



Color Selection in Operative Dentistry

3

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3.1 Illumination

As previously explained in Chap. 1, different light sources contain different wavelengths. This means that the color of the same object can be perceived differently under different illuminations.

People are usually exposed to light sources during their routine: daylight, shade or cloudy sky, fluorescent light, incandescent light, etc. These different light sources have different color temperatures. The color temperature is related to the color appearance of the light emitted by the light source.

3.1.1 Color Temperature

The color temperature is expressed in Kelvin (K). Color temperatures over 5000 K are called cool colors (blueish white), while lower color temperatures are called warm colors (yellowish white). Daylight, fluorescent light, incandescent light, for example, are warm colors, while the shade and cloudy sky are cooler colors (Fig. 3.1). Thus,

the same object can have its color distorted when exposed to light sources with different color temperatures.

While low light intensity can affect hue perception, the high light intensity can cause glare and result in fatigue to the eyes. In Dentistry, the recommended standard for color selection is a color temperature of 5500 K, which corresponds to the ideal natural daylight. However, natural light conditions vary from 3000 to 8000 K depending on the time (sunrise/sunshine) and the weather (sunny/cloudy). A practical way to have more color matching success regardless of the natural conditions is to use a standardizing daylight lamp in the dental office. However, portable light-correcting devices are also available to assist chairside shade matching.

3.1.2 Light-Correcting Devices

Portable light-correcting devices were designed to assist chairside shade matching in Dentistry (Fig. 3.2). These devices consist of a ring with a window-hole that enables viewing the patient's teeth. The ring is attached to an ergonomic handle that allows the dentist to get very close to the patients' teeth. Inside the window-hole, LEDs simulating different illumination conditions. The different LEDs are disposed of so that the teeth are illuminated equally from all directions to avoid glare, distortion, and reflection.

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Color Temperature [K]

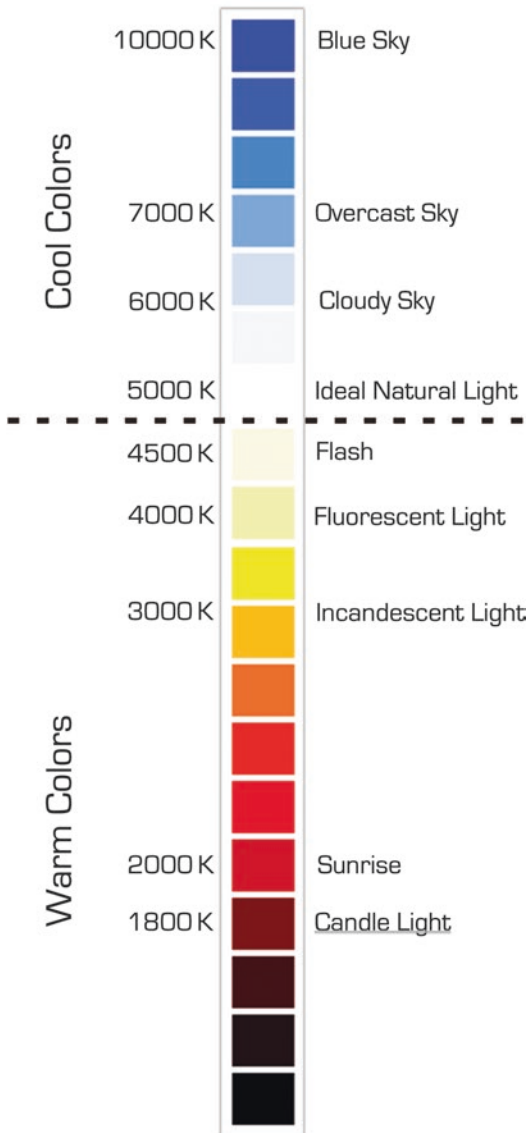


Fig. 3.1 Cool colors and warm colors: color temperature of different light sources

Both devices contain LEDs with 5500 K color temperature simulating the outdoor daylight. Other LEDs simulate indoor ambient light from halogen and incandescent light sources.

These devices also have a polarizing filter that eliminates reflection and enhance the visualization of internal details of the teeth (Fig. 3.3). It is

worthwhile to mention that the use of a polarizing filter does not help shade matching. But it can help achieve shade matching by identifying internal details of the teeth for future characterization and layering [1, 2].

3.2 Color Selection Methods for Composite Restorations

Color selection is the first step before restoring a tooth. Different methods are described in the literature to select color in Dentistry. These methods are mainly categorized as subjective methods (more commonly known as visual methods) or objectives methods. The most traditionally used method is the visual analysis of color.

3.2.1 Visual Methods

The color of teeth is mainly subjectively measured by the visual comparison method using a shade guide tab, or material increments placed close or onto the tooth surface [3].

