Beyond Visible: Exploring Shade Interpretation

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Over the last decade, there has been profound interest in newer photographic illumination techniques for increasing the accuracy and objectivity of dental shade evaluation and laboratory communication. To minimize errors in clinical practice, reproducible imaging modalities and objective image analysis methods are needed.

Despite modern technological advancements in the field of color management, shade matching of natural anterior teeth remains a formidable task that often results in an uncertain outcome. Until recently, delivering predictable results was solely dependent on the clinician's skill and the knowledge base of the restorative team.

This article proposes a novel approach for improving the accuracy of dental shade interpretation and communication. This protocol is based on cross-polarization imaging modalities, fluorescence evaluation protocols, and previsualization of the final shade of unsintered ceramic. Ultimately, this technique assists the dental team in their daily task of getting the color right the first time.

PHOTOGRAPHIC PROTOCOL

Cross Polarization

The evaluation and selection of tooth shade is typically based on direct visual assessment and ordinary flash photography, both of which are compromised by viewer subjectivity. Standard flash photography possesses inherent limitations because specular reflections (ie, glare) do not permit consistent visualization of subtle enamel variations and tend to blur distinctions between surface and subsurface dental characteristics (Fig 1). As proposed by Vanini,[1] the use of reflective cross-polarized light photography mitigates glare and allows unobstructed visualization of surface and subsurface enamel characteristics via a nondestructive contrast

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Fig 1 Minimally invasive feldspathic veneer on the maxillary left central incisor and implant-supported metal-ceramic crown on the left lateral incisor photographed using standard flash photography, which does not allow consistent visualization of enamel variations.

Fig 2 Reflective cross-polarized light photographic equipment.

Fig 3 Cross polarization eliminates the superficial influence of value.

mechanism (Fig 2) (polar_eyes, Emulation, Frankfurt, Germany).

By eliminating the superficial value influence, a high-contrast/hypersaturated chromatic map can be immediately obtained (Fig 3). This map enables easy and accurate selection of the base dentin shade. By spatially visualizing subsurface dentin histoanatomy,[2] the stratification techniques can be significantly improved during the application of esthetic biomaterials.

Fluorescence

Natural teeth emit a strong whitish-blue light under ultraviolet (UV) radiation.[3] The extent of the effect of fluorescence upon color perception under ambient light conditions is debatable[4]; nonetheless, a dental restoration must provide optimal visual integration under multiple lighting conditions, including UV-rich environments such as nightclubs (Fig 4). The fluorescence of natural teeth can be recorded with a customized fluorescence macro flash (Fig 5) (fluor_eyes, Emulation) developed by the authors. This macro flash provides an ideal excitation wavelength of 365 nm[5] for UV irradiation to record the fluorescence of natural teeth and/or dental ceramics and composite resins. This effect can be easily achieved using a shutter speed of 1/125 seconds, aperture of f22, and ISO of 200 to 400, resulting in images of high fidelity with proper depth of field and eliminating the need for cumbersome and substandard UV light setups (Fig 6).

Fig 4 Dental restorations must blend with the natural dentition under multiple lighting conditions, including UV-rich environments.

Fig 5 Customized fluorescence macro flash.

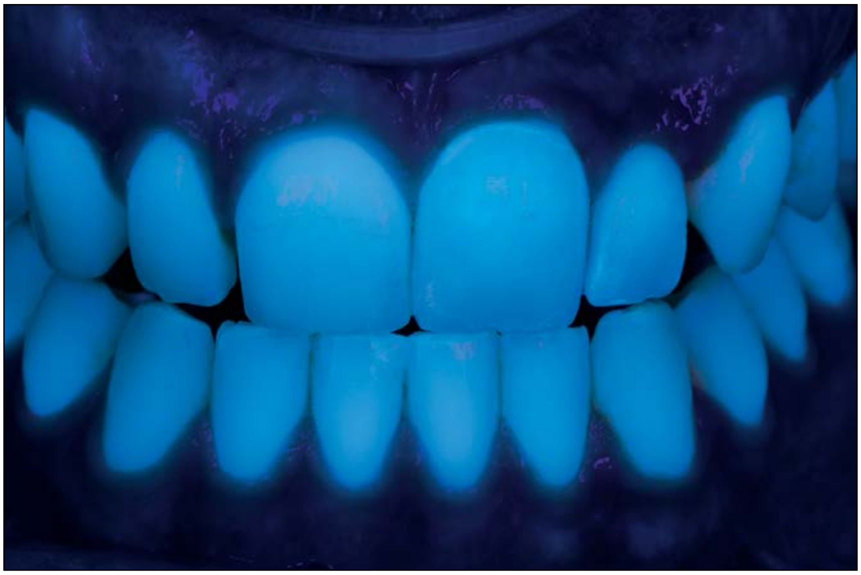


Fig 6 Intraoral image captured using the fluorescence macro flash.

