A new shading concept based on natural tooth color applied to direct composite restorations

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Objective: Patient demands have prompted manufacturers to improve intrinsic optical properties of resin composites and clinicians to refine application procedures. The aim of this study is to present a shading concept based on colorimetric L*a*b* and contrast ratio data of human dentin and enamel. **Method and materials:** Extracted teeth of the A and B Vita shade groups (n = 8 per group) were sectioned according to 2 different planes to measure specific color (using the CIE L*a*b* system) and opacity (contrast ratio). Standardized samples of enamel and dentin shades of a new composite system (Miris, Coltène Whaledent) were submitted to the same colorimetric evaluation for comparison with natural tissues. **Results:** Comparison of teeth from the Vita groups A and B having the same chroma showed limited variations regarding a* (green to red) and b* (blue to yellow) values; the only significant variation was the increasing b* values (yellow) with increasing chroma (A1 to A4 and B1 to B3). As for dentin contrast ratio, limited differences were reported, while enamel proved to increase in translucency with age (reduced contrast ratio). **Conclusion:** These data served as the foundation of the so-called natural layering concept, which makes use of 2 basic composite masses (dentin and enamel) that optically mimic natural tissues. This concept allows for simplified clinical application and layering of composite, as it uses only 1 universal dentin hue with several chroma levels and 3 enamel types for young, adult, and old patients, each exhibiting specific tints and translucency levels. *(Quintessence Int 2006;37:91–102)*

Key words: CIE L*a*b*, contrast ratio, dentin color, natural layering technique

Resin composites nowadays occupy a paramount position among restorative materials because they offer an excellent esthetic potential and acceptable longevity, with a much lower cost than equivalent ceramic restorations for the treatment of anterior teeth.[1–3] In addition, composite restorations allow for minimally invasive preparations or no preparation at all for the replacement of decayed or missing tissues.

The identification of respective dentin and enamel optical characteristics is of considerable interest for the development of tooth-colored materials[4,5] (Fig 1). Master ceramists and manufacturers of dental porcelains have made a lot of effort in developing specific powders that mimic the 2 main constituents of natural teeth, when placed in the specific configuration of a ceramic restoration.[6] However, ceramics are to be used for the veneering of a metal or ceramic framework, in thin layers and in a configuration that does not correspond to the arrangement of natural

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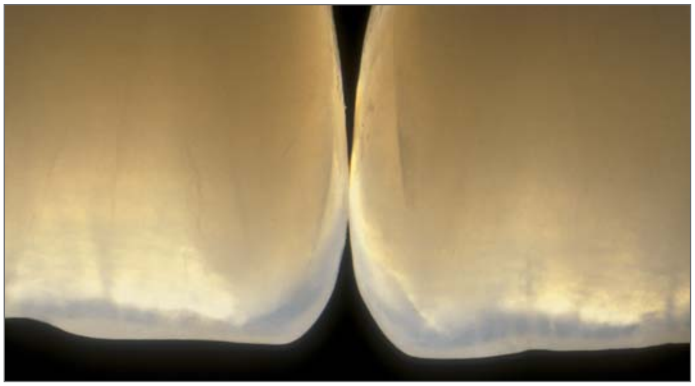


Fig 1 The transillumination of natural teeth shows the major features of both dentin and enamel. Dentin gives the tooth its color, the perception of which is modulated by enamel, a semitranslucent and highly opalescent tissue.

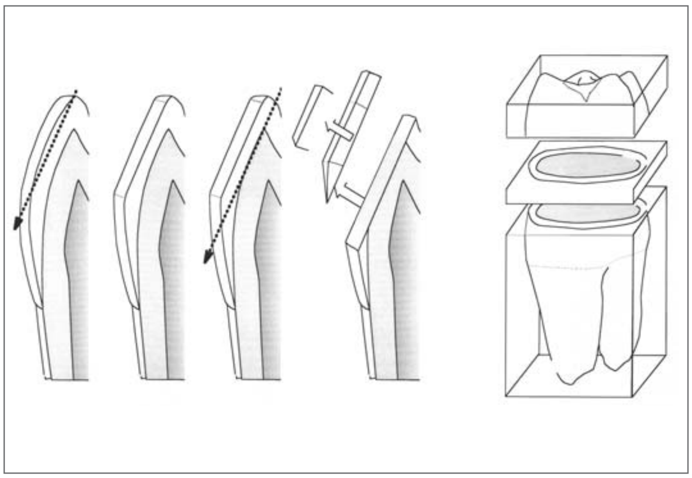


Fig 2 Localization and preparation technique for enamel and dentin sections of natural teeth used for colorimetric and opacity measurements (each type of section is 1.0 ± 0.05 mm).