3.2.1.1 Using Shade Guides for Ceramics

The *Vitapan Classical* shade guide (VITA Zahnfabrik) is the most used shade guide in worldwide clinical practice. Introduced in 1983, it is based on VITA previous shade guide, *Lumin-VACUUM* (which was introduced in 1956). It has 16 different acrylic shade tabs empirically organized by the manufacturer (Fig. 3.4). Each tab has cervical, body, and incisal colors over an opaque background, and it is identified and named according to the body shade. The color range is divided into four different hue groups designated by *A*, *B*, *C*, and *D* letters, representing reddish–brownish for *A* hue, reddish–yellowish for *B* hue, grayish for *C* hue, and reddish–gray for *D* hue. For each hue group, there are different tabs differentiated by an Arabic number ranging from 1 to 4, with different Chromas and values. The higher the number, the higher Chroma and the lower the value. The tabs of the Vita Classical shade guide can also be repositioned in value

Portable Light-Correcting Devices

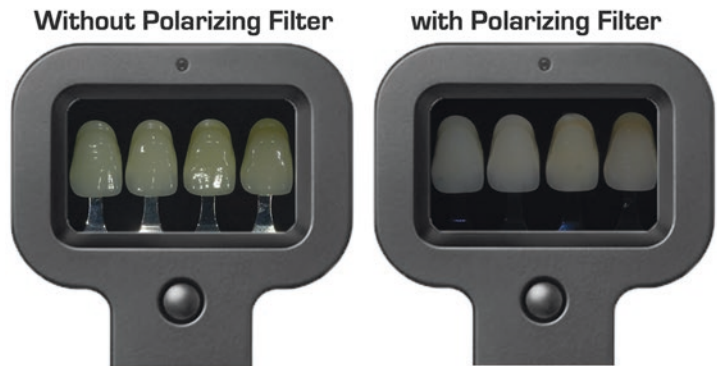


Fig. 3.2 Portable light-correcting devices: Smile Lite (Styleitaliano) and Rite Lite (Addent)

Fig. 3.3 Details' perception using light-correcting devices with and without polarizing filters

Polarizing Filters

Smile Lite (Smile Line)



Rite Lite II (Addent)

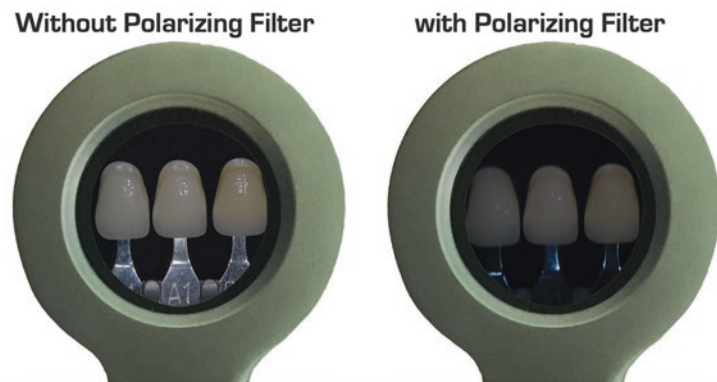




Fig. 3.4 Ceramic shade guides: *Vitapan Classical* (VITA Zahnfabrik)



Fig. 3.5 Ceramic shade guides: *Noritake* (Kuraray Noritake)

order: B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, C4. In this way, the tabs will be reordered from the brighter to the darker shade.

There are other shade guides designed for ceramic restorations that follow the *Vitapan Classical* color distribution concept. The *A-D* shade guide (Ivoclar Vivadent) is the common color standard for Ivoclar Vivadent ceramics (Fig. 3.5). It also has 16 different acrylic shade tabs. The *Noritake* shade guide (Kuraray Noritake) is the color standard for Noritake ceramics (Fig. 3.6). It contains 20 different shade tabs, 16 based on *Vitapan Classical* color concept

and 4 original shade tabs (NW0, NW0.5, NP1.5, and NP2.5). The NP hue corresponds to the slightly reddish shades than VITA A hue. The NP1.5 Chroma is between A1 and A2 shades while the NP2.5, between A2 and A3 shades. The NW hue was created for whiter teeth (low Chroma and high value) and its two tabs were design to match adjacent bleached teeth.

