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BASIC RESEARCH:

Effect of Temporary Cement on the Color of Temporary Crowns Made by Conventional Pressing Methods and Substractive CAM/CAD Technologies

Efecto del cemento temporal sobre el color de las coronas temporales realizadas mediante métodos de prensado convencionales y tecnologías sustractivas CAM/CAD

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ABSTRACT: The color stability of temporary restoration is crucial, especially in sensitive areas in terms of aesthetics. This research aimed to determine the effect of temporary cement on the color of temporary crowns made by conventional pressing methods (indirect) and CAM/CAD technologies using milling machines and 3D printers. This study was carried out in a laboratory, utilizing A2 color in all manufacturing methods. The color of the restorations was measured by a spectrophotometer after cementation with semi-permanent resin cement. Subsequently, color changes of the samples (ranging from 0 to 100) were calculated using the Commission International de l'Eclairage (CIE) Lab system. Data analysis was based on descriptive statistics methods and statistical tests, including one-way analysis of variance (ANOVA) and Tukey's post hoc test. According to the results of ANOVA, there was a significant difference between the three groups in terms of the 'a' and 'b' indexes ($P<0.001$). However, regarding the 'l' index, no significant difference was observed among the three groups ($P=0.250$). Also, based on Tukey's post hoc test, a significant relationship was seen between the first and second pairs in the 3D printer group, and between the first and third pairs in the milling group ($P<0.001$). However, no significant difference was observed in the conventional pressing group. The results showed that the

3D printing method exhibited the highest amount of color change among the three methods, while the milling method demonstrated the lowest amount of change.

KEYWORDS: Temporary cement; Temporary crowns; Press (indirect); CAM/CAD, 3D printer.

RESUMEN: La estabilidad del color de la restauración temporal es muy importante, especialmente en zonas sensibles desde el punto de vista estético. En la presente investigación, el objetivo fue determinar el efecto del cemento temporal sobre el color de coronas temporales realizadas mediante métodos de prensado convencionales (indirectos) y tecnologías CAM/CAD utilizando fresadora e impresora 3D. Este estudio se llevó a cabo en un laboratorio y se utilizó color A2 en todos los métodos de fabricación. El color de las restauraciones se midió mediante un espectrofotómetro después de cementarlas con cemento de resina provisional. Luego se calcularon los cambios de color de las muestras (de 0 a 100) utilizando el sistema CIE Lab. El análisis de los datos se basó en métodos de estadística descriptiva y pruebas estadísticas, incluido el análisis de varianza unidireccional (ANOVA) y la prueba post hoc de Tukey. Según los resultados del análisis de varianza unidireccional, hubo una diferencia significativa entre los tres grupos en términos de los índices a y b (P<0,001), pero en términos del índice l, no hubo diferencias significativas entre los tres grupos (P=0,250). Además, según la prueba post hoc de Tukey, se observó una relación significativa entre el primer y el segundo grupo de impresoras 3D y entre el primer y el tercer grupo de fresado (P<0,001). Sin embargo, no se observó ninguna diferencia significativa en el grupo de prensado convencional. Los resultados mostraron que el mayor cambio de color entre los tres métodos fue con el método de impresión 3D, y la menor cantidad fue con el método de fresado.

PALABRAS CLAVE: Cemento provisional; Coronas provisionales; CAM/CAD; Impresora 3D.

INTRODUCTION

One of the most crucial procedures in fixed prosthesis treatments is the creation of temporary crowns. There may be a delay of several weeks between the preparation of the tooth and the cementing of the permanent crowns due to the necessity for laboratory procedures in crown and fixed bridge preparation. Therefore, it is necessary to make a temporary cover to protect the subject tooth during this period. These crowns have many advantages, including protecting the pulp, providing periodontal health, maintaining the position of the tooth, preventing movement of the tooth or its opposing counterpart, and generally maintaining the tooth until final restoration (1). Temporary crowns and final fixed prostheses, together complete the treatment process for fixed dental prostheses. The principles of using temporary crowns include pulp protection, marginal compatibility, wear resistance, and aesthetics. The appearance of temporary restorations in exposed areas holds particular significance, and evaluation of the treatment result is vital for the patient (2). From an aesthetic standpoint, the color of temporary restoration is crucial, especially in sensitive areas (3), and it is important to have an understanding of the scientific principles relating to color, which can increase the appeal of restoration (4).