tissues. Therefore, unlike with many previous attempts, it is necessary to use the natural tooth as a model for analyzing or developing a composite system. The literature provides abundant information on human tooth color.[7–14] Colorimetric (tristimulus L*a*b* data, Commission Internationale de l'Eclairage [CIE] 1976) and opacity or contrast ratio measurements of human natural tissues are the usual data reported in the literature on tooth color.[10,14–16] All authors attempted to analyze the whole tooth, and only rare reports describe optical characteristics of dentin and enamel separately.[17,18]

Existing or former composite generations were developed mainly according to 3 specific layering/shading concepts.[19] This classification relies on the respective anatomic position, increment thickness, and optical properties of the different masses provided in each specific composite system. These concepts include the application of 2 or 3 layers of shaded and unshaded (incisal or transparent) masses, a configuration that does not precisely mimic the natural tooth structure and anatomy.

The aim of the present article is to present a shading concept based on colorimetric L*a*b* and contrast ratio data of human dentin and enamel that represents an innovative and more rational approach for the layering of anterior composite restorations.

METHOD AND MATERIALS

Eight intact, freshly extracted human molars representing all A (A1 to A4) and B (B1 to B3) groups of the Vita shade system (Vita Zahnfabrik) were collected for an evaluation of their color (L*a*b* values according to CIE 1931 and 1976)[20] and opacity—contrast ratio [CR], calculated from Yxy chromaticity coordinates[21]: CR = Y* (B) / Y* (W)—where B is a black background and W is a white background.

Samples used for analyzing CR of the 3 enamel types were selected from the whole collection of teeth evaluated in this study. They were included in the group of young, adult, or old enamel according to the morphology of their incisal edge (no wear, slight wear, or pronounced wear) and intrinsicate tint (white, neutral, or yellow-gray). Teeth with no clear morphologic or color attribute were excluded from this evaluation. No attempt was made to select the teeth according to their actual age.

The roots of each tooth were embedded in a clear self-curing epoxy resin. Thereafter, a superficial slice was produced on the widest enamel plane, and a 1-mm section (± 0.05 mm) following this axis was prepared using a slow-rotating saw (Isomet 11-1180, Buehlers) (Fig 2). The remaining sample was

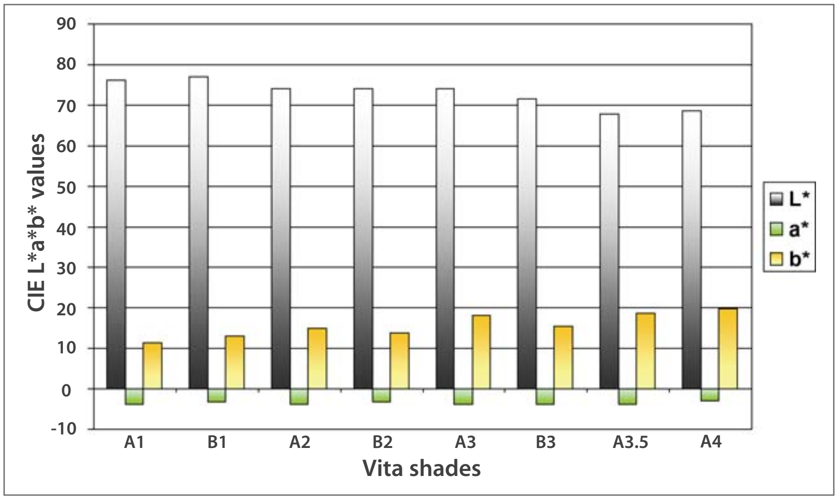


Fig 3a CIE L*a*b* values of natural dentin samples arranged according to the Vita shades.