The *Toothguide 3D-MASTER* shade guide (VITA Zahnfabrik), however, is shade guide already structured on Value (Fig. 3.7). The *Toothguide 3D-MASTER* shade guide is based on the principle of choosing color in three quick steps. First, selecting an appropriate value (from 1 to 5)

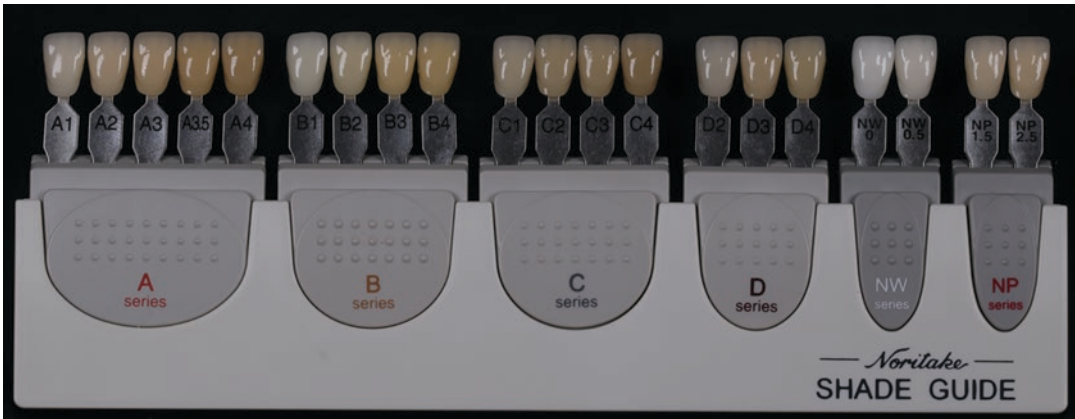


Fig. 3.6 Ceramic shade guides: A–D (Ivoclar Vivadent)



Fig. 3.7 Ceramic shade guides: *Toothguide 3D-MASTER* shade guide (VITA Zahnfabrik)

according to the patient’s tooth. Then, selecting the corresponding Chroma into that value. In this step, it is recommended to choose the middle hue group (M) to determine the Chroma (from 1 up to 3). Finally, choosing the final color, checking whether the patient’s tooth is more reddish (R) or more yellowish (L) in comparison to the guide tab. In order to simplify the color selection of *Toothguide 3D-MASTER*, the *Linearguide 3D-MASTER* shade guide (VITA Zahnfabrik), was introduced in 2008 (Figs. 3.8, 3.9, 3.10 and 3.11). It contains the same

shade tabs but with simplified presentation and a two-step shade matching procedure: only 6 (step 1) and up to 7 (step 2) linearly arranged tabs instead of 29 tabs presented at the beginning of a three-step procedure with *Toothguide 3D-MASTER*.

3.2.1.2 Using Shade Guides for Composites

The majority of resin-based composites colors are named based on the *Vitapan Classical* color distribution concept. However, several other



Fig. 3.8 Ceramic shade guides: *Linearguide 3D-MASTER* shade guide (VITA Zahnfabrik)



Fig. 3.9 Ceramic shade guides: first step of shade determination using the *Linearguide 3D-MASTER* shade guide. Six linearly arranged shade tabs that indicate the value (0M2–5M2)



Fig. 3.10 Ceramic shade guides: second step of shade determination using the *Linearguide 3D-MASTER* shade guide. Taking the linear arranged group of tabs with same value from the shade guide

resin-based composites are non-VITA-based, having other color concepts and different nomenclatures. Shade tabs made from the same material used in the restoration are necessary to avoid color mismatch. Despite the same nomenclature, the color match is frequently not acceptable



Fig. 3.11 Ceramic shade guides: second step of shade determination using the *Linearguide 3D-MASTER* shade guide. Linear arranged group of tabs with the same value (2), but different hue and Chroma

between the color of a *Vitapan Classical* tab and the correspondent resin-based composite. This color mismatch is mainly explained due to the translucency difference between the different materials [4].

For this reason, several resin-based composite systems have their shade guide. Differently from color shade guides made for ceramic restorations, their tabs have similar translucency of the respective composite restorative materials. There are different tab shapes and thicknesses with the color concept based on the individual restorative system's color availabilities (Figs. 3.12, 3.13, 3.14, 3.15, 3.16, 3.17 and 3.18).

3.2.1.3 Using Personalized Shade Guides

When a resin-based composite system does not have its shade guide, dentists may craft their personalized color guides [5, 6]. Based on the selected mastered layering concept of the dentist, the shade tabs can be monochromatic or have multiple layers. These personalized tabs can be craft using a polyvinyl siloxane mold, with ceramic shade tab shape, e.g., from *Vitapan Classical* (Fig. 3.19). There are some commercially available custom-made shade guides as *My Shade Guide* (SmileLine) (Fig. 3.20) or even from the resin-based composite system itself as the Estelite composites (Tokuyama) (Fig. 3.18).