There are many types of temporary cements; the richest ones include eugenol-based,

non-eugenol-based, and resin-based. Due to the presence of eugenol and its negative effects, the original temporary cements prompted the development of new types, including resin cements. Eugenol, in small amounts, has therapeutic, antimicrobial, and analgesic effects on the pulp (5). Essential features of a temporary cement include suitable availability for temporary restoration, easy removal of excess cement, suitable working and setting time, easy removal of cement from inside the temporary cover and from the tooth if needed, biocompatibility with the soft tissue of the gums and dental pulp, non-interference with the ultimate restoration, and long-term durability (6). Temporary restorations can generally be made and prepared in two different ways: one performed inside the patient's mouth (direct method), and the other made on a plaster cast (indirect method) (7).

Digital technology has significantly transformed all facets of life, including dentistry. The use of digital technology in dentistry has grown in popularity for a variety of reasons, including speeding up the creation and delivery of restorations (8). In recent years, technology based on CAM/CAD has become common, usually including three stages: 1) data collection or digitization; 2) data processing (CAD); and 3) production (CAM) (9-12). In comparison to restorations carried out directly, those manufactured using this method are stronger and more precise (9, 13). However, in this system, the range of milling movements and the size of milling cutters create limitations, which are among the disadvantages of this method (14). 3D printing is a layered construction method used to create 3D models of a wide range of structures with complex shapes (15). It has gained popularity in different fields of dentistry, such as making dental models, surgical guides, various dental veneers, and the process of implanting (16).

Barghi *et al*. in their research on the effect of Reline on the accuracy of the edge coordination of temporary crowns, found that the lack of optimal coordination of acrylic temporary crowns is caused by the inherent shrinkage due to their polymerization (17). In a study, Yildirim *et al*. used the color formula CIEDE2000 (ΔE00) to measure translucency and color changes, and they observed that LDS and ZLS ceramics have similar translucency, with significant color changes induced by cement and composite backgrounds in both groups (18). Also, Tabatabaian *et al*. used four cements: Glass Ionomer, Panavia F2.0, Zinc Phosphate, and TempBond with a thickness of one millimeter, noting a statistically significant difference in color differentiation between Zinc Phosphate and TempBond, while Glass Ionomer and Panavia F2.0 did not show a significant difference (19). While there are many different types of temporary cements, the most common ones include eugenol-based, non-eugenol-based, resin-based, and eugenol-based. The initial temporary cements led to the introduction of other types due to the content of eugenol and its negative effect on resin cements. Eugenol, in small amounts, has therapeutic, antimicrobial, and analgesic effects on the pulp (7, 20). Given that prior studies have predominantly focused on the effect of permanent cements on the color of ceramic restorations, with temporary cements receiving limited attention in the context of temporary crown restorations. Therefore, in this research, the effect of temporary cement on the color of temporary crowns made by conventional, additive, and substractive CAD/CAM technologies was evaluated, using both milling machines and the 3D printers.

MATERIALS AND METHODS

This study was conducted at the Hamadan Faculty of Dentistry laboratory in 2019. In this study, 36 temporary restorations were divided into three groups of 12 each (21). To create the main model, a 9.5mm long and 4mm diameter SIC Invent AG implant fixture was fixed and

mounted in the upper right canine using a denticle. Subsequently, a standard abutment of type code 936163 (Switzerland, Basel; AG Invent) was affixed to it in a die-like form. Methyl methacrylate was then applied to the desired abutment. To create temporary digital restorations, the Trios 3shape dental scanner was employed, and the final restoration design was crafted using GMBH (2016 Exocad) software.

For the conventional method of making temporary restorations, the canine abutment was waxed, the required index of Tus Poti was prepared, and 12 temporary restorations made of polymethyl methacrylate (JAPAN, TOKYO; GC) (Tempron GC) were made on the desired abutment. Dentic Birch was scanned using a Trios 3Shape scanner to create temporary digital restorations, and the final Birch restoration design was created using the CMBH 2016 (Exocad) program. To make restorations through the milling method, 12 temporary restorations were cut from prepared blocks of polymethyl methacrylate (Japan, CO, MFG DENTAL YAMAHACHI), utilizing a birch milling machine (Korea, Dentium), and Mill™ rainbow. To make the samples by 3D printer method, the designed file was transferred to the printer. Prior to transferring the samples to the printer, the following steps were taken:

Cleaning printed parts: The printed parts were immersed in ethanol/Isopropyl alcohol and washed using the post-wash-cure system for at least 15 minutes. Subsequently, the cleaned parts were again cleaned in ethanol/Isopropyl alcohol using an ultrasonic bath for not more than 4-5 minutes, as exceeding this time frame may result in defects in printed parts.