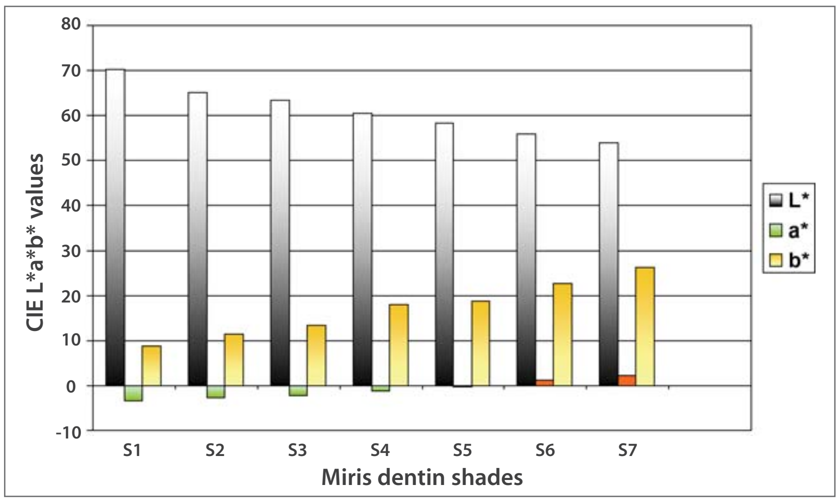


Fig 3b CIE L*a*b* values of Miris dentin shades, which were developed according to the natural layering concept.

sectioned perpendicular to the tooth's long axis, 1.5 mm below the deepest point of the occlusal surface, and a 1-mm section (± 0.05 mm) was made below this plane (see Fig 2).

Colorimetric measures of enamel (on the inner side) and dentin samples (on the occlusal side) were performed using a reflectance colorimetric device (Minolta CR-21, Minolta). Detailed evaluation protocol was presented in previous reports.[18,22]

During a second phase, standardized samples (1 × 15 × 15 mm ± 0.05 mm) made of a composite developed according to the data produced from human tissues (Miris, Coltène Whaledent) were fabricated to assess its optical properties (L*a*b* and CR). Five samples of each dentin (S1 to S7) and enamel (white bleach, WB; white regular, WR; neutral regular, NR; neutral transparent, NT; ivory regular, IR; ivory transparent IT) shade were produced.

Descriptive statistics were computed for either natural tissues or composite data (mean and standard deviation). The Student *t* test unpaired was used to explore the differences in dentin L*, a*, and b* values between A and B Vita shades, within the same chroma range (1 to 3).

RESULTS

The L*a*b* and CR data of natural tissues and Miris composite are presented in Tables 1 to 4 and Figs 3a and 3b.

Table 1	Mean in vitro CIE L*a*b* (± SD) and contrast ratio (CR) measures of dentin from natural teeth of the A and B Vita shade groups (n = 8 per shade)*			
Vita shade	L*	a*	b*	CR
A1	76.11 (3.76)	-3.85 (0.49)	11.46 (1.56)	0.67
B1	77.12 (3.76)	-3.23 (0.57)	13.08 (3.21)	0.63
A2	73.88 (2.07)	-3.85 (0.45)	14.93 (2.90)	0.66
B2	74.06 (3.38)	-3.28 (1.0)	13.72 (2.81)	0.62
A3	74.05 (1.96)	-3.82 (0.78)	18.11 (4.06)	0.67
B3	71.52 (3.56)	-3.73 (0.82)	15.54 (3.71)	0.62
A3.5	67.67 (4.69)	-3.87 (0.46)	18.71 (3.47)	0.69
A4	68.48 (3.05)	-2.93 (0.92)	19.82 (3.35)	0.70

*Dentin sections without enamel were used.

Table 2	Mean in vitro CIE L*a*b* and CR measures of dentin shades of Miris composite (n = 5 per shade)			
Miris dentin shade	L*	a*	b*	CR
S1	70.26	-3.43	8.75	0.78
S2	65.21	-2.60	11.42	0.74
S3	63.53	-2.19	13.47	0.71
S4	60.46	-1.20	18.03	0.66
S5	58.21	-0.22	18.8	0.64
S6	55.78	1.10	22.66	0.62
S7	53.90	2.23	26.41	0.61

Table 3	Mean L* and CR values of natural enamel (n = 5 per shade)	
Enamel age/type	L*	CR
Young/white	75.89	0.485
Adult/neutral	66.77	0.434
Old/yellow-gray	71.84	0.402
Mean value	70.83	0.435