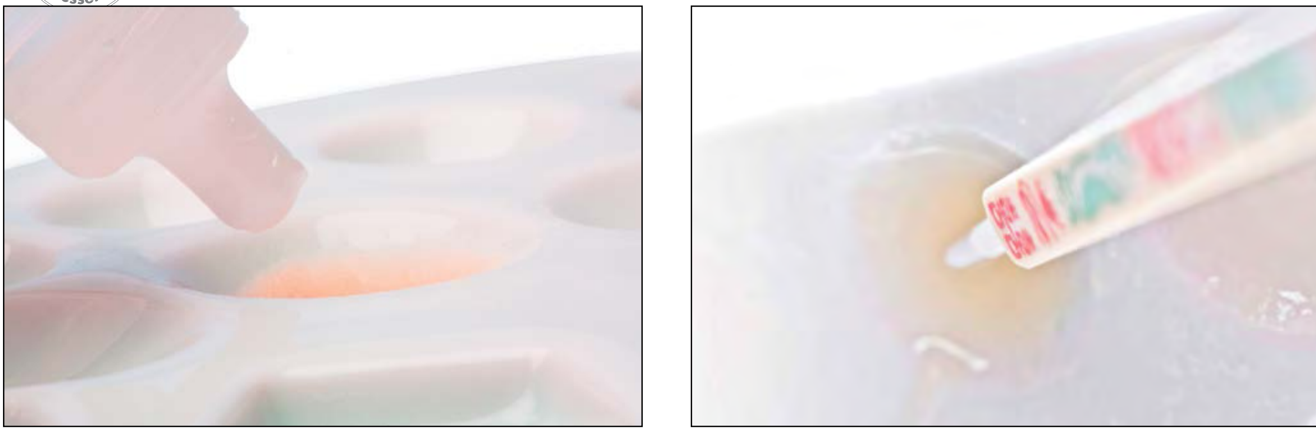
7a 7b 7c

Figs 7a to 7c Removal of organic coloring dyes from the standard dentin and enamel powders. *(a)* A small quantity of dentin ceramic should be placed on a reversed standard firing tray. *(b)* Alternatively, a specially designed tray can be used with an entire 20-g bottle. *(c)* The powders are heated at a low heat rate of 30°C/min and a high temperature equal to that of the manufacturer's recommended start temperature for approximately 5 minutes without vacuum.

PREVISUALIZATION TECHNIQUE

In the early 1980s, Riley et al[6] proposed the use of a liquid organic binder mixed with dental ceramic to achieve the previsualization of the color of the unsintered ceramic. The working principle is based on the consolidation of the refractive indexes of both the ceramic particles and mixing medium, allowing the passage of light at a constant velocity[7] and achieving simulation of the sintered ceramic state. Unfortunately, commercially available products based on this concept proved to be mild irritants and in some instances even possessed hazardous chemical compositions, failing to provide an accurate and stable refractive index. Recently, a new, non-irritant liquid was developed (visual_eyes, Emulation) to provide optical contact resembling the collimated refractive index of a number of sintered dental ceramic samples from various manufacturers spanning a range of coefficients of thermal expansion (CTEs). This liquid also accounts for the inherent reduction of the refractive index of a sintered ceramic due to natural air inclusions, providing close shade congruity between the sintered and unsintered ceramic.

