COMMENTARY

SPECTROPHOTOMETRIC ANALYSIS OF TOOTH COLOR REPRODUCTION ON ANTERIOR ALL-CERAMIC CROWNS PART 1: ANALYSIS AND INTERPRETATION OF TOOTH COLOR PART 2: COLOR REPRODUCTION AND ITS TRANSFER FROM IN VITRO TO IN VIVO Rade D. Paravina, DDS, MS, PhD*

These two articles emphasize some of the fundamental topics of esthetic dentistry: color matching, interpretation, communication, reproduction, and verification. The authors' success in these procedures resulted in an excellent color match of an all-ceramic crown to the contralateral maxillary central incisor.

The first paper is related to preparatory phases, tooth color measurement and matching, and interpretation of instrumental and visual color measurements by means of laboratory communication form that included drawn and written instructions. Preparatory steps encompassed tooth whitening and monitoring of postwhitening color stabilization, and analysis of dehydration-dependent changes of tooth color. Although this might be considered a supplementary finding, it is clinically relevant and contributes to the comprehensiveness of the study. Once completed, these steps established and defined a lighter baseline color at the gingival, middle, and incisal third. Besides quantification of hue, value, and chroma, the authors considered opacity and translucency when, and where, appropriate. It was also found that no die material matched the prepared tooth.

The second article reported on thorough monitoring and adjusting of color and translucency in each phase of the crown fabrication. After reporting that the ceramic coping was not perfectly opaque, the authors described a step-bystep reduction of color difference (ΔE^*) in the gingival, middle, and incisal third between the restoration and respective regions on the target tooth. They started with the ceramic coping on the die, then reported ΔE^* values after the first bake, for the full contoured crown, and ended with the final color of the restoration from the effect of the composite luting cements (see Table 1). Throughout the study, the results were quantified by means of an intraoral spectrophotometer and monitored visually.

In addition to a remarkable color match of the all-ceramic crown, the authors provided instructions on how to achieve specific and predictable color corrections. Their approach is predominantly based on the subtractive nature of color mixing and complementary color theory. It is very convenient that the CIELAB color notation system (Commission Internationale de l'Eclairage, $L^*a^*b^*$ system), used in color quantification, is based on Hering's opponent color theory. The final result was also verified visually under four different light sources in order to evaluate metamerism. Metamerism can be a significant source of frustration in esthetic dentistry. By definition, it is a nonspectral match or conditional match. One type of metamerism is illuminant metamerism, where two colored samples match under one lighting condition and mismatch under another. When two objects match under any conditions, it is called a spectral match or an unconditional match, and these samples are called isomers. When it comes to color appearance, the unconditional match (isomers) is the ultimate goal of esthetic dentistry.

Many handheld color measuring devices for dentistry were developed in the last decade. Some of these devices are spectrophotometers, some are colorimeters; some average color information from limited area, some provide tooth color "maps"; some provide images, some not. These devices are, to a different extent, useful in clinical shade matching, communication, and reproduction. However, the dental professional's role is still the most important for the final outcome. At this point, it seems that this will always be the case and that no machine or technology will ever be able to create all these fine details, subtle color transitions, and local color characterizations of human teeth. On the other

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TABLE 1. STEP-BY-STEP REDUCTION OF COLOR DIFFERENCES BETWEEN THE GINGIVAL, MIDDLE, AND INCISAL THIRD OF THE RESTORATION AND RESPECTIVE REGIONS ON THE TARGET TOOTH.			
Phase	∆ <i>E</i> *		
	Gingival	Middle	Incisal
Coping on die	5.3	1.6	7.7
First bake	3.7	1.8	5.0
Full contoured crown before cementation	2.4	1.7	1.3
Crown after cementation	1.2	1.3	0.7

hand, such a statement might be as correct as the suggestion of the thesis advisor to young Max Planck to choose a different field of study, as all the important discoveries in physics had already been made—luckily for mankind, he disagreed.

Matching and reproducing the color of an upper central incisor, a "key player at center stage," has been extensively elaborated in the literature. This has always been a challenging task in restorative dentistry, and the success, when achieved, brings a lot of pleasure to both patients and dental professionals. These articles present a noteworthy contribution, a valuable source of information, and a rarely seen demonstration of clinical excellence backed with sound color science. These are probably the last publications authored by late Dr. Lloyd L. Miller, one of the pioneers of color in dentistry. Based on these papers, Dr. Miller will keep teaching us for years to come through his publications, and those of his colleagues and students. In our profession, the acronym L.L.M. still stands for *Master of Laws . . . of Esthetic Dentistry*.

This commentary is accompanied by article, "Spectrophotometric Analysis of Tooth Color Reproduction on Anterior All-Ceramic Crowns: Part 1: Analysis and Interpretation of Tooth Color," Shigemi Ishikawa-Nagai, DDS, MSD, PhD, Aki Yoshida, RDT, John D. Da Silva, DMD, MPH, ScM, Lloyd Miller, BS, DMD, DOI 10.1111/j.1708-8240.2009.00311.x, and "Spectrophotometric Analysis of Tooth Color Reproduction on Anterior All-Ceramic Crowns: Part 2 Color Reproduction and Its Transfer from In Vitro to In Vivo," Aki Yoshida, RDT, Lloyd Miller, BS, DMD, John D. Da Silva, DMD, MPH, ScM, Shigemi Ishikawa-Nagai, DDS, MSD, PhD, DOI 10.1111/j.1708-8240.2009.00312.x

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