Reproducibility of a Non-Contact Tooth Color Measurement System

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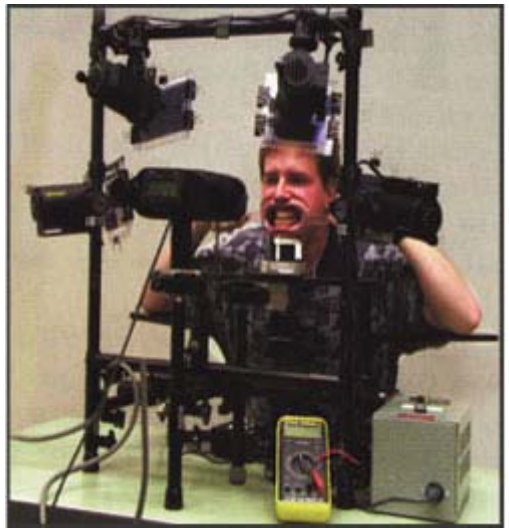
INTRODUCTION

Long term color measurement is aided by having access to a reproducible, non-contact tooth color measurement method. Mechanical robustness and precise adjustment of the imaging system are two obvious constraints. The impact of constant lighting conditions is too often minimized or overlooked, as is the value of maneuverability.

A method was developed that allows for repeatable, non-contact, objective reporting of intact human tooth color, while also mitigating edge loss effects for a portable image system. The study was designed to measure 12 subjects' tooth color once per day, for a total of eight days, using spectral reflectance.



MATERIALS AND METHODS

System description

A metal frame was configured with a chinrest, four dedolights, a colorimeter, and a digital camera with monitor. Crosshairs from a side digital camera/monitor ensured consistent repositioning of the subjects' teeth in the plane of measurement.

System components

Colorimeter

Spectrascan PR650 Colorimeter, manufactured by PhotoResearch, a division of Kollmorgan Instrument Laboratories, California. The PR650 was positioned at a 45°/0° geometry with respect to the lights to measure the CIEL*a*b* color values.

Lighting

Four 100-watt bulb dedolights were mounted at 45 degrees to the vertical plane of measurement. Filters were used to reject heat, remove specular reflectance, and produce a uniform light. Distance from the lamp lens to plane of measurement was 31 cm. Voltage output of the power supply and the input of each lamp were maintained between 12.2 and 13.0 volts.

CALIBRATION OF SYSTEM

The lights were turned on and allowed to equilibrate for 1 hour before calibrations began. The control of light level and color was made with the PR650 measuring the white reflectance standard in the Y x y color space (the Y value represents the brightness, and the x and y values represent the hue). The PR650 was then adjusted to display L*a*b*, and the white calibration tile was measured. L* value was maintained between 99 and 100 during the day by adjusting the voltage within the range described. A control chart with color tiles was also used for calibration.

PROCEDURE

During the course of this study, the measurement equipment was disassembled and relocated to four different sites (two days at each site) to simulate the intended use of this system.

Subjects

Twelve subjects were instructed to maintain their normal eating patterns and oral habits during the panel, and asked to refrain from a dental prophylaxis. A new Crest Complete toothbrush was provided for each panelist and they brushed with a wetted toothbrush before measurements were taken to assure food, plaque, or loose extrinsic stains were removed. Subjects were given retractors and asked to make their upper and lower teeth meet together so that the anterior surfaces were in the same plane.

Measurements

Measurements of the subjects' upper, left, central incisor were made. Each central incisor was divided into thirds, and a measurement of 2.5mm diameter was taken of the top third (zone 1), middle third (zone 2), and bottom third (zone 3) of each tooth, for a total of three measurements per tooth. These values were manually recorded in an excel spreadsheet, and the average and standard deviation calculated by the software program. A total of eight averaged whole tooth measurements per tooth were recorded for each subject, as well as the individual, unaveraged data.

RESULTS

Statistical Analysis of Data

The data were modeled using analysis of variance with random effects for location, day within location, subject, and all interactions with subject. Variance components for each of the random effects was estimated and expressed as part of the total variation.

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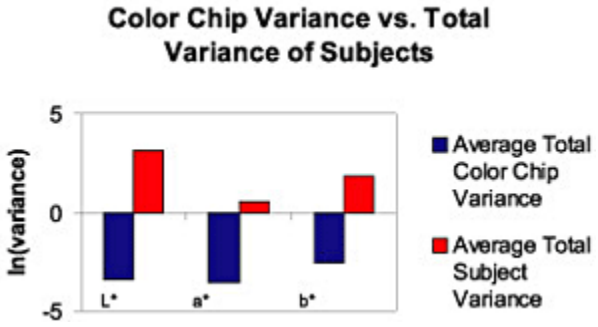
The results are displayed in Table I. The second column displays the mean color value from the PR650 reading averaged over all zones from all subjects. Columns 3-7 display the estimated variance component for the different sources in the ANOVA model: Location, Day within Location, Subject, Location by Subject, and Measurement Error. Note that the Measurement Error column gives the sum of two variance components: the Measurement Error variance component and the variance in repeat measurements of a Subject with the PR650 (where subjects are re-positioned for the replicates). Column 8 displays the total variation. The shaded entries in the table correspond to variance components that are significantly greater than zero at α = 0.05.

Differences between subjects was the largest contributor to the variance while the measurement error contribution was small. The L*a*b* variance of control chart color chips showed very small variance (all >0.1) relative to the subject teeth data, displayed in Chart 1.

Chart 1.

Color Value	Mean	Estimated Variance Component for Source: Location	Day within Location	Subject	Location by Subject	Msmt. Error	Total Variance
L*	71.9	0.06	-0.34	21.96	0.27	0.80	22.75
a*	6.3	0.01	-0.04	1.60	-0.01	0.11	1.67
b*	19.9	0.01	-0.07	5.90	-0.04	0.32	6.12



The measurement system is reproducible. Thus the variance seen with the subjects is due either to the subject positioning or differences in actual tooth color each day.

CONCLUSION

The mechanical robustness, and the precision of the system was demonstrated. This non-contact color measurement system, using broad-source illumination to reduce edge loss effects, was found to be repeatable in measuring intact human tooth color.

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