Most manufacturers add organic food coloring to the dentin and standard enamel powders. These organic dyes must be removed before shade previsualization of the unfired ceramic.[8] This can be easily done by placing a small quantity of dentin ceramic on a reversed standard VITA firing tray (Fig 7a) (Vita Zahnfabrik, Bad Säckingen, Germany) or by emptying an entire 20-g bottle into a specially designed tray (Fig 7b) (visual_eyes_tray, Emulation). To neutralize the organic dye, the ceramic needs to be heated to a maximum temperature equal to the regular pre-dry temperature as recommended by the manufacturer. The new pre-dry temperature should be reset to 100°C lower than the former pre-dry temperature (now the new high temperature). No particular heat rate is required, but it is advisable to reduce the heat rate to 30°C per minute without vacuum for 5 minutes (Fig 7c). The newly prepared dentin and standard enamel powders can be immediately mixed with the previsualization liquid in a ratio of 15 drops to 1 g of ceramic powder (Figs 8a and 8b). The remaining ceramic powders are typically free of organic dyes and can be used without further preparation. This technique may be used with any ceramic system, regardless of the fusing temperature or CTE (Fig 9).



Figs 8a and 8b The newly prepared dentin and standard enamel powders can be immediately mixed with the previsualization liquid to reveal the final color prior to sintering.

Fig 9 The previsualization technique can be used with any ceramic system.

CASE REPORTS

Case 1: Masking Discoloration

In cases of discoloration requiring minimally invasive, bonded ceramic restorations, achieving balanced opacity of the dentin ceramic is of particular importance. Insufficient opacity will fail to mask the underlying discoloration, whereas excessive opacity will result in an unnatural appearance. The limited space for the restoration challenges the ceramist to find the ideal opacity-thickness ratio.

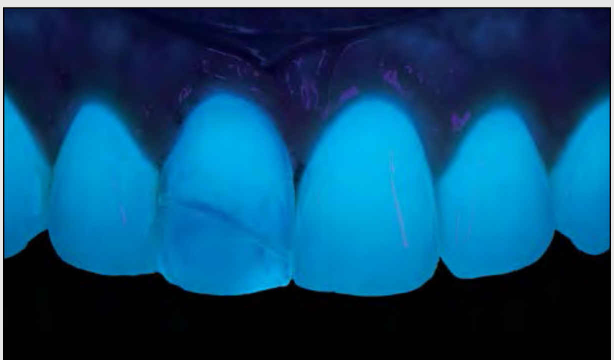
In this case, the patient presented with a maxillary right central incisor that had suffered traumatic fracture during early childhood. At the time of the accident, the incisal fragment was recovered and adhesively attached, leaving a clearly visible demarcation line. Reflected, cross-polarized, and fluorescence photography was used to analyze the defect (Figs 10a to 10d).

The previsualization technique was used to check the opacity of the dentin ceramic (Creation Classic, Willi Geller Creation, Meiningen, Austria) through direct application onto the prepared tooth (Fig 11a). The result was then examined using reflected, cross-

CASE 1

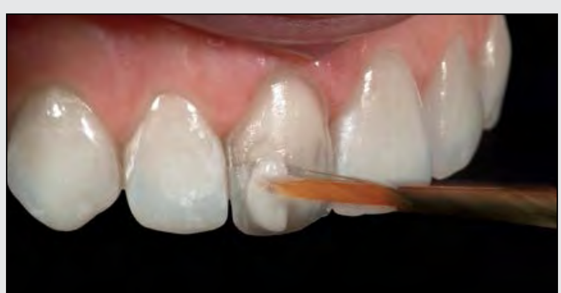

10a


10b


10c


10d

Figs 10a to 10d Reflected, cross-polarized, and fluorescence photography used to analyze the demarcation line in case 1.


11a


11b

Figs 11a and 11b The previsualization method was used to check the opacity of the dentin ceramic.

12a

12b

12c

12d

Figs 12a to 12d Final result of treatment. The restorations showed optimal integration with excellent optical properties.

polarized, and fluorescence photography. The opacity of the chosen dentin powder (A1) was incrementally increased through addition of opaque dentin of the same shade until the masking power and fluorescence were deemed appropriate (Fig 11b).

The precise definition of the basic shade, opacity-thickness ratio, and fluorescence generated the necessary masking power while also maintaining a satisfactory degree of visually perceived depth (Figs 12a to 12c). From a normal speaking distance, the results showed optimal visual integration (Fig 12d).

Case 2: Incisal Shade Characterization

The patient presented with abfraction in the labiocervical region of both maxillary central incisors (Fig 13). Analysis of the fluorescence revealed no abnormalities in the remaining dentition (Figs 14a to 14c).