3.2.1.4 Using Increments of Composites

The majority of restorations do not occupy an extensive area on the tooth. The placement of

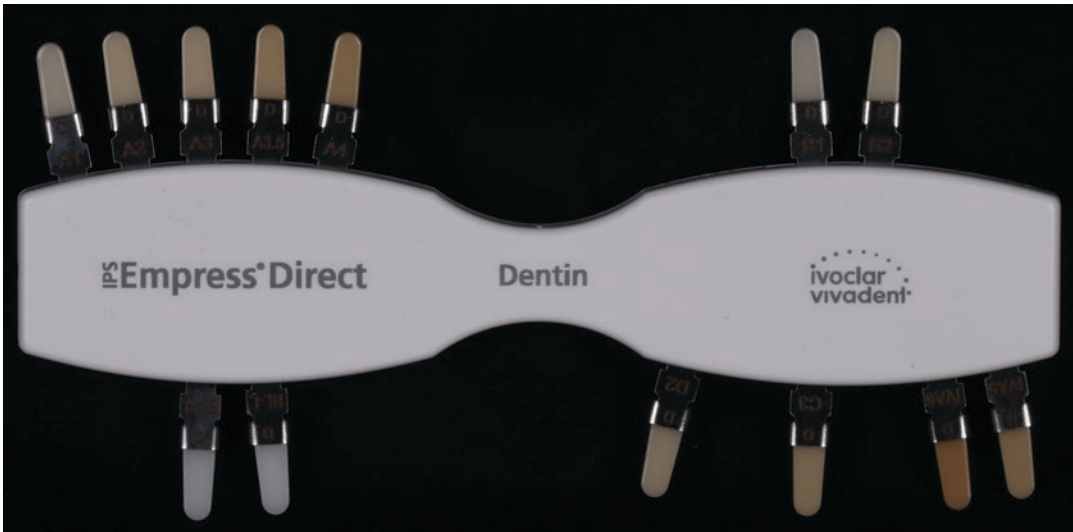


Fig. 3.12 Composite shade guides: dentin shades of IPS Empress Direct system (Ivoclar Vivadent)

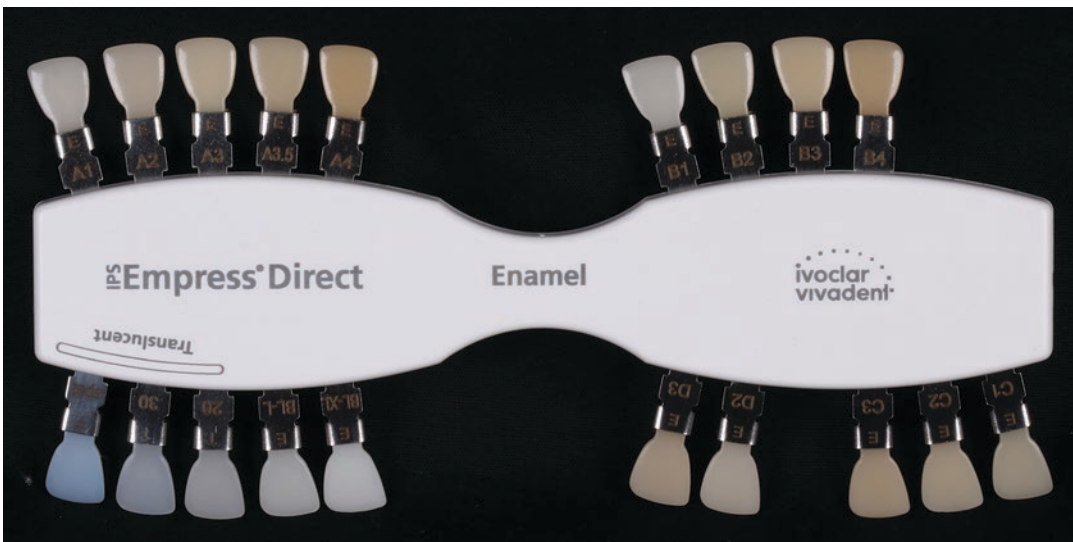


Fig. 3.13 Composite shade guides: enamel and translucent shades of IPS Empress Direct system (Ivoclar Vivadent)

increments of the restorative material onto the dental surface allows observation of optical properties interaction between the material and the dental tissues. Moreover, the thickness of a shade tab is higher compared to most restorations. There is no rule for placing the increments onto the dental surface. However, the dentist should have in mind the layering concept used (Figs. 3.21–3.23).

In this technique, the increments should be large enough to allow proper observation ($\varnothing = 1$ mm at least). The photoactivation should be performed the same as for the “final” restoration to avoid color misinterpretation due to the color change that occurs after cure. Then, the tooth and material should be wet, and the observation should be performed for no longer than 5 s (Fig. 3.24). The chosen composite colors should



Fig. 3.14 (a) Composite shade guides: dentin shades of Miris2 system (Coltene). (Photography courtesy of Coltene). (b) Composite shade guides: enamel and effect shades of Miris2 system (Coltene). (Photography courtesy of Coltene)