Table 4	Mean L* and CR values of Miris enamel shades (n = 5 per shade)	
Miris enamel shade	L*	CR
White regular (WR)	65.11	0.44
White bleach (WB)	64.82	0.46
Neutral regular (NR)	62.59	0.42
Neutral transparent (NT)	65.82	0.29
Ivory regular (IR)	64.09	0.375
Ivory transparent (IT)	62.62	0.335

Dentin color

L*a*b* and CR data of natural dentin samples are presented in Table 1 and Fig 3a. The a* values proved to be slightly negative in all teeth, which shows a shift toward green color in extracted teeth. There was practically no variation in a* values among all A or B Vita shades. The b* values were positive, the amount of yellow increasing in darker shades (from A1 to A4 or from B1 to B3). L* values (lightness) varied inversely to the chroma (related to a* and b* values) within the same shade (L* decreased from A1 to A4 or from B1 to B3, while chroma increased).

Mean values and distribution of L*a*b* values between teeth of Vita groups A and B, as determined by the Vita shade guide, proved not to be significantly different.

Opacity of enamel and dentin

The recorded mean CR was 0.66 for dentin and 0.435 for enamel (see Tables 1 and 3, respectively). The CR of enamel also proved to vary according to age and type: young, white (0.485); adult, neutral (0.434); old, gray-yellow (0.402) (see Table 3).

Composite colorimetric data

The L*a*b* and CR data of Miris are presented in Table 2 and Fig 3b (dentin) and Table 4 (enamel). The dentin shades present a moderate increase of a* values (shift from green toward red) with increasing chroma (S1 to S7); likewise, b* values are increasing with chroma (S1 to S7). L* values diminish with chroma (S1 to S7) (Fig 3b).

DISCUSSION

Only A1 to A4 and B1 to B3 shades of the Vita system were evaluated, those being the most common shades found within the collection of extracted teeth. Regarding the other Vita shades (C and D), it proved impossible to collect samples in sufficient number to evaluate them. These 2 shades proved to be rarely observed in the natural dentition.[12,13,23,24]

Implications of natural tooth color measurements in the development of a clinical concept

The analysis of L*a*b* measures, including their standard deviation, led to the conclusion that an ideal dentin replacement material should exhibit the following characteristics: single hue, single opacity, and large chroma scale.

Actually, the variations of a* and b* values between A and B Vita shades do not seem to justify the use of distinct dentin colors, at least for a direct composite restorative system. Likewise, the variations of the contrast ratio within a single shade group do not support the use of different dentin opacities (ie, translucent, regular, and opaque dentins). However, chroma (related to a* and b* values) proved to increase from light to dark shades (A1 to A4 or B1 to B3) and then support the concept of a large chroma scale covering all variations of natural dentitions, plus some specific conditions like sclerotic dentin (as found underneath decay, restorations, or cervical lesions).

As for enamel, differences in L* and CR values proved to vary in relation to tooth age, which confirmed the clinical concept of 3 specific enamel types[25]:

- *Young enamel:* white tint, high opalescence, less translucency
- *Adult enamel:* neutral tint, less opalescence, and intermediate translucency
- *Old enamel:* yellow tint and higher translucency

This whole interpretation of CIE L*a*b* and CR data of natural tissues led to a clinical approach called the natural layering concept, which embraces more accurately the optical and anatomic characteristics of natural teeth[2,18,26] (Fig 4). It actually defines the features of an optimal restorative material aimed to replace dentin and enamel, respectively. Dentin shades should be available in a single hue (Vita A or universal dentin shade) with a large range of chroma (usually expending the existing Vita shade range) and presenting opacity close to that of natural dentin. Enamel shades should present different tints and opacity levels, tentatively replicating all variations found in nature. Products that provide such shade features are Miris, Vitalescence (Ultradent), and Ceram-X duo (Dentsply).

The optical properties of the product tested in this study (Miris) mimic those of the natural tissues quite closely . However, the color of dentin masses had to be slightly modified based on the clinical experience gained during the product development; actually, the influence of surrounding soft tissues and vital pulp on color perception proved different between natural tissues and the restorative material. Therefore, a* and b* values were adjusted to obtain a better color match in vivo; this is why no attempt was made to correlate statistically L*a*b* and CR values of the composite and natural tissues.