A full photographic protocol was carried out to analyze the nature of the abfraction more closely (Figs 15a to 15c). The protocol was repeated with the presence of a shade tab of adequate value (Figs 16a and 16b), which revealed the documented fluorescence

CASE 2

13

14a

14b

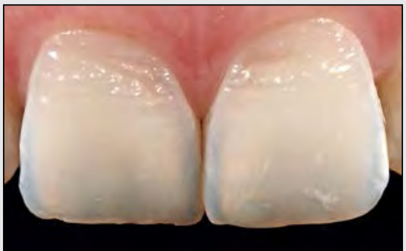
14c

Fig 13 Preatreatment view of case 2 showing the abfraction in the labiocervical region of both maxillary central incisors.

Figs 14a to 14c Analysis of the fluorescence revealed no abnormalities in the remaining dentition.

deficiency of some shade guides (Fig 16c).[9] To address this issue, an acrylic resin shade guide (PE Hard Acrylic Shade Guide, Ivoclar Vivadent, Schaan, Liechtenstein) was used to serve as a fluorescent intensity standard (Fig 17). In this way, the required degree of fluorescence of the dentin powder can be compared, regulated, and adjusted. If increased opacity is needed to elevate the reflectivity and value while maintaining the basic shade, the fluorescence can be intensified using opaque dentin (Fig 18). If increased translucency is needed to reduce reflectance and increase absorption, thus lowering the value while maintaining the basic shade, HT and SI powders (Creation Classic) can be used to maintain the desired fluorescence (Fig 19). This may be necessary with dark shades since they typically present with lower fluorescence.[10]

The platinum foil technique was chosen to fabricate two minimally invasive and two noninvasive feldspathic veneers (Fig 20).[11] To achieve precise incisal characterization, the core was reduced incisally after the first bake to perform the envelope technique.[12] The effect modifiers were mixed with the optical contact liquid to achieve previsualization and customize the incisal aspect (Figs 21a and 21b) in accordance with the photographic data. The fluorescence was also checked before sintering using the fluorescent intensity standard and fluorescence photography (Fig 22).

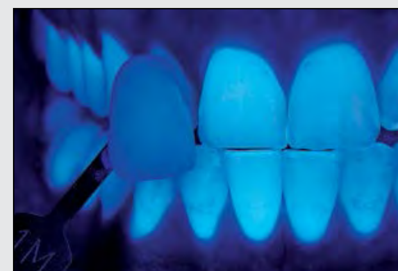

15a


15b


15c


16a

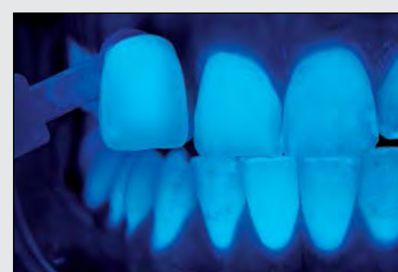

16b


16c

Figs 15a to 15c Reflected, cross-polarized, and fluorescence photography.

Figs 16a to 16c The photographic analysis was repeated with the presence of a shade tab. Note the shade tab's lack of fluorescence.

Fig 17 Acrylic resin shade guide used as a fluorescent intensity standard.


17

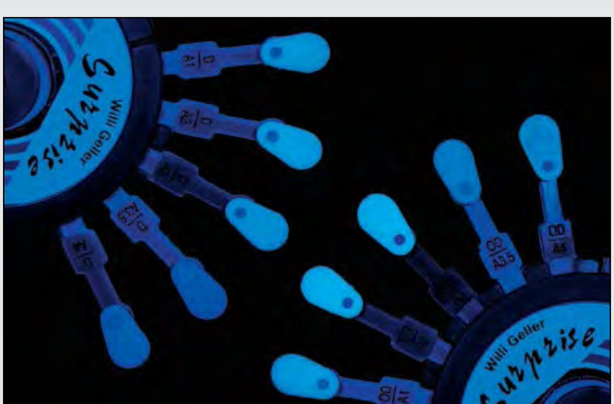


Fig 18 The fluorescence of the dentin powder can be compared, regulated, adjusted.