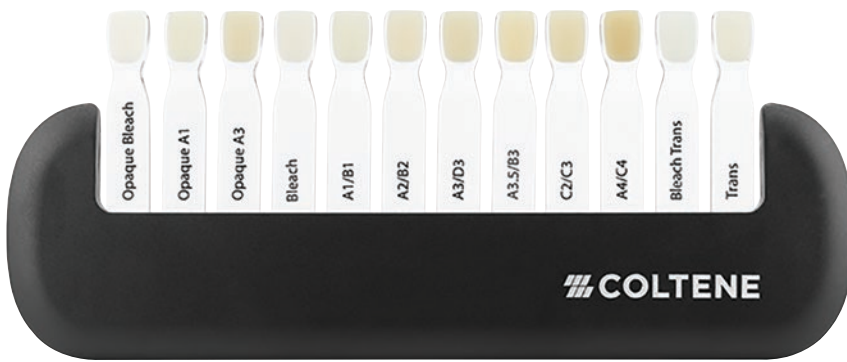


Fig. 3.15 Composite shade guide: Brilliant system (Coltene). (Photography courtesy of Coltene)

Fig. 3.16 Composite shade guide: Opallis system (FGM)



be registered as well as the respective color map draw (further explained in Chap. 7).

The resin composite that is not polymerized into the syringe is usually darker than the photopolymerized increment used during resin placement. These color differences are mainly

caused by a decrease in lightness and Chroma after photopolymerization. In general, the decrease in lightness occurs because the monomers form polymers through the polymerization process. This reaction causes the reduction of their refractive indices, thus changing the way the light is transmitted, reflected, and refracted. The decrease in Chroma, however, occurs due to the consumption of the photoinitiator during the photoactivation process. Camphorquinone is the most commonly used photoinitiator in Dentistry. However, as a yellow-colored molecule, after reacting, its consumption leads to a decrease in composite yellowness.

3.2.1.5 Using the Mock-up Technique

To confirm the selected composite colors, regardless of shade selection technique (e.g., using ceramic or composite shade guide tabs or by increments of composites), a color mock-up may be made [7]. It is a non-bonded full shape restoration made free-handed. Then, it is flaked off from the tooth to observe the layering from both inner and outer aspects. It provides the opportunity to “rehearse” the contour and thickness of each den-



Fig. 3.17 Composite shade guide: Palfique system (Tokuyama)



Fig. 3.18 Composite shade guide: Estelite Omega system (Tokuyama). (Photography courtesy of Tokuyama Dental)



Fig. 3.19 Composite shade guide: Filtek Universal system (3M). (Photography courtesy of 3M)

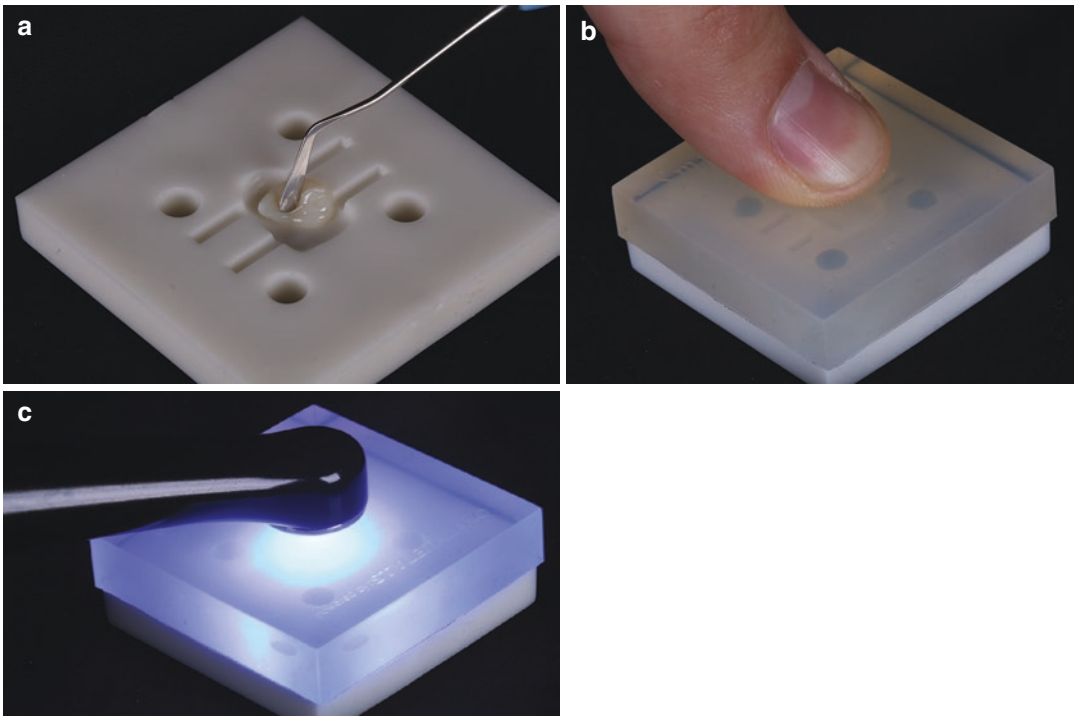


Fig. 3.20 Personalized shade guides using My Shade Guide (Smile Line): (a) filling a rubber mold with resin-based composite; (b) pressing to remove excess; and (c) photoactivation

tin and enamel layer and ascertain the color outcome from the mixed shades [8,9]. This technique allows checking whether the combination of the different shades that were chosen to do really match with the polychromatic appearance of the

natural tooth. This technique also helps to avoid goniochromism (previously explained in Chap. 1), once the different translucent layers are reproduced to confirm the final color of the restoration from different angles.