Influence of the natural layering concept on shade recording

The quality of the final restoration, of course, depends on a correct shade recording. According to the natural layering concept, only 3 steps are involved: *(1)* selection of

Fig 4 Description of the natural layering concept with specific features of young, adult, and old teeth and how it influences the choice of related composite shades.


Dentin
Same Hue and Opacity
Spacial relationships
Varying enamel coverage at incisal edge
Young
Young
Adult
Adult
Old
Old

Figs 5a to 5f Shade recording according to the natural layering concept. **(a)** The new shade guide of the Miris system comprises shade tabs with anatomic shape, dimensions, and thicknesses. Glycerin gel, which has a refractive index close to that of resin composites resins, must be applied in between both shade tabs to allow for an accurate shade selection. **(b)** Teeth are cleaned with a prophylactic nonfluoridated paste. **(c)** For the selection of dentin, a serial of dentin tabs is first placed in front of the teeth to select the most likely dentin chroma. **(d)** The choice of dentin chroma is confirmed by placing the composite tab close to the cervical area, where there is the least amount of enamel, allowing for a more precise selection. **(e)** The enamel shade, which was visually selected, was placed over the selected dentin tab. Combined samples are then brought to the mouth and placed incisal edge to incisal edge for shade comparison. If shade match is not adequate, another enamel tab can be tested. **(f)** Completed restorations showing good color and translucency integration of the restoration.

dentin chroma in the cervical area, where enamel is the thinnest, using samples of the composite material, *(2)* selection of enamel tint and translucency, by simple visual observation, and *(3)* preparation of a simplified chromatic map (visually or through an intraoral photograph) to decide whether the application of effect materials is needed. The most useful effect materials are the blue (reinforcement of composite natural opalescence), gold-yellow (for a local increase of restoration chroma), and white (for simulating white spots or hypocalcifications). A new technique to record shade has been recently introduced to facilitate this clinical procedure and make it more accurate, by superimposing the dentin and enamel samples (Fig 5).

Clinical application of the natural layering concept

A 50-year-old patient shows discolored and worn incisal composite reconstructions that necessitate a replacement for esthetic and functional reasons (Fig 6a). Shade selection is always performed first, to avoid any interference in chroma and opacity evaluation due to tissue dehydration (see Fig 6a). A mockup is performed to restore the normal tooth length and width; an esthetic, functional, and phonetic check can be performed before proceeding with further restorative steps (Fig 6b). As soon as the incisal edge position is confirmed, a silicone index is fabricated that will be used during the next steps and also at the time of finishing (Fig 6c).

The selected enamel composite is applied directly on the silicone index (Miris, Neutral Regular), which is then placed against the teeth. This allows the lingual buildup of enamel to be performed easily and precisely (Fig 6d). The reference of the new incisal edge serves for a 3-dimensional placement of dentin (Miris, dentin S3); with this "linguobuccal" incremental approach, the space needed for the subsequent application of effect materials and enamel is maintained with superior accuracy (Fig 6e). A little increment of blue-tinted composite (Miris, Blue effect) is placed on top of the dentin buildup to mimic opalescence of natural enamel (Fig 6f). This was judged necessary since the intrinsic opalescence of the composite enamel was insufficient in this case. Finally, unshaded, translucent enamel mass (same as that used on the lingual surface) is applied to complete the proximal and buccal profiles and provide desired translucency and brightness (Figs 6g and 6h).

The application of the natural layering concept through a logical application of 2 separate composite masses that mimic natural tooth anatomy presents clear advantages for the clinician; it makes the whole procedure more efficient and predictable.