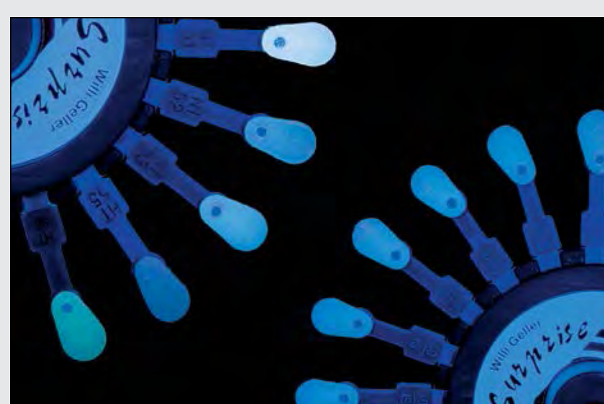
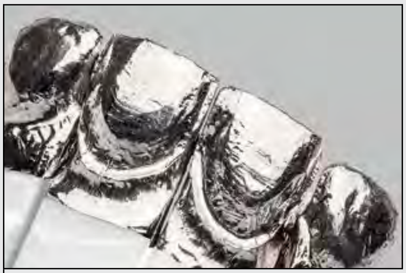


Fig 19 The translucency can also be adjusted.



20

21a

21b

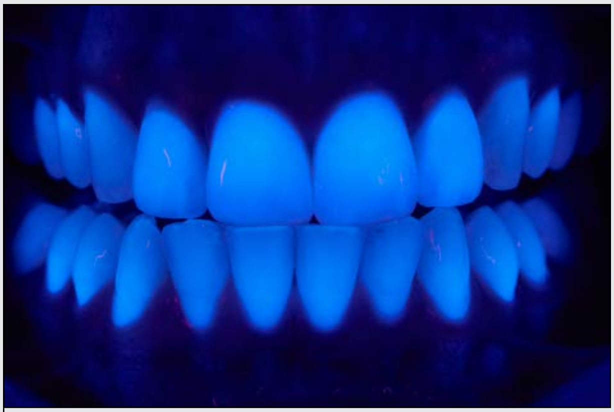
22

Fig 20 The platinum foil technique was used to fabricate two minimally invasive and two noninvasive feldspathic veneers.

Figs 21a and 21b Incisal characterization.

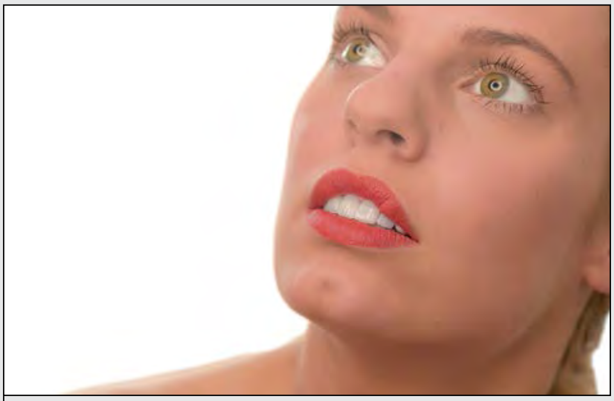
Fig 22 The fluorescence was evaluated before sintering using the fluorescent intensity standard.

23a



23b

23c



23d

Figs 23a to 23d Final result. Precise emulation of incisal characteristics resulted in a natural look.

