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Original article

COLOR CHANGES OF 3D PRINTED AND CONVENTIONAL DENTAL RESINS FOR REMOVABLE PROSTHODONTICS AFTER IMMERSION IN DIFFERENT STAINING AGENTS

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ABSTRACT

Introduction: The discoloration of the denture base resins is one of the shortcomings of this type of dental materials, and it could be determined through various visual and instrumental methods.

The aim of the current study was to evaluate the color stability of 3Dprinted and conventional denture base resins after immersion in different staining solutions.

Materials and methods: A total of 200specimens were manufactured from two types of materials: 3D printed dental resin NextDent Denture 3D+ (NextDent, 3D Systems, The Netherlands) and heat-polymerized PMMA Vertex (3D Systems, The Netherlands), which were immersed in four types of colorants - artificial saliva, coffee, red wine and coke (n = 25). For measuring the color changes (CIE-L*a*b* system) of all specimens after storage in artificial saliva for 24 h at 37 degrees C (T0), a spectrophotometer SpectroShade Micro (SpectroShade, USA) was used. After seven days (T1), 14 days (T2) and 21 days (T3), the mean ΔE values were calculated and compared by Bonferonni post-hoc test. The data were processed using thestatistical software SPSS 26. The level of significance forrejecting the null hypothesis was fixed at p<0,05.

Results: The values for ΔE were investigated, and the interactions between the type of material,the immersion time and the different staining solutions were statistically significant. The highest mean for ΔE was evaluated for both types of dental resin in red wine. Respectively, 3D printed specimens in artificial saliva were with the lowest mean.

Conclusions: The 3D printed denture base resin demonstrated better color stability than the conventional acrylic materials. The staining effect correlated with the immersion time, with the red wine and coke being with the most chromogenic impact and the period with the highest color changes being 21 days.There was a significant interaction between theselected time periods and the type of staining agent, as both types of dental materials showedchanges in color stability at T1 compared to T3.

Keywords: 3D printing, color changes, removable prosthodontics, PMMA, dental resins, staining agents

INTRODUCTION

Removable dentures are still a preferred treatment option for edentulous patients by a lot of dental specialists. They can be manufactured by the conventional method, using heat-polymerized polymer polymethyl methacrylate (PMMA), injection molding or the CAD /CAM method – using subtractive or additive manufacturing [1]. Digital fabrication technology, also referred to as 3D printing or additive manufacturing (AM), is a widely applied method which is based on stereolithography (SLA), and the objects are printed through the 3D printer layer by layer [2]. This method is used for fixed and removable prosthodontic restorations, orthodontic aligners, surgical guides and implants [3, 4].

Dental resins for removable dentures undergo color changes over time due to different staining factors, because of the fact, that they are in constant interaction with oral fluids, food and beverages [5].According to numerous studies, 3D printed dental resins have better color stability than conventional PMMA (polymethyl methacrylate) resins for removable prosthodontics [6]. Color stability is an important property of denture base resins because it ensures the aesthetical appearance and patients' comfort [7].

In comparison with the conventional heat-polymerized PMMA for removable dentures, 3D printed dental resins have a number of advantages, such as simplified laboratory protocol, time effectiveness and more efficient planning of the prosthetic restoration [8]. The shortcomings of both types of dental materials include discoloration over time, which affects negative the aesthetics and the long-term success of the prosthetic treatment [9].

Color determination is possible via different visual and instrumental methods. The visual method consists of a clinical evaluation of the dental practitioner, using different color shade guides [10]. In comparison, the instrumental techniques are more accurate and exclude the pos-

sibility of subjective errors. They include colorimeters and spectrophotometers, which are detecting color values, according to the CIE Lab coloring system. The CIE L*a*b* system defines the color space with both chromatic value and saturation of the L*a*b* coordinates: L* measures color bleaching (a value of 100 corresponds to perfect white and 0 to black); a* color in the red (a* > 0) and green (a* < 0) dimensions; and b* measures color in the yellow (b* > 0) and blue (b* < 0) dimensions [11].

The aim of this in-vitro study was to investigate the color changes, occurring in these two types of denture base resins in various staining solutions, for the selected time periods.

MATERIALS AND METHODS

For the purpose of the current study, 200 samples were prepared in the shape of a parallelepiped with dimensions of 20 mm by 20 mm in width and length and respectively 3 mm in cross-sectional diameter. The shape and size of the test specimens were designed according to the predetermined criteria using non-parametric software (Free CAD Version 0.19), and a .STL file was created for this purpose.