Finishing: After cleaning and drying, the printed parts were rested for at least 10 minutes to make sure that they were free of ethanol/Isopropyl alcohol residue. Any support structures from the printed parts were removed using a plastic spatula.

Post-Curing: The printed parts were placed in a post-wash-cure system for final polymerization. Post-curing is an UV-light treatment to ensure that printed parts obtain optimal polymer conversion. Through this, the residual monomer is reduced to a minimum, and the required mechanical properties are obtained. This procedure is necessary to achieve the desired material properties using the post-wash-cure system. To obtain stable cured parts, a prescribed curing time of 45-60 minutes was used; furthermore, an additional 15 minutes of exposure at a temperature of 60 °C/140 °F was given to the cured parts. The dispensed material was not returned to the container, and the dose, once applied and used, was not reused.

Next, samples were printed with digital light processing technology (Iran, Tabriz, Mecatronic Bonyan Product). Then, the base color of the restorations was measured by a spectrophotometer. In this study, A2 color was used in all manufacturing methods. The color of the restorations was re-measured with a spectrophotometer

after cementing them with resin cement. After that, the amount of color change (l: degree of brightness ranging from 0 (black) to 100 (white), a: red versus green, which shows a positive number in red and a negative number in green, and b: yellow against blue, which shows a positive number in yellow and a negative number in blue) in the samples using the CIE Lab system was determined. Data analysis was based on descriptive statistics methods and statistical tests, including one-way analysis of variance (ANOVA) and Tukey's post hoc test. A significance level of 0.05 was considered, and SPSS version 21 software was used for analysis.

RESULTS

Table 1 shows the mean and standard deviation of the color coordinates before and after cementing. ANOVA showed a significant difference in color coordinates among the three methods of fabrication of temporary crowns ($P<0.05$).

In general, the mean color changes in all three groups were obtained for a:

-7.57 ± 10.34, b: -5.34 ± 8.46, and l: -1.21 ± 2.5.

The Tukey's post hoc test for pairwise comparisons of color changes before and after cementing in each group is shown in Table 2.

The results of Tukey's post hoc test indicated a significant relationship between the first and second pairs in the 3D printer group (P-value<0.001). Also, a significant difference was observed between the first and third pairs in the milling group. However, no significant difference was observed in the pressing group (P>0.005).

Table 1. Mean and standard deviation of color coordinates before and after cementing.

	Group		Mean ± standard deviation	Number
Press	The first pair	a before	-.20 ± .59	12
(indirect)		a after	.01 ± .61	12
	The second pair	b before	23.15 ± 2.58	12
		b after	21.99 ± 2.30	12
	The third pair	l before	77.09 ± 2.16	12
		l after	77.93 ± 2.19	12
3D printer	The first pair	a before	-2.58 ± .34	12
		a after	19.35 ± 1.48	12
	The second pair	b before	2.32 ± .34	12
		b after	18.80 ± 1.95	12
	The third pair	l before	85.20 ± .61	12
		l after	85.80 ± .64	12
Milling	The first pair	a before	-1.00 ± .27	12
		a after	-.43 ± .31	12
	The second pair	b before	19.44 ± .71	12
		b after	20.15 ± 1.77	12
	The third pair	l before	78.21 ± .75	12
		l after	80.40 ± 1.80	12

Table 2. Comparison of color changes before and after cementing

	Group		Mean ± standard deviation	P value
Press	The first pair	a: before - after	-.225± .90	.408
(indirect)	The second pair	b: before - after	1.15± 3.83	.318
	The third pair	l: before - after	-.84± 3.64	.440
3D printer	The first pair	a: before - after	-21.94± 1.46	.000
	The second pair	b: before - after	-16.48 ± 2.10	.000
	The third pair	l: before - after	-.60± 1.09	.083
Milling	The first pair	a: before - after	.-.56± .33	.000
	The second pair	b: before - after	-.70± 1.92	.229
	The third pair	l: before - after	-2.19 ± 1.97	.003

DISCUSSION

Making temporary crowns is one of the most important steps in fixed prosthesis treatments. The preparation of crowns and fixed bridges usually requires laboratory procedures, which can cause a gap of several weeks between the tooth preparation and the cementing of the permanent crowns. Therefore, it seems necessary to make a temporary cover to protect the subject tooth during this period (22).

Temporary restorations are used to protect the pulp from heat, mechanical stress, and bacterial contamination. As methyl methacrylate-based resin has low mechanical properties, attempts have been made to enhance its strength by adding materials such as glass, silica, fiberglass, metal wire, and polyaramid (23, 24).

There are various methods for making temporary prostheses, including pressing, milling, and 3D printing methods. In the pressing method, the dependence of the results on hand skills may be considered a weakness. On the other hand, new methods for the production of prostheses are more accessible and reduce the likelihood of processing and manufacturing errors, of the prostheses, making them a more recommended method (25, 26).

The results of this study indicated that in the 'a' and 'b' indexes, the reported values show a significant difference between the three groups at a 5% level. In the conducted investigations and analyses, ΔE, which is approved by the Commission International de l'Eclairage (CIE), was used to assess color difference. In the CIE system, 'l' represents brightness, 'a' represents the red/green intensity, and 'b' represents the yellow/blue intensity. Determining the color of restorations has always been an important issue for dentists and patients performing cosmetic procedures. For patients, the color of the restoration is one of the most important issues in judging the attractiveness and beauty of a finished restoration process (27). Determining the color can be very difficult and complicated. In fact, this part of the restoration process can be a kind of challenge due to the individualized nature of color and its perception (28, 29). The results of our study showed that the most significant color change was related to the 3D printer group. This result is in conflict with some studies; for instance, Harsono *et al*. compared conventional, subtractive, and 3D printing method,

with the results indicating that the prosthesis made by the 3D printer method outperformed the other methods (30). Lee *et al*. evaluated the internal fit of temporary prostheses by CAM/CAD and the 3D method, reporting that the internal fit of temporary prostheses created through 3D printing surpassed that of the subtractive method (31), aligning with our study's results. In a research, Mai *et al*. evaluated the fit of interim crowns fabricated using photopolymer-jetting 3D printing, milling, and compression molding methods. The comparison of the studied groups showed that polymer-jet 3D printing significantly enhanced the fit of interim crowns, particularly in the occlusal region (32). In our study, no difference in color change was observed among temporary crowns made by the conventional method and CAD/CAM technologies with milling machines and 3D printers. In a study, Rayyan *et al*. compared temporary restorations (prostheses) made by CAD/CAM with the conventional method. The results revealed a great difference in the color changes of the conventional temporary restorations, while samples from the CAD/CAM group showed color stability. Also, CAD/CAM samples showed lower water absorption, higher wear resistance, higher surface hardness, and higher fracture resistance compared to manually fashioned temporary prostheses (33). In this research, it was also shown that the color of the temporary crowns made by the three methods changed significantly. In our study, no significant difference was found in terms of color changes for the 'a' and 'b' indexes between the three methods used in making temporary crowns. The results of our study are not consistent with Dede *et al*. (34), who found a significant impact of cement brand and color on the color difference of the samples. Both RelyX cement and Translucent Variolink cement colors were found to induce the least and most significant color difference, respectively. In this research, resin cement was also used, and the color changes in the crowns made by the three methods were significantly different from each other, which is similar to the study conducted by Malkondu *et al*. (35).

CONCLUSION

The results of this study show that the 3D printing method resulted in the highest rate of color change in all methods, while the milling method exhibited the lowest rate of change. Also, in terms of the 'a' and 'b' indexes, the three groups had significant differences with each other, but the 'l' index did not differ between the groups. Although, there was a significant relationship between the first and second pairs in the 3D printer group, as well as between the first and third pairs in the milling group ($P<0.001$), no significant difference was observed in the pressing group. This study represents the inaugural comparison of discoloration in temporary crowns made by conventional pressing methods (indirect) and CAM/CAD technologies with milling machines and 3D printers. However, considering that this study was conducted *in vitro* condition, it does not fully represent *in vivo* conditions, so it is suggested to repeat the study clinically.

AUTHOR CONTRIBUTION STATEMENT

Designed the study, developed the methodology, collected the data, performed the analysis, and wrote the manuscript: F. F., F. V., A. I., M. F., H. R. and F. N.

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