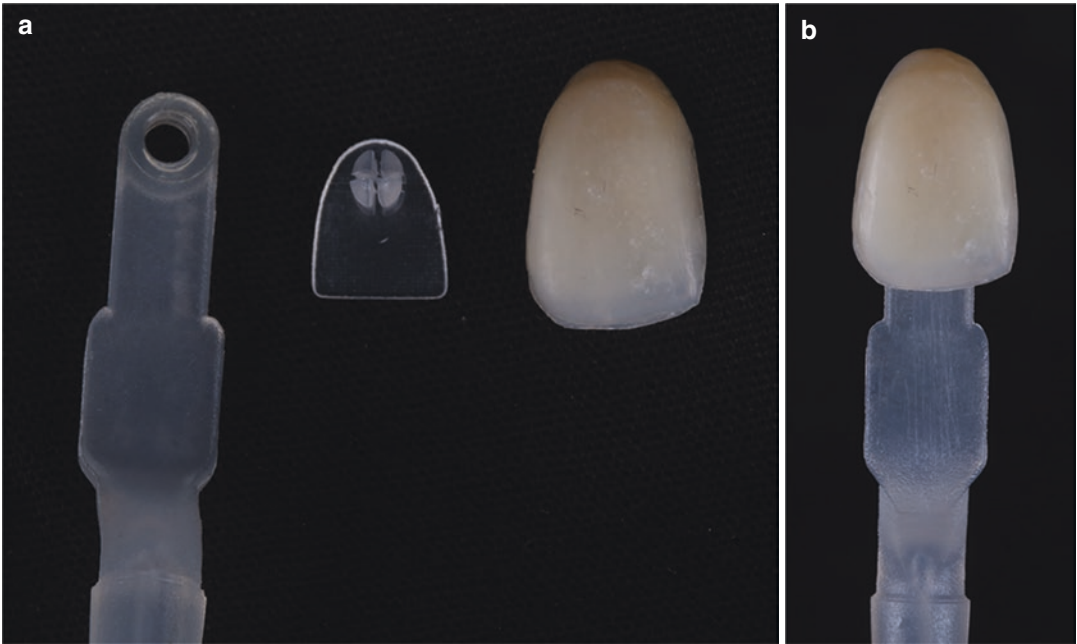


Fig. 3.21 Personalized shade guides using My Shade Guide (Smile Line): crafted tab of resin-based composite, before (a) and after (b) joining pieces



Figs. 3.22-3.24 Visual color selection for direct restorations using increments of composite according to different layering concepts

3.2.1.6 Visual Color Measurement Technique

Color from any object, as the tooth and shade guide tab, is directly influenced by illumination. Then, it is essential to place the tab equally leveled with teeth to get the same amount of illumination (Fig. 3.25). To perform an optimized color measurement, first, patients should be asked to remove any lipstick or shiny lip balms. The patient should be asked to sit and tilt his head up, pointing their smile towards the ceiling light. The shade guide must be brought close to the smile to initially pre-select a few coloring tabs.

Then, lip retractors should be used to expose teeth, and a black or gray background should be inserted behind them to neutralize the reddish influence of the oral cavity tissues (Figs. 3.26, 3.27, 3.28 and 3.29). Finally, one at a time, the pre-selected tabs should be mirrored placed close



Fig. 3.25 Visual color selection for direct restorations using increments of composite: after photoactivation, teeth and restorative material should be wet for visual observation

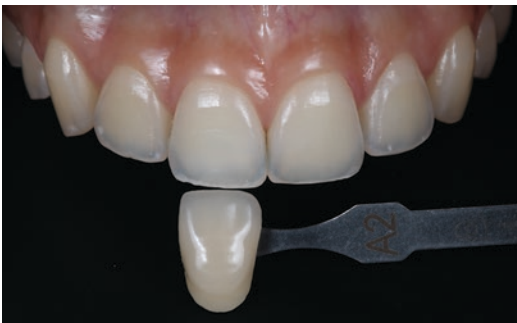


Fig. 3.26 Visual color selection for direct restorations using shade tabs: mirrored shade tab placement to teeth in order to get the same amount of illumination



Fig. 3.27 Visual color selection for direct restorations using shade tabs: different shade tabs mirrored placed to teeth without any neutral background



Fig. 3.28 Visual color selection for direct restorations using shade tabs: placement of a gray background behind upper teeth to neutralize the reddish influence of oral cavity background



Fig. 3.29 Visual color selection for direct restorations using shade tabs: importance of lip retraction to provide proper illumination to teeth and shade tab

to the tooth to receive the same amount of light. Therefore, the tab that most closely matches the tooth color should be registered. Visual observation should not exceed 5 s to avoid color misinterpretation due to visual fatigue.