Two groups of specimens were manufactured, respectively - 100 pieces of each type of dental resin. The first group of experimental samples was made from Vertex BasiQ (Vertex Dental, 3D Systems, The Netherlands) heat-polymerizing acrylic by a conventional flasking method. The second group of experimental bodies were made by the 3D printing method from dental resin for removable dentures of NextDent Denture 3D+ (NextDent, 3D Systems, The Netherlands). From each group, we divided the experimental samples into 4 subgroups (n = 25), which we immersed in four different types of staining solutions – artificial saliva, coffee, Coca-Cola and red wine. The artificial saliva was prepared according to a preliminary recipe by a chemist. The coffee was prepared according to the manufacturer's instructions (Nescafe, Nestle, Switzerland) and placed after cooling in a glass container. Red wine (Mezzek Merlot, Katarzyna Estate, Bulgaria) and coke (Coca-Cola, Coca-Cola HBC) were purchased and also placed in identical glass containers. The solutions were 200 ml each and were replaced with new ones every day. The study was conducted at room temperature, and changes in the color of the materials were recorded on day 7, day 14 and day 21 by spectrophotometric analysis. For this purpose, a spectrophotometer SpectroShade Micro (SpectroShade, USA) was applied. Before each measurement with the apparatus, the experimental samples were washed with distilled water. Excess water on the surfaces of the samples was removed with a paper towel and allowed to dry.

The color changes of the test specimens were determined by the Commission Internationale de l'Eclairege L*a*b* (CIELab) system using visible UV light. The CIE L*a*b* values were measured for each test specimen three times to eliminate the possibility of an error and to calculate the average value for each test body.

According to the ISO/TR-28642:2016 standard, reported ΔE values that are ≤ 1.2 are accepted as the lower sensitivity threshold, and ΔE values between 1.2 and 2.7 are considered clinically acceptable. Any ΔE values that are above 2.7 are not clinically acceptable. The obtained results were recorded in tables and analyzed using the IBM SPSS 26 statistical package.

RESULTS

The results were obtained and summarized in Tables 1 and 2 - the mean and the standard deviation of the color changes (ΔE), of two types of denture base resin, after immersion for three periods of time (7, 14, 21 days) in four different types of staining solutions (artificial saliva, coke, red wine, coffee) were evaluated.

Table 1. Scheme of the experiment organization – color changes values of the selected materials

Type of material	Period of time (T)	Artificial Saliva ΔE (mean)	Coffee ΔE (mean)	Coca-cola ΔE (mean)	Red Wine ΔE (mean)
NextDent Denture 3D+	7 days (T1)	0,498	2,129	2,676	3,016
Vertex BasiQ		0,512	2,328	2,867	3,268
NextDent Denture 3D+	14 days (T2)	0,471	2,194	2,722	3,163
Vertex BasiQ		0,484	2,576	2,966	3,508
NextDent Denture 3D+	21 days (T3)	0,462	2,269	2,875	3,312
VertexBasiQ		0,457	2,793	3,158	3,866

The Bonferroni post-hoc test was applied to assess the interaction effect of the type of denture resin, immersion time and type of staining agent on the color stability. ΔE of all denture base materials wasaffected by the immersion period. The coloring solution, especially combined with the period of time, significantly affected the values of ΔE for all types of specimens (Table 2). The selected interval of confidence was 95%.

Table 2. Multiple comparisons - Bonferroni post – hoc test

Multiple Comparisons						
Dependent variable; ΔE						
Bonferroni post – hoc test						
(I) Period	**(J) Period**	**Mean Difference (I-J)**	**Std. Error**	**P**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
7	14	-.098750	.0685752	.504	-.280817	.083317
	21	-.237250*	.0685752	.009	-.419317	-.055183
14	7	.098750	.0685752	.504	-.083317	.280817
	21	-.138500	.0685752	.178	-.320567	.043567
21	7	.237250*	.0685752	.009	.055183	.419317
	14	.138500	.0685752	.178	-.043567	.320567

Based on observed means.The error term is Mean Square(Error) = .019.
*. The mean difference is significant at the .05 level.

The results in figure 1 represent the interaction between the type of material and immersion time, showing the lowest values for the first week for both of the tested materials and the highest values of color changes were for Vertex for the duration of three weeks, respectively.