CASE 3

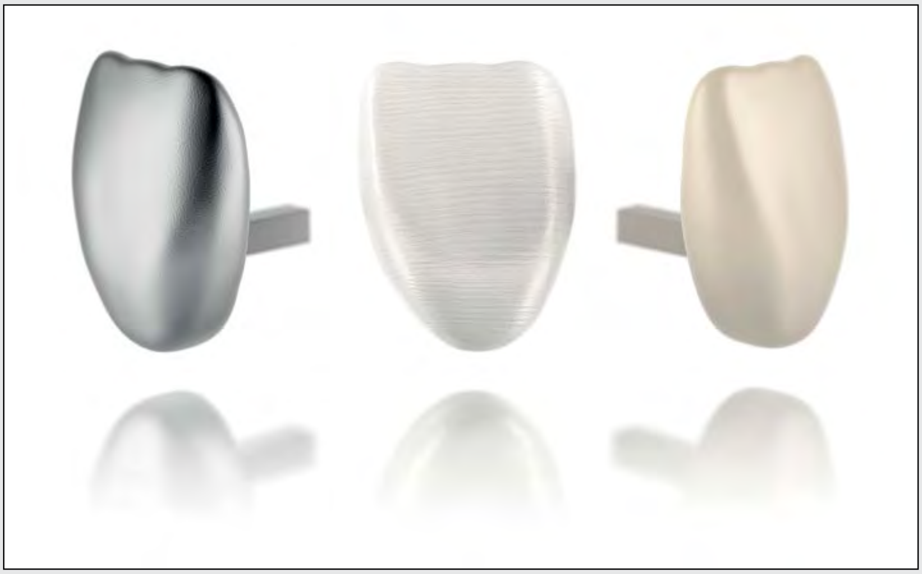


Fig 24 The visual_eyes_shade_tab used to aid the shade-estimating process for case 3.

The precise emulation of the incisal characteristics under visible and invisible illumination resulted in a natural, dynamic appearance independent of the lighting condition and angle of incident (Figs 23a to 23d).

Case 3: Shade Estimation

The most useful application of the previsualization technique is the composition of individual shade mixtures on site during the shade appointment. The vast majority of standard shade guides involve free-standing ceramic shade tabs. The lack of a framework substrate (metal, zirconia, lithium disilicate) and the absence of any form of standardization among ceramic manufacturers contribute to the inaccuracy and unpredictability of these products. For this reason, Hegenbarth[13] proposed the use of a custom shade guide tab using the same ceramic system and framework material that would be used for the definitive restoration. The fabrication of such a shade guide, however, proved to be both expensive and time consuming; thus, the concept faded into obscurity despite its merits. Now, a new premade shade tab for pressable ceramics has been developed (visual_eyes_shade_tab, Emulation) and is available in nonprecious metal, zirconia, or wax (Fig 24). In conjunction with the previsualization technique, the ceramist can now determine the correct shade mixture, opacity, and fluorescence of the composition immediately in the mouth, before sintering (Fig 25a). The ability to use the same substrate material that will be used for the final restoration is crucial to simulating the final result. Zirconia, for example, has a comparatively high index of refraction of 2.3, which gives this material its high reflectance and often results in the typically bright look of such restorations. Veneering ceramics for zirconia-based frameworks differ in chemical composition from those used for metal ceramics.[14] There is also great shade variation among the zirconia veneering ceramics of different manufacturers.[15] The


25a


25b


26

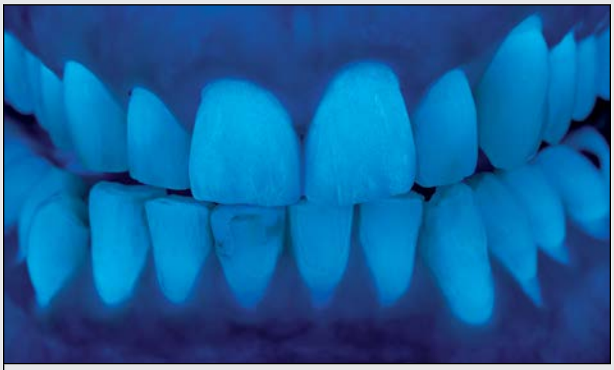
Figs 25a and 25b The shade tab and previsualization technique were used to determine the correct shade and dentin opacity directly in the mouth before sintering.

Fig 26 The same substrate material was used for the shade tab as for the final restoration.

Figs 27a to 27d Final result showing the excellent shade match under various lighting conditions.


27a


27b


27c


27d

influence of such factors is difficult to estimate and can only be evaluated once the restoration has been fired or by using the previsualization technique, ideally in conjunction with cross-polarized (Figs 25b and 26) and fluorescence photography. The application of this concept results in a predictable shade match under reflected (Fig 27a), cross-polarized (Fig 27b), and UV illumination (Fig 27c), which is reflected also in the patient's smile (Fig 27d).

CONCLUSIONS

Previsualizing the ceramic shade composition before sintering, when modifications are still possible, offers a significant treatment advantage. The use of reflected, cross-polarized, and fluorescence photography provides the ceramist with the ultimate roadmap to achieve predictable shade matching, regardless of his or her technical skill and experience. The previsualization technique promotes predictability and consistency over intuition and guesswork and lessens the daily challenge of getting the shade right the first time.

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