As previously described in Chap. 1, several factors can negatively influence the correct color measurement by visual methods, including variations in the type, quality, and intensity of light, professional's color blindness or deficiency in color perception, differences in gender and professional's experience [10–13].

Visual color measurements should be taken at ideal illumination conditions. As earlier explained in this chapter, a light source suitable for visual observation should have correlated color temperature of a full-spectrum balanced light between 5500 and 6500 K. During the visual shade matching, the light intensity should be diffuse, allowing clinicians to perceive color accurately and comfortably. The recommended lighting intensity for the dental office is 200–300 fc or 500–600 lx [2, 14]. Light-correcting devices are available to minimize the external lighting interference of dental offices due to variations in the daytime, the season of the year, and the resultant mixture between daylight and fluorescent or incandescent light from the room. Handheld light-emitting diode devices with 5500 K of color temperature can be used for this purpose as the *Rite-Lite 2* and the *Rite-Lite Pro* (Addent) (previously illustrated, Figs. 3.2 and 3.3), and the *Smile Lite* and the *Smile Lite MPD* (Smile Line) (Figs. 3.30 and 3.31).



Fig. 3.30 Visual color selection for direct restorations using shade tabs: zoomed view of operative field in ideal lighting conditions



Fig. 3.31 Use of a portable light-correcting device to color measurement: *Smile Lite MPD* (Smile Line)

3.2.2 Objective Measurements

Clinically, the objective tooth color measurement can be assessed by different dental shade-matching devices that have been brought to the market to surpass the inconsistencies of visual shade matching. Examples are the spectrophotometers [15, 16] and the colorimeters [17, 18].

The dental spectrophotometers measure the amount of light energy reflected from the tooth surface at different wavelengths (1–25 nm intervals) of the visible spectrum and convert the numerical color values (CIELAB color coordinates) to the equivalent tab from a dental shade guide. *CrystalEye* (Olympus America), *Vita Easyshade V* (VITA), *Shade-X* (X-Rite), and *SpectroShade Micro* (MHT) are commercially available examples of dental spectrophotometers. On the other hand, dental colorimeters do not register spectral reflectance; they measure tooth color according to the tristimulus values (CIE XYZ) by filtering the reflected light into red, green, and blue areas of the visible spectrum and converting these to CIELAB color coordinates, and then to the correspondent tab from dental shade guide [19]. *ShadeVision* (X-Rite) is a commercially available example of a dental imaging colorimeter.

Colorimeters and spectrophotometers have broad application in tooth whitening longitudinal studies, and they can be used clinically to evaluate tooth color variation during the whitening treatment period. However, clinicians must take care to avoid inaccurate measurements when



Fig. 3.32 Using a phone to register photographically the shade matching with the *Smile Lite MPD* (Smile Line)

using these devices. Since they are contact-measuring instruments, the results can be affected by the wrong positioning of the measuring probe, fogging of the optical lens, ambient illuminant used, and by the background, while taking the measurements [20, 21].

These devices have different prices, designs, software, and data output. They can measure the tooth's overall surface color or in limited areas. Overall tooth surface color measurement devices such as the *CrystaEye*, the *SpectroShade Micro*, and the *ShadeVision* provide a color map with the correspondent color tab from a shade guide according to the tooth three thirds: cervical, body, and incisal. Limited area measurement devices such as the *Easyshade V*, and the *Shade-X* provide the color correspondent the color tab from a shade guide according to the 3–5 mm diameter area of measurement of the tip of the probe of the device. For this reason, to monitor color change during tooth whitening, for example, the probe should be placed in the center of the middle third from the tooth buccal surface (Fig. 3.32).

The tooth color can also be objectively measured by image analysis techniques obtained with digital cameras [22–24] or intraoral digital scanners [25–27]. Despite the encouragement of its use to improve communication with dental technicians to diminish the color matching disagreement among teeth and indirect restorations, and



Fig. 3.33 Objective color measurement using Vita Easyshade V. (Photography courtesy of Bryce Brandfon, Franciele Floriani, and Nathalie Sawczuk)

even their indication for research studies, its clinical use to monitor color change during tooth whitening treatments is still a challenge due to its complexity (Fig. 3.33).

