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The effect of enamel porcelain thickness on color and the ability of a shade guide to prescribe chroma

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ABSTRACT

Objective. To test the null hypothesis that there is no color change when enamel porcelain thickness is changed and to evaluate the ability of a shade guide to prescribe chroma.

Methods. Three shades (3M1, 3M2 and 3M3) were selected from a Vitapan 3D master shade guide. Five disk specimens were prepared for each shade, consisting of three layers (opacious dentin, dentin and enamel) at thicknesses of 0.6, 0.8 and 0.6 mm, respectively. The color of each disk was measured using a spectrophotometer. Enamel porcelain was reduced in thickness to 0.3 mm and porcelain disks were remeasured.

Results. Reducing the enamel thickness of porcelain disk specimens significantly increased L^* ($p < 0.05$), b^*, metric chroma and hue angle ($p < 0.001$). For the three shades studied (3M1, 3M2 and 3M3) L^* values were not significantly different ($p > 0.05$) and chroma increased for 3M1 with the lowest chroma to 3M3 with the highest chroma, which is in line with the shade guide specifications. Although statistically significant ($p < 0.001$) changes in hue angle between the three shades were small (less than 3° overall). The difference in chroma between the three shades 3M1, 3M2 and 3M3 was greatest for the thin enamel layer than the thick enamel layer.

Significance. A change in enamel thickness from 0.6 to 0.3 mm resulted in a three-unit change in L^* and metric chroma and a 4° change in hue angle. A change in enamel porcelain thickness will have a greater effect on higher chromatic shades than those with lower chroma. The ability of the shade guide to prescribe chroma was demonstrated but this could be offset by an anomalous enamel thickness.

1. Introduction

The increase in patient awareness and demand for aesthetic restorations is challenging for the dental team. Dentists are required to provide the laboratory with a correct shade match and the technicians have to reproduce this. The difficulty of an observer to perceive and reproduce a correct color match has previously been reported [1–3]. On the other hand, there are a number of variables in laboratory reproduction of the shade prescribed by the dentist. The thickness of different layers of porcelain, metal substrata and the porcelain batch are all factors, which may

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contribute to a color difference in the porcelain build up [4].

Whilst previous workers have studied the effect of thickness, firing, glazing, aging, metal or ceramic substrate with dentinal and opaque porcelain on the final color of restoration [4–15], the effect of enamel porcelain thickness has not been investigated.

Shade guides should have basic requirements in color matching including the logical arrangement within the color space and adequate distribution within color space of natural teeth [16]. The classical Vitapan shade guide, which is widely used only enables the clinician to prescribe hue (A–D). Value and chroma are linked together. When value decreases, chroma increases, i.e., A1 has high value and low chroma where A4 is the reverse. The Vitapan 3D-Master shade guide is a development of the Classical Vitapan shade guide, and is based on a systematic colorimetric principle of representing three-dimensional color space.

Evaluation of color can be achieved by two means: qualitative by subjective visual matching or quantitative (objective). The visually perceived color space consists of three-dimensions represented by lightness (black to white), hue (whether it is red, green, blue, etc.) and saturation or chroma (high chroma or saturation indicates a pure color, whereas, a low chroma or saturation indicates a color that contains more grey) [17]. In the Munsell color system, the three correlates of lightness, hue and saturation are value, hue and chroma [18]. This evaluation depends on the ability of human observers to detect color differences [1–3]. The CIE (Commission International de l'Eclairage) specifies methods for the instrumental measurement including illumination/viewing geometry and quantification of color [19]. The CIELAB color system describes the color of an object in terms of its position in three-dimensional space where the three axes are lightness (L^*), red–green axis (a^*) and yellow–blue axis (b^*). Quantitative measurement of L^*, a^*, b^* can be obtained from reflectance spectrophotometers or colorimeters with standard CIE illumination viewing geometry [19]. However, their intraoral use has some limitation related to the size, curvature of teeth, and the color difference across the tooth surface [20]. A number of dental color measurement instruments are available in the dental market, which may improve the shades of dental restoration but validation studies are needed to support their use.

There is very limited scientific literature available regarding the layering of dental porcelain and the effect upon the resultant color. Therefore, the aims of this study were to test the null hypothesis that there is no color change when enamel porcelain thickness is changed and to evaluate the ability of a shade guide to prescribe chroma.

2. Materials and methods

Three shades (3M1, 3M2 and 3M3) were selected from the 3D shade guide (Vitapan 3D-Master VITA Zahnfabrik, Bad Säckingen, Germany). This shade guide consists of 26 shades (compared to 16 shade tabs in the original), arranged (as claimed by manufacturers) in five levels of lightness (1–5). Within each lightness, there are three hue groups [L, M, R], with some limitation. For M-hue at a specific lightness level, shades only differ in chroma. For example, for shade 3M2, the first number (3) represents level 3 lightness, the letter M represents M hue and the last number (2) represents level 2 chroma. The selected shades were chosen as they are specified as representing three levels of chroma of the same hue and value. A total of fifteen disk specimens of the three shades of dental porcelain were constructed and all disk specimens were initially 2 mm thick to simulate the clinical thickness. They consisted of three layers each of 0.6 mm opacious dentin, 0.8 mm dentin and 0.6 mm enamel porcelains (Vitadur Alpha, VITA Zahnfabrik, Bad Säckingen, Germany). The layers were obtained at consistent thickness by using a set of master patterns. Five disk specimens were prepared for each of the shades to determine variations in color between samples of the same shade.

2.1. *Preparation of refractory casts*

A 22 mm diameter stainless steel washer of 2 mm thickness with an internal diameter of 12 mm was mounted on a lathe and the inner surface turned to widen the inner diameter to 13 mm at a depth of 0.6 mm. A second similar adjustment was made on the opposite side of the washer leaving a ridge 0.8 mm thick (Fig. 1a). A wax cylindrical disc was secured to one side of this washer with sticky wax (Fig. 1b). An impression was then taken of the washer using polyvinylsiloxane impression material (Fig. 1c). Following removal of the original washer the original washer and wax base was removed and the mould inverted (Fig. 1d). Refractory material (Vitadurvest VITA Zahnfabrik, Bad Säckingen, Germany) was mixed using a vacuum mixer (30 g powder, 7 ml liquid) and poured into the impression. The refractory casts were fired in a furnace (Dentsply DeTrey, Dreieich, Germany) according to the manufacturer's recommendations. A total of 15 refractory casts were produced for porcelain disk construction (Fig. 1d).

2.2. *Porcelain build-up*

Each step in the inner surface of the refractory cast was marked around the rim with red-wax pencil to improve visibility before soaking them in water prior to the porcelain build-up. The porcelain powders were mixed with porcelain molding liquid and a blue food dye so that they could be distinguished from the white background of the refractory material. A moistened brush was used to apply each porcelain layer in small increments until it reached its step level. The porcelain disk specimens were fired in a porcelain furnace (Dentsply DeTrey, Dreieich, Germany) after each build-up according to the manufacturer's recommendations. A corrective build-up for each porcelain layer and a second firing was necessary to compensate for firing shrinkage. After the three-layer build-up of dental porcelain (opacious dentin, dentin and enamel) had been completed, the disk specimens were then placed in the furnace for glaze firing (according to the manufacturer's instructions).

2.3. *Color measurements*

Reflectance spectra data were measured for the fifteen porcelain disk specimens with 0.6 mm enamel layer thickness. The