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Elaboration of Recipes for 3D - Printing Resins, Reproducing Proportionally and Properly the Color Standards

Delyan Georgiev[1], Magdalena Gugleva[2]

[1]Department of Dental Materials Science and Propaedeutics of Prosthetic Dental Medicine, Faculty of Dental Medicine, Medical University of Varna
Email: *dr.delyan. georgiev[at]gmail.com*

[2]Department of Clinics of Prosthetic Dental Medicine, Faculty of Dental Medicine, Medical University of Varna
Email: *magdalena.gugleva[at]yahoo.com*

Abstract: ***Purpose: The aim of the research was to achieve recipes of 3D - printing resins for provisional restorations that provide wide choice of shade colors. Methods: Three types of resins: White Resin®, Model Resin® and Dental LT Clear Resin® (Formlabs™) were combined and mixed in different proportions. After the polymerization process the shade of each samplethe values: Color difference (ΔE), Chroma, Value and Hue was measured using a color measuring device VITA Easyshade®. Results: The shades B1, B4 and C4 can be easily reproduced by the newly created resins for temporary restorations. The results about shades A4, B2, B3 and D4 deviate from the acceptable norm for color difference (ΔE≤5.0). Conclusion: The created resins have limitations in reproducing of a greater variety of shades and the choice is limited up to seven primary colors. Only three of them find place within the tolerance of color deviation and are unnoticed to the untrained eye of the patient.***

Keywords: prosthetic dental medicine, 3D - printing, tooth shade

1. Background

One of the main elements of aesthetics in Prosthetic dentistry is the achievement of a color that is as close as possible to the natural color of the dentition. The need of available color shades that covers a wide range of the color spectrum of natural dentition, for provisional restorations remains an unresolved issue. The introduction of additive technologies in prosthetic dentistry provides an opportunity to improve and optimize the technological process in the manufacture of temporary restorations [1].

The color of the teeth becomes darker, with aging and turns more yellowish and reddish. Certain basic shades dominate in different population groups depending on age and gender. In the studies conducted in the Korean population the most common colors are 2L1.5 and 2M2 according to the Vita 3D Master Shade guide and A2 to the Vita Classic Shade guide. In similar studies the most common tooth shade in the Spanish population is 3M1, in the United States is 3R1.5, and A3 in the United Kingdom [2, 3, 4, 5]. Women have lighter and less chromatic teeth compared to men in different age groups, which is due to the smaller size of their teeth and the less amount of dentin.

The acrylic and composite resin materials for conventional methods of making temporary restorations are available in limited colors and are offered mainly in shades as A2 and A3, which are the most common in populations.

The cutting discs and blocks for the CAD/CAM technology offered by different manufacturers are mainly in colors A2, A3 and A3.5 or 1M2, 2M2 and 3M2 [6]. In recent years with the development of the additive technologies, theprinting resins for temporary restorations have been offered in colors as A2, A3, B1, C2 [7].

Although these materials cover the most common tooth shades in populations, they do not cover a wider range of colors. This could lead to a compromise in the choice of shade of this part of the patients with a different from the available shade and this way to mismatch and dissatisfaction.

Through the measurement by spectrophotometers and colorimeters, the subjective processes in the color determination can be eliminated. These devices are used to overcome problems with the visual shade matching. They help to obtain fast, accurate and objective results. Different studies show significantly less deviation of ΔE in the color of prosthetic restorations determined with spectrophotometers or colorimeters then using subjective technique with dental shade guides [8, 9, 10, 11]. The shade of the temporary restorations depends of the type of material used for their printing. The purpose of the study is to examine the presence of regularity, variety and proportionality in the obtained colors, obtained by combination of different resins for 3D printing with different colors and mechanical - strength properties [12, 13, 14].

2. Materials and Methods

Three resins were used: White Resin®, Model Resin® and Dental LT Clear Resin® (Formlabs™) in different combinations and proportions between them.

For this purpose they were divided into three groups:

- White Resin® – Model Resin®;
- White Resin® - Dental LT Clear Resin®;

- Model Resin® - Dental LT Clear Resin®.

Each group was divided into nine subgroups depending on the ratio of concentrations in them. The proportions were equated to a total volume of 2 ml as follows:

- White Resin® – Model Resin®: 9: 1, 8: 2, 7: 3, 6: 4, 5: 5, 4: 6, 3: 7, 2: 8, 1: 9;
- White Resin® - Dental LT Clear Resin®: 9: 1, 8: 2, 7: 3, 6: 4, 5: 5, 4: 6, 3: 7, 2: 8, 1: 9;
- Model Resin® - Dental LT Clear Resin®.: 9: 1, 8: 2, 7: 3, 6: 4, 5: 5, 4: 6, 3: 7, 2: 8, 1: 9;

An automatic pipette with variable volume Plastomed VARI 3000 W. was used for precise dosing of the proportions of the test samples. The resulting mixture was stirred until the color of the resins was homogenized and placed in transparent plastic blister (Fig.1). The test samples were placed for photopolymerization in the device Form Cure® for 60 min at 60 °C (Fig.2). After the polymerization process was completed (Fig.3), the shade and its characteristics: value, chroma and hue of each sample was measured using a color measuring device VITA Easyshade®V. The obtained data were registered, recorded and subjected to statistical processing (Fig.4 and Fig.5).

Figure 1: Placement of the mixed resin in the transparent plastic blister

Figure 2: Photopolymerization of the test samples in Form Cure®.