References

1. Clary JA, Ontiveros JC, Cron SG, Paravina RD. Influence of light source, polarization, education and training on shade matching quality. *J Prosthet Dent.* 2016;116(1):91–7.
2. Gasparik C, Grecu AG, Culic B, Badea ME, Duda D. Shade-matching performance using a new light-correcting device. *J Esthet Restor Dent.* 2015;27(5):285–92.
3. Joiner A. Tooth colour: a review of the literature. *J Dent.* 2004;32(Suppl 1):3–12.
4. Browning WD, Contreras-Bulnes R, Brackett MG, Brackett WW. Color differences: polymerized composite and corresponding Vitapan classical shade tab. *J Dent.* 2009;37(Suppl 1):e34–9.
5. Fahl N Jr. Single-shaded direct anterior composite restorations: a simplified technique for enhanced results. *Compend Contin Educ Dent.* 2012;33(2):150–4.
6. Dietschi D, Fahl N Jr. Shading concepts and layering techniques to master direct anterior composite restorations: an update. *Br Dent J.* 2016;221(12):765–71.
7. Dietschi D. Free-hand bonding in the esthetic treatment of anterior teeth: creating the illusion. *J Esthet Dent.* 1997;9(4):156–64.
8. Fahl N Jr. Achieving ultimate anterior esthetics with a new microhybrid composite. *Compend Contin Educ Dent Suppl.* 2000;26:4–13.
9. Dietschi D. Optimising aesthetics and facilitating clinical application of free-hand bonding using the 'natural layering concept'. *Br Dent J.* 2008;204(4):181–5.

10. Della Bona A, Barrett AA, Rosa V, Pinzetta C. Visual and instrumental agreement in dental shade selection: three distinct observer populations and shade matching protocols. *Dent Mater.* 2009;25(2):276–81.
11. Simionato A, Pecho OE, Della BA. Efficacy of color discrimination tests used in dentistry. *J Esthet Restor Dent.* 2020;33(6):865–73.
12. Pecho OE, Ghinea R, Perez MM, Della BA. Influence of gender on visual shade matching in dentistry. *J Esthet Restor Dent.* 2017;29(2):E15–23.
13. Samra APB, Moro MG, Mazur RF, Vieira S, De Souza EM, Freire A, Rached RN. Performance of dental students in shade matching: impact of training. *J Esthet Restor Dent.* 2017;29(2):E24–32.
14. Wee AG, Meyer A, Wu W, Wichman CS. Lighting conditions used during visual shade matching in private dental offices. *J Prosthet Dent.* 2016;115(4):469–74.
15. Chen H, Huang J, Dong X, Qian J, He J, Qu X, Lu E. A systematic review of visual and instrumental measurements for tooth shade matching. *Quintessence Int.* 2012;43(8):649–59.
16. Kim-Pusateri S, Brewer JD, Davis EL, Wee AG. Reliability and accuracy of four dental shade-matching devices. *J Prosthet Dent.* 2009;101(3):193–9.
17. Li Q, Wang YN. Comparison of shade matching by visual observation and an intraoral dental colorimeter. *J Oral Rehabil.* 2007;34(11):848–54.
18. Karaagaciloglu L, Terzioglu H, Yilmaz B, Yurdukoru B. In vivo and in vitro assessment of an intraoral dental colorimeter. *J Prosthodont.* 2010;19(4):279–85.
19. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. *J Dent.* 2010;38(Suppl 2):e2–16.
20. Chu SJ. Use of a reflectance spectrophotometer in evaluating shade change resulting from tooth-whitening products. *J Esthet Restor Dent.* 2003;15(s1):S42–8.
21. Raoufi S, Birkhed D. Effect of whitening tooth-pastes on tooth staining using two different colour-measuring devices—a 12-week clinical trial. *Int Dent J.* 2010;60(6):419–23.
22. Gerlach RW, Barker ML, Sagel PA. Objective and subjective whitening response of two self-directed bleaching systems. *Am J Dent.* 2002;15:7A–12A.
23. Wee AG, Lindsey DT, Kuo S, Johnston WM. Color accuracy of commercial digital cameras for use in dentistry. *Dent Mater.* 2006;22(6):553–9.
24. Lasserre JF, Pop-Ciutrlila IS, Colosi HA. A comparison between a new visual method of colour matching by intraoral camera and conventional visual and spectrometric methods. *J Dent.* 2011;39(Suppl 3):e29–36.
25. Liberato WF, Barreto IC, Costa PP, Almeida CC, Pimentel W, Tioffi R. A comparison between visual, intraoral scanner, and spectrophotometer shade matching: a clinical study. *J Prosthet Dent.* 2019;121(2):271–5.
26. Yoon HI, Bae JW, Park JM, Chun YS, Kim MA, Kim M. A study on possibility of clinical application for color measurements of shade guides using an intraoral digital scanner. *J Prosthodont.* 2018;27(7):670–5.
27. Ebeid K, Sabet A, Della BA. Accuracy and repeatability of different intraoral scanners on shade determination. *J Esthet Restor Dent.* 2020;33(6):844–8.