Fig. 1. Interactive plot for mean color difference – interaction between type of material and immersion time

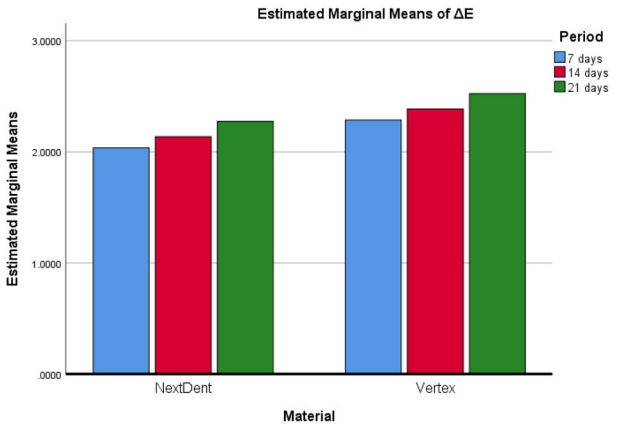

Fig. 2. Interactive plot for mean color difference – interaction between type of material and staining medium

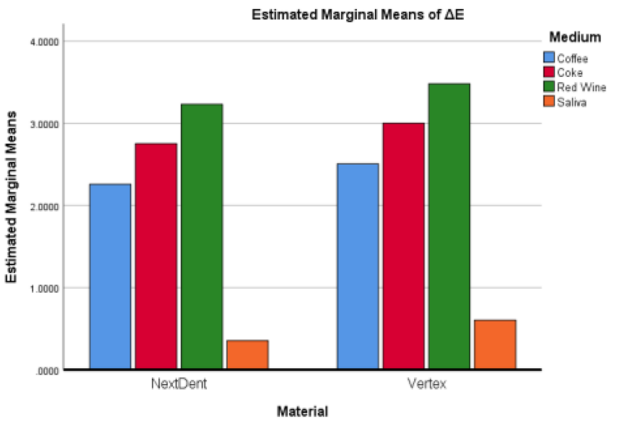

Figure 2 represents the interaction between the staining agent and the type of tested material. The color changes for red wine, coffee and coke gradually increased during the three weeks of the observation, as they were the highest after the 21st day. The discoloration effect of the artificial saliva between the selected periods of time was not significant for both groups of specimens.

DISCUSSION

In this in-vitro study, the color changes of 3D printed and conventional heat-cured denture base resins were investigated. They were immersed in four staining agents for three periods of time - 7, 14 and 21 days. The results demonstrated that the different duration influenced the ΔE of all specimens. Furthermore, the type of staining agent interacted significantly with the selected immersion periods. Therefore, the null hypothesis that there would be no major color difference in any of the tested materials, irrespective of the staining medium and duration of immersion can be rejected.

Our surveys results were supported by the findings of other authors [12, 13]. A lot of researchers investigated dental materials immersed in different colorants, which suggests the necessity for standardization of the method. According to the study of Alfouzan et al., the color stability of 3Dprinted denture resins was better compared to conventional PMMA for the selected periods of time [14]. Dyumus et al. discovered that after one week all of the specimenshad significant color changes, with a steady increase for the other immersion periods [15]. The discoloration effect of the artificial saliva was investigated by a number of authors, which evaluated that there was a slight decrease in the delta E values with the progress of time [16, 17]. This rate shows only a light degree of discoloration, which indicates a negligible change in the color stability of the tested materials.

According to the survey of Hipolito et al., coffee and coke were the staining agents, demonstrating the highest coloring effect without any major differences [18]. However, our findings showed that the highest values for staining are for the red wine for all immersion periods in both of the tested groups, which was in agreement with the studies of Sarkis et al., and Gregorius et al. [19, 20].

CONCLUSIONS

In the current study, the values of NextDent were slightly lower for all coloring solutions, in comparison with Vertex, showing the better color stability of the 3D printed denture base resins. The red wine and coke were with the most significant impact and the period with the highest color changes was 21 days. There was a significant interaction between the immersion periods and the type of staining agent, as both groups of specimens demonstrated changes in color stability at T1 compared to T3.

Abbreviations:

AM – additive manufacturing

CAD/CAM - computer-aided-design/computer-aided – manufacturing

PMMA – polymer polymethyl methacrylate

SLA - stereolithography

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