreases.

**Value**
Value is the amount of light that is reflected (or absorbed) by a tooth. It is the dimension of color that we perceive most easily.

Value is also called luminance. It is a measure of the quantity of light reflecting (brightness) from the tooth, not the amount of grey in the color. (Adding the color black to paint is a commonly used technique to decrease brightness in an opaque material, but that is different than controlling brightness in artificial, translucent teeth.)
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Figure 11. In the gingival one third of the central incisor the influence of the underlying dentin color is predominated, because the enamel thins to approximately 0.3 mm at the area of cementoenamel junction. The chroma and the degree of calcification of the dentin increases with age. The pink gingiva also affects the hue.

Figure 12. In the middle one third the enamel is approximately 1 mm thick. Due to its increased thickness, there is increased scattering of all wavelengths of light. The color saturation perceived is less than that in the gingival one third.

Figure 13. In the incisal one third there is high translucency at the incisal edge and proximal areas, because there is little, if any, dentin underlying the enamel. The enamel is approximately 0.9-1.2 mm thick at the incisal height of the dentin. Internal dentin mammelons appear as diffused feather-like structures, which may appear to be high in value, with hues ranging from pink to yellow-orange. The opalescent effect and halo are also apparent.

Figure 14. The maxillary central incisors viewed in total. In the middle one third Hunter-Schreger bands become more apparent as the teeth dehydrate.
The value (brightness) of a tooth is influenced by the chroma level, thickness and character of the enamel, surface texture, and surface luster. A change in value is accompanied by slight shifts in hue or chroma perceptions.

The perceived color of a tooth results from the combination of light directly reflected from the tooth surface combined with the light that has entered the tooth and internally has been refracted, and then reflected off the dentin back to the viewer. The dentin is the prime source of color and value. It determines the amount of light reflected back through the enamel. The enamel modifies the reflected light by its thickness and translucency (Figures 11 to 14).

Perception of tooth color is a complex phenomenon complicated by the lack of correlation between the hue, chroma, and value of natural teeth and available shade guides, as reported by Clark (1931), Sproull (1973), Lemire and Burke (1975), and Miller (1981).  

**LIGHT EFFECTS**

**Fluorescence**

Fluorescence is a form of photoluminescence, whereby radiant energy below the visible spectrum (ultraviolet) is absorbed by an object, which then emits the light energy within the visible spectrum.  

Natural and many artificial light sources have ultraviolet components. When exposed to these light sources, the fluorescence of natural teeth gives them the quality of “vitality.”
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Opalescence
Opalescence is the light effect that occurs when light disperses and refracts on microcrystals or colloidal inclusions. This causes short wavelengths (blue) to be scattered and longer wavelengths (red/orange) to be transmitted.

Enamel is a translucent, almost transparent, colorless entity. The rods within the enamel and the spaces between them cause the light to be scattered. Opalescence will give a tooth a bluish translucency, particularly at the incisal edge, when viewed from the labial aspect. The transmitted light will give the tooth a reddish/orange appearance, when viewed from inside the mouth. That is why the enamel appears bluish at the incisal edge even though it is colorless. There are no blue particles in the enamel. It is strictly a light effect (Figures 16 to 19).

Enamel can appear fairly white over the remainder of the tooth due to the following possible factors:

1. An increased scattering of all wavelengths of light, short and long, will make enamel appear white or pale blue.
2. The difference in optical density between enamel and dentin reflects more light off the dentin surface. Light reflection off dentin in young teeth, in particular, is more intense because the dentin is high in value and lacking color saturation.
3. When teeth dehydrate, air replaces the water between the enamel rods, changing the refractive index and making the enamel appear opaque white.

4. The strong fluorescent quality of dentin increases the amount of light being emitted from it. Therefore, even though the enamel is highly translucent and is colorless, it can appear bluish toward the incisal edge (no dentin underlying), because of the opalescent effect. The remainder of the tooth appears white.

