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In vitro color and roughness stability of different temporary restorative materials

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SUMMARY

Objective. The aim of this study was to evaluate the effects of staining solutions on the color stability and roughness of different provisional resin material.

Material and methods. Three different materials were tested (two polymethylmethacrylate and one bis-acryl composite resins) in cola and coffee and for 1 and 4 weeks. 240 specimens were used – half of them polished and other half not. Color measurements were made before and after immersions using CIE L*a*b*. Surface roughness was measured using profilometer. Data was analyzed by ANOVA and Tukey HSD multiple comparison tests.

Results. The highest ΔE values were observed in the coffee. Unpolished and polished bis-acryl resin showed the highest ΔE values ($p<0.00$) in both intervals. The i-TEMP had the lowest or one of the least color changes. The time factor had influence on the color stability of provisional materials ($p<0.01$). The highest Ra values of polished specimens were observed in the cola; i-TEMP exposed the best result ($p<0.00$). The Pearson Correlation test showed a strong correlation between ΔE and Ra in provisional restorative materials in coffee and weak -moderate correlation in cola.

Conclusions. The higher color stability of polished and unpolished specimens was shown by polymethylmethacrylate than bis-acryl resins. All polished specimens shown better color stability properties than unpolished except for the hot polymerization provisional materials (i-CAB). Polished polymethylmethacrylate showed better results of average roughness in comparison with bis-acryl resin. Cold-polymerization polymethylmethacrylate had better results of color and roughness stability than hot-polymerization polymethylmethacrylate.

Keywords: color stability, roughness.

INTRODUCTION

The term ‘‘provisional’’ denotes ‘‘serving for the time being’’, as a necessary step in providing for the final arrangement. Provisional fixed prosthodontic rehabilitation, whether involving complete or partial coverage, natural tooth or dental implant abutments, commonly relies on indirect fabrication of a definitive prosthesis in the dental laboratory (1, 2). Materials available for provisional fixed partial dentures fabrication include polymethylmethacrylate, polyethylene methacrylate, polyvinyl methacrylate, urethane methacrylate, bis-acryl and microfilled material. These materials can be polymerized with heat, cold or light (2-4). Regardless to composition and polymerization method, these materials tend to undergo color changes and roughness over time due to the use of various staining beverages (5). The requirements should satisfy biological, mechanical and esthetic concerns (1, 2). Incomplete polymerization, water absorption, chemical reactivity, diet, oral hygiene and surface roughness of the restoration can affect the degree of the color change (3-4). Studies have demonstrated that adequate finishing and polishing is crucial in restoration’s resistance to plaque accumulation and staining (6).

Several studies indicated that some polymethylmethacrylate PMMA-based resins tend to discolor less than other provisional resins, including bis-acryl-based. However, research has also demonstrated that there are resin composite materials with similar color stability. According to the review of the literature the color change is not categorical, but rather material specific (7).

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This study was planned to compare the color and surface roughness stability of provisional restorative materials with different composition, polymerization method and surface standardization after immersing them in various kinds of beverages and food (8).

MATERIALS AND METHOS

In the present study, different types of provisional materials were investigated. Materials used in the study had different composition and polymerization types. All materials are commonly used and commercially available. Details of the study samples are listed in Table 1.

Eighty specimens, similar in shade, 10±0.1 mm in diameter by 2±0.1 mm in thickness, were fabricated from different polymethylmetacrylate-based and bis-acryl-based resins. All the provisional materials were mixed according to manufacturers' directions. Polimerization process was performed strictly according to the manufacturer's instructions. Upon polymerization, specimens were removed from the mold and examined for consistency of the polymerized surface. For specimens from bis-acryl a silicone mold was used (putty soft normal set, A-silicone impression material, packed in Italy by Zhermack company). Both PMMA specimens were processed in gypsum (Siladent "Excalibur" dental gypsum, type IV) mold cuvette made by investing the wax disks.

The set thickness was approximately 2.0 mm which is generally the maximum facial or occlusal thickness of a provisional crown. This allowed to ease all the manipulations as well as polishing. The 240 specimens were randomly divided into two groups (n=120) for two tests. Half of each material discoid specimens (n=120) were polished and other half was not. On the other hand, unpolished specimens served as control. In this study combined polishing technique was used. An electric hand piece operating at 10,000 rpm was used for all polishing procedures using green fresa for 5-second for each specimen. One operator polished all the specimens. Specimens were polished using a 10-second application of coarse pumice using a goat hair wheel (Hager & Meisinger) for 2 minutes on each side of the specimens. The next step was to perform polishing of the samples with silicon carbide abrasive papers (3M ESPE, St. Paul, MN, USA), with grits #150 and #180, in an automatic polishing machine at 6,000 rpm (EcoMet Pro Grinder/Polisher (Buehler – USA) for 2 minutes on each side of the specimen. Finally, diamond polishing paste (Universal Polishing Paste, Ivoclar Vivadent, Schaan, Liechtenstein) with a moist muslin wheel was applied for 2 minutes in order to remove possible residues left on the surface. All the specimens were kept dry at the room temperature until the rest specimens are fabricated.

To evaluate color stability in different solutions, 40 specimens were randomly divided into 2 groups (n=20) (Figure 1). All specimens were washed under running distilled water before color evaluations and immersion in solutions. Baseline color measurements were captured before immersion in solutions.

The staining solutions were prepared in following concentrations:

Twenty specimens were immersed in cola ("Coca-cola" Company, HBC, Latvia) 100 ml and other 20 were immersed in a coffee ("Nescafe", Brasilia) 100 ml. For preparation of coffee solution 3g of coffee was added to 100 ml of distilled water. Specimens were kept in solution at 37°C and evaluated for color change in 1 and 4 weeks. The solution was changed every 3 days and stirred two times daily.

Color difference (ΔE) was assessed with a colorimeter (Konica Minolta CM-5; Tokyo, Japan). Seghi *et al.* (9) demonstrated that color measurement using a colorimeter provides consistent color evaluation. The color change was calculated for each specimen at the specific time interval (before immersion, after 1 and 4 weeks) and compared to its baseline color. After immersion all the specimens were washed under running distilled water and cleaned using paper towels.

The total color change (ΔE) was calculated for each specimen relative to its baseline color using the color difference formula:

$$\Delta E = \sqrt{\left(L_f^* - L_b^*\right)^2 + \left(a_f^* - a_b^*\right)^2 + \left(b_f^* - b_b^*\right)^2},$$

where the baseline (b) and final (f) are color descriptors. ΔE represents the color difference and ΔL*, Δa*, Δb* represent the changes in lightness, in the red-green coordinate and yellow-blue coordinate respectively, after immersion in the various staining solutions or in the control solution.

The surface roughness was measured in nanometers in 3 different areas of each specimen with profilometer (XP-200 profilometer; Ambios Technology, Inc; CA, United States) (9). The solution impact on unpolished specimens' roughness cannot be objectively evaluated due to the specimens' uneven surface and huge Ra standard deviations. Scaning was obtained by the needle passing across 3 mm length at 0.2 mm/s and obtaining a height (Zi) of 1,834 data points. Average roughness is the arithmetic average of the absolute values of the profile height deviations measured from the mean line:

$$R_a = \sqrt{\frac{Z_1^2 + Z_2^2 + Z_3^2 + \cdots + Z_N^2)}{N}}$$

As surface roughness was measured at three positions and a final Ra average was calculated for each specimen.

Three specimens from each group were examined under a microscope (ECLIPSE LV150; Nikon, Tokyo, Japan). The surface roughness was measured on the specimens before and after immersion in the solutions.

The data was analyzed using the computer statistical software SPSS 23. To determine the color change after 1 and 4 weeks, ΔE values of specimens in each staining solution were evaluated with one-way ANOVA. The significant differences were analyzed with Tukey Test to find out how various groups differ, at a level of significance α=0.05.

RESULTS

The results of the Tukey HSD (Honestly Significant Difference) and values of the mean color difference ΔE and standard deviations for each combination of discoloration solutions and provisional material are listed in Table 2. The results of the one-way ANOVA and the Tukey test indicated that the effects of the interaction between solutions and provisional restorations were statistically significant.

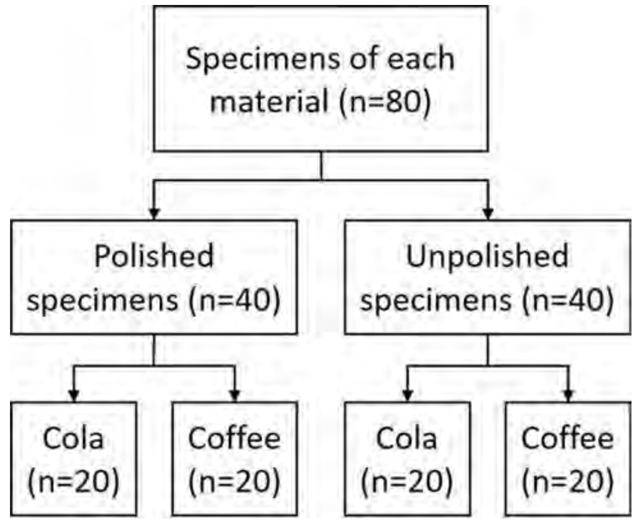

Fig. 1. Total number of fabricated specimens

Table 1. Materials used in study

Product name	Resin type	Shade	Polymerization method	Manufacturer
i-TEMP	Polymethylmethacrylate	A3	cold-polymerized	Medicinos linija, UAB (Lithuania)
i-CAB	Polymethylmethacrylate	A2	heat-polymerized	Medicinos linija, UAB (Lithuania)
Bossklein Dentatemp Plus TM Temp C&B composite	Bis-acryl	A3	cold-polymerized	Bossklein products company (England)

Table 2. Mean color differences (ΔE), standard deviations of provisional restorative materials and results of the Tukey HSD test

	1 week				4 weeks			
	Polished		Unpolished		Polished		Unpolished	
	Coffee	Cola	Coffee	Cola	Coffee	Cola	Coffee	Cola
Bossklein Dentatemp Plus TM Temp C&B composite	6.35±0.95 C	1.24±0.60 A	20.02±1.63 A	2.33±0.84 B	11.36±2.20 B	1.17±0.36 A	20.50±2.80 B	3.05±0.36 B
i-CAB	3.43±0.90 B	2.67±1.20 B	4.83±1.25 B	2.69±0.69 B	9.29±1.85 B	2.57±1.42 B	9.68±2.47 A	2.46±1.09 AB
i-TEMP	1.87±0.75 A	1.57±0.74 A	2.30±1.36 B	1.57±0.62 A	3.65±0.83 A	1.19±0.73 A	6.47±1.99 A	1.21±0.71 A

Different letters indicate dissimilarity of the groups ($p < 0.05$).

Table 3. Mean and Standard Deviation for the average roughness (Ra) of provisional restorative materials in nanometers and results of the Tukey HSD test

	Baseline	1 week	4 weeks		
		Coffee	Cola	Coffee	Cola
Bossklein Dentatemp Plus TM Temp C&B composite	172±87 A	911±157 C	1480±343 B	1670±426 C	3174±989 B
i-CAB	189±99 A	554±148 B	789±264 A	897±295 B	1288±231 A
i-TEMP	143±101 A	265±170 A	544±144 A	384±175 A	750±189 A

Different letters indicate dissimilarity of the groups ($p < 0.05$).

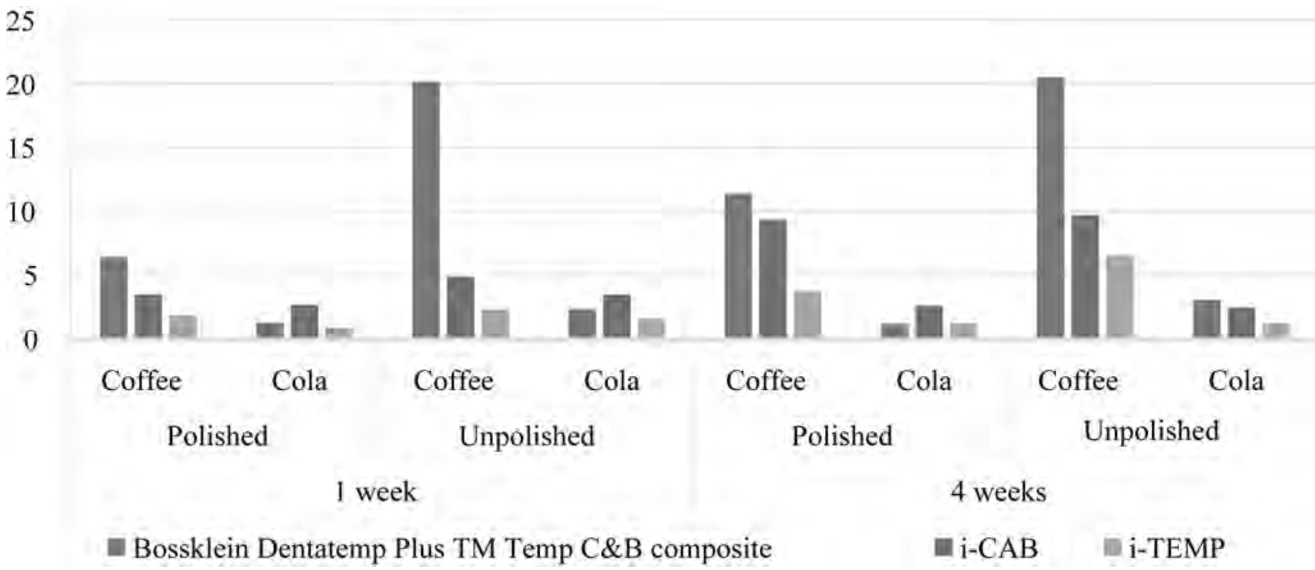

Fig. 2. Mean color differences (ΔE) and standard deviations of provisional restorative materials