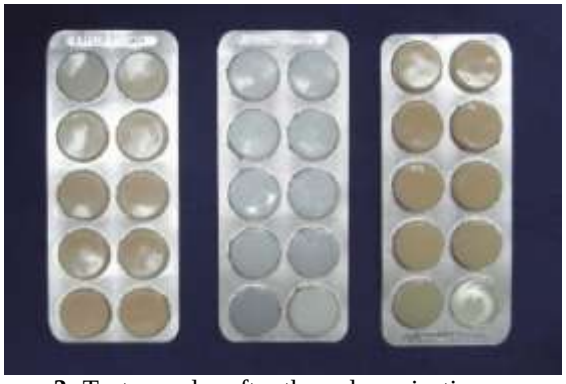

Figure 3: Test samples after the polymerization process is completed

Figure 4: Shade measuring of the test samples using VITA Easyshade®V

Figure 5: The measured values of a test sample - ΔE, value, chroma and hue

3. Results

In the first group the results of mixing White Resin® with Model Resin® are presented in Fig.6.

In the second group the results of mixing White Resin® with Dental LT Clear Resin® are presented in Fig.7. White Resin® /
Dental LT Clear Resin® ratio 0.1 ml / 0.9 ml was not recognized as a color by the shade measuring device.

In the third group the results of mixing Model Resin® with Dental LT Clear Resin®are presented inFig.8.

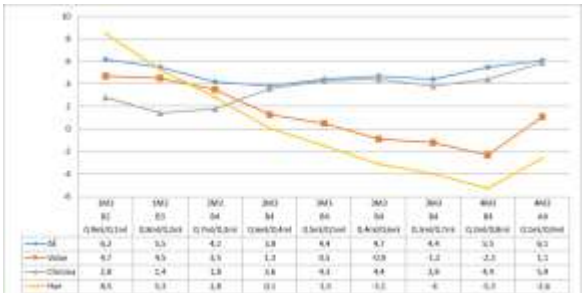

Figure 6: Variation in shade characteristics in the White Resin® / Model Resin® group

Figure 7: Variation in shade characteristics in the White Resin® / Dental LT Clear Resin® group

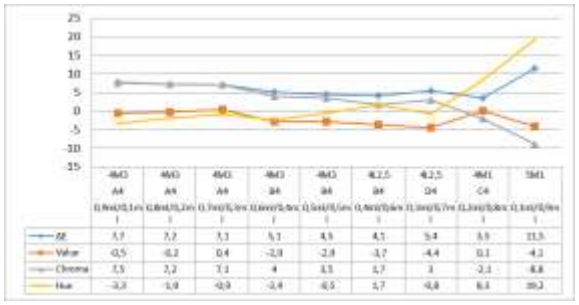

Figure 8: Variation in shade characteristics in the Model Resin® /Dental LT Clear Resin® group

White Resin / Model Resin in ratio 0.1ml / 0.9ml is close to shade A4 according to VITA Classic and shade 4M3 according to VITA 3D Master (ΔE = 6.1)

White Resin / Dental LT Clear Resin in the ratio 0.6ml / 0.4ml is close to shade B1 (VITA Classic) and shade 0M1 (VITA 3D Master), where ΔE is 4.8.

Although there is a significant difference in the color deviation shade B2 according to VITA Classic and 1M3 according to VITA 3D Master was achieved only in one combination White Resin / Model Resin in the ratio 0.9ml / 0.1ml (ΔE = 6.2)

Color B3 (VITA Classic) and 1M2 (VITA 3D Master) was also achieved in one combination White Resin / Model Resin in the ratio 0.8ml / 0.2ml, where ΔE is 5.5, slightly above the accepted deviation limit.

The combination White Resin / Model Resin in the ratio 0.6ml / 0.4ml is close to shade B4 according to VITA Classic and shade 3M3 according to VITA 3D Master. (ΔE = 3.8)

Shade C4 (VITA Classic) and shade 4M1 (VITA 3D Master) was achieved only in one combination White Resin / Model Resin in the ratio 0.9ml / 0.1ml, where ΔE is 3.5.

Shade D4 according to VITA Classic and shade 4L2.5 according to VITA 3D Master was achieved only in one combination White Resin / Model Resin in the ratio 0.9ml / 0.1ml. (ΔE = 5.4).

4. Discussion

The clinically acceptable color deviation limit (ΔE) varies in different studies. The limit criteria adopted in the present study (ΔE ≤ 5) is commonly used in determination of shade differences, which is due to the parameters of the shade measuring device.

Other authors define the limit values of ΔE ≤ 3.3 or ΔE ≤ 2.7. As there is still disagreement about the gold standard for the color deviation limit and further researches are needed. This will help clinicists to rate better the clinical cases. Values of ΔE that are less than 1.0 are considered to be invisible to the human eye. When ΔE is between 1.0 and 5.0 the differences are noticeable to trained professionals but are clinically acceptable. While values of ΔE are 5.0 and above, they are considered to be perceived by untrained observers, such as patient. Therefore, they are determined as unacceptable.

The results in this study for the color determination of the test samples confirm the initially formulated hypothesis that the different combinations of the three initial resins affect the final color and cover a wide range of possible shades. This guarantees high aesthetic qualities of the constructions by choosing appropriate shade as close as possible to the natural shade of the patient's teeth.

5. Conclusion

Based on the results of these tests and analyzes it can be assumed that the shades B1, B4 and C4 can be reproduced easily by the newly created resins for temporary restorations. The results about shades A4, B2, B3 and D4 deviate significantly from the acceptable norm for color difference, which is visible to the patient and is associated with a possible unsatisfying clinical aesthetic outcome. The newly created resins have limitations in reproducing of a greater variety of shades, and the choice is limited up to 7 primary colors. Only 3 of them find place within the tolerance of color deviation and are invisible to the untrained eye of the patient.

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