**Halo**

The appearance of a slightly opacified border at the incisal edge of the tooth, framing the translucency, is attributable to near total light reflection. It is called the halo.

The light entering the incisal edge is reflected toward the inside of the tooth. Little or no light is transmitted through in this case, because of the angle of the lingual surface at the incisal edge (Figure 20).

The yellow–orange color often apparent in this halo is due to light reflecting from the dentin, off the lingual surface of the incisal edge, and through the labial incisal edge.

The width of the halo varies with the angle of the incisal edge. The halo creates contrast between the shadowed (dark) oral cavity and the bluish translucency in the incisal edge. Without it, the incisal edge has less definition and blends more easily into the background.

**Figure 20.** The incisal halo appears to be a slightly opacified edge because there is little or no light transmission. The reflected yellow–orange color from the dentin often gives the halo a slight coloration.
SPECIAL CONSIDERATIONS

Surface Texture and Luster
The surface topography of teeth alters the quantity and quality of light reflected directly off them, as well as that which penetrates the surface. The topography and luster of a tooth affects perceived hue, chroma, and value.

The luster (gloss) on the surface is related to the relative amounts of specular and diffuse reflection. A smooth surface, like a mirror, will exhibit specular (regular) reflection without diffusion. An irregular or rough surface will exhibit diffuse reflection, scattering the light in many directions.

The surface of young teeth is covered with rod ends and perikymata. Perikymata are transverse, wave-like grooves believed to be the external manifestations of the striae...
of Retzius.\textsuperscript{18} They are parallel to each other and to the cemento-enamel junction. These incremental lines are the successive apposition of layers of enamel during crown formation. They represent variations in structure and mineralization, either hypomineralized or hypermineralized.

Very fine white bands may be apparent in the tooth. These become more distinguishable as the tooth dehydrates. The change in the direction of the enamel rods is responsible for the appearance of these Hunter-Schreger bands (Figures 21 to 26).\textsuperscript{18}

As teeth age, the surface wears and the perikymata gradually disappear. This first occurs on the heights of contour; shallow or concave areas often retain a rough or stippled surface. Eventually, all the surface texture may be lost. The tooth surface will be smooth with either a high or dull luster (Figures 27 and 28).

\textbf{Figures 25 and 26.} The central incisors have a stippled surface texture. The cuspid generally exhibits a smoother surface, higher chroma, and possibly a different hue than the central incisors. All the teeth have a high luster.

\textbf{Figures 27 and 28.} These teeth are relatively smooth with a few surface cracks in the enamel. The teeth have a low or dull luster. This 28-year-old female patient exhibits the classic interdental contacts, embrasures, and gingival architecture.
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Figures 29 and 30. An example of an older dentition. Gingival recession exposes the roots of the teeth. Less translucency is apparent in the incisal one third because the enamel is worn to expose the dentin. The color of the reparative dentin will influence the perceived color in the incisal one third, when viewed from the labial. Cracks are the outer edges of lamellae and are apparent on all teeth, of all ages, and on all surfaces. Most cracks appear to be colorless, but some pick up stain and appear a variety of colors.
The gingival embrasure is determined by the gingival proximal contour of the tooth and the root proximity. The gingival embrasure is filled with the papilla. If a space exists, this can affect phonetics, food impaction, and detract from esthetics.

The labial and lingual embrasures are viewed from the incisal edge and are simply formed by the interdental contact and the transitional line angle. The form of the proximal aspect of the teeth dictates the contact area and establishes the 3-dimensional appearance of the tooth arrangement.

**CONCLUSION**

We must learn to form mental visual images of natural teeth if we are to successfully communicate what we see. We have focused our attention on the physical characteristics of the maxillary anterior teeth. It is the challenge of the dental team to use their creativity in providing a beautiful esthetic restoration that attempts to reproduce nature (Figure 31).

**REFERENCES**


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Figure 31. The beauty of nature.
Figure 1. Single tooth replacement abutment seated on osseointegrated implant.

Figure 2. Labial view of completed implant crown.