Effect of tooth aging on optical properties of dentin and enamel

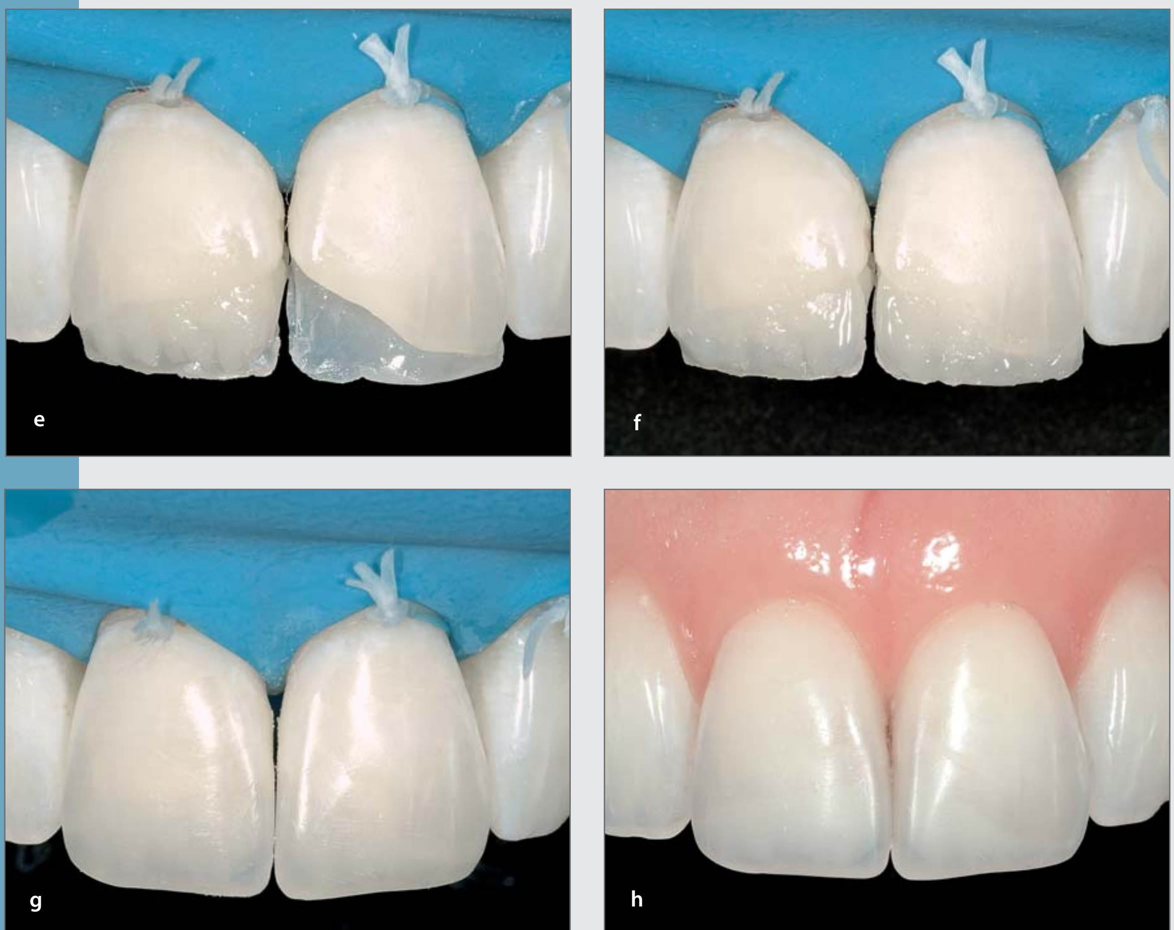
Special attention has to be paid to the morphologic changes that affect the incisal edge structure as a result of tissue aging and functional wear. Actually, in addition to the increase in dentin chroma and enamel translucency, the progressive thinning of the enamel layer and exposure of dentin at the incisal edge necessitates an adaptation of the basic layering technique (see Fig 4).

CONCLUSION

The traditional restorative objectives have not changed over time; they simply were implemented by the esthetic demands of an increasing number of patients. Resin composite then became the material of choice for young patients and less privileged people, or for any case that requires a strictly conservative approach. The contemporary practitioner is ultimately challenged to replace the missing tissues or eventually modify their configuration by applying on the patient's teeth an artificial material, which has to simulate the appearance of natural tissues.

The natural layering concept has enabled this objective to be achieved in a predictable way by incorporating newly acquired knowledge about natural tissue optical properties into contemporary composite systems. This advance can be regarded as a milestone in operative dentistry, as it will give direct composite application a tremendous advantage, enabling a larger number of patients to receive more conservative and esthetic restorations.

Figs 6a to 6h Buildup of 2 large Class 4 cavities according to the natural layering concept. **(a)** Preoperative view and shade selection with dual Miris shade guide. **(b)** Freehand mockup that reproduces the normal length and width of the incisal edge. **(c)** A silicone index records this information to facilitate further procedures. **(d)** The lingual enamel walls are built up directly against the index.



(e) Dentin can be applied and placed precisely in relation with the future incisal edge, respecting the specific tooth and age configurations. **(f)** Effect masses are applied in small quantities on top of dentin to mimic specific light effects such as opalescence (blue tinted). **(g)** A final enamel layer is applied on proximal and buccal surfaces to complete the restoration. **(h)** Completed restorations after tissue rehydration.

REFERENCES

1. Osborne JW, Normann RD, Gale EN. A 12-year clinical evaluation of two composite resins. Quintessence Int 1990;21:111–114.
2. Dietschi D. Free-hand composite resin restorations: A key to anterior aesthetics. Pract Periodontics Aesthetic Dent 1995;7:15–25.
3. Fahl N. Optimizing the esthetics of Class IV restorations with composite. J Can Dent Assoc 1997;63: 108–115.
4. Winter R. Visualizing the natural dentition. J Esthet Dent 1993;5:103–117.
5. Chiche G, Pinault A. Esthetics of Anterior Fixed Prosthodontics. Chicago: Quintessence, 1994.
6. Sieber C. Voyage. Chicago: Quintessence, 1994.
7. Sproull RC. Color matching in dentistry. Part I: The three-dimensional nature of color. J Prosthet Dent 1973;29:416–424.
8. Sproull RC. Color matching in dentistry. Part II: Practical applications of the organization of color. J Prosthet Dent 1973;29:556–566.
9. Macentee M, Lakowski R. Instrumental color measurement of vital and extracted human teeth. J Oral Rehabil 1981;8:203–208.
10. Clarke FJJ. Measurement of color of human teeth. In: McLean JW (ed). Dental Ceramics: Proceedings of the First International Symposium on Ceramics. Chicago: Quintessence, 1983:441–488.
11. Goodkind RJ, Schwabacher WB. Use of a fiber-optic colorimeter for in vivo color measurements of 2830 anterior teeth. J Prosthet Dent 1987;58:535–542.
12. Miller L. Shade matching. J Esthet Dent 1993;5: 143–152.
13. Miller L. Shade selection. J Esthet Dent 1994;6: 47–60.
14. O'Brien WJ, Hemmendinger H, Boenke KM, Linger JB, Groh CL. Color distribution of three regions of extracted human teeth. Dent Mat 1997;13:179–185.
15. Crisp S, Abel G, Wilson A. The quantitative measurement of the opacity of dental filling materials. J Dent Res 1979;58:1585–1596.
16. Inokoshi S, Kataumi M, Pereira PNR, Yamada T, Tagami J. Appearance of composite resins in posterior teeth. In: Dondi dall'Orologio G, Prati C (eds). Factors Influencing the Quality of Composite Restorations: Theory and Practice. [Proceedings of the Bologna International Symposium, 22–23 Nov 1996, Bologna, Italy]. Haarlem, The Netherlands: Cavex,1995:141–154.
17. Cook WD, McAree DC. Optical properties of esthetic restorative materials and natural dentition. J Biomed Mat Res 1985;19:469–488.
18. Dietschi D, Ardu S, Krejci I. Exploring the layering concepts for anterior teeth. In: Roulet JF, Degrange M (eds). Adhesion: The Silent Revolution in Dentistry. Berlin: Quintessence, 2000:235–251.
19. Dietschi D. Layering concepts in anterior composite restorations. J Adhes Dent 2001;3:71–80.
20. Chamberlain GJ, Chamberlain DG. Colour: Its measurement, computation and application. London: Heyden & Son, 1980:60–61.[Au: Is this the full range of pages?]
21. Hunter RS, Harold RW. The Measurement of Appearance, ed 2. New York: John Wiley & Sons, 1987.
22. Rossier S. In vitro colorimetric evaluation of the efficacy of various bleaching methods and products [thesis]. Geneva, Switzerland: University of Geneva, 2005.
23. Schwabacher WB, Goodkind RJ. Three-dimensional color coordinates of natural teeth compared with three shade guides. J Prosthet Dent 1990;64: 425–431.
24. Hasegawa A, Ikeda I, Kawaguchi S. Color and translucency of in vivo natural central incisors. J Prosthet Dent 2000;83:418–423.
25. Ubassy G. Shape and Color: The Key to Successful Ceramic Restorations. Berlin: Quintessenz, 1993.
26. Dietschi D. Free-hand bonding in esthetic treatment of anterior teeth: Creating the illusion. J Esthet Dent 1997;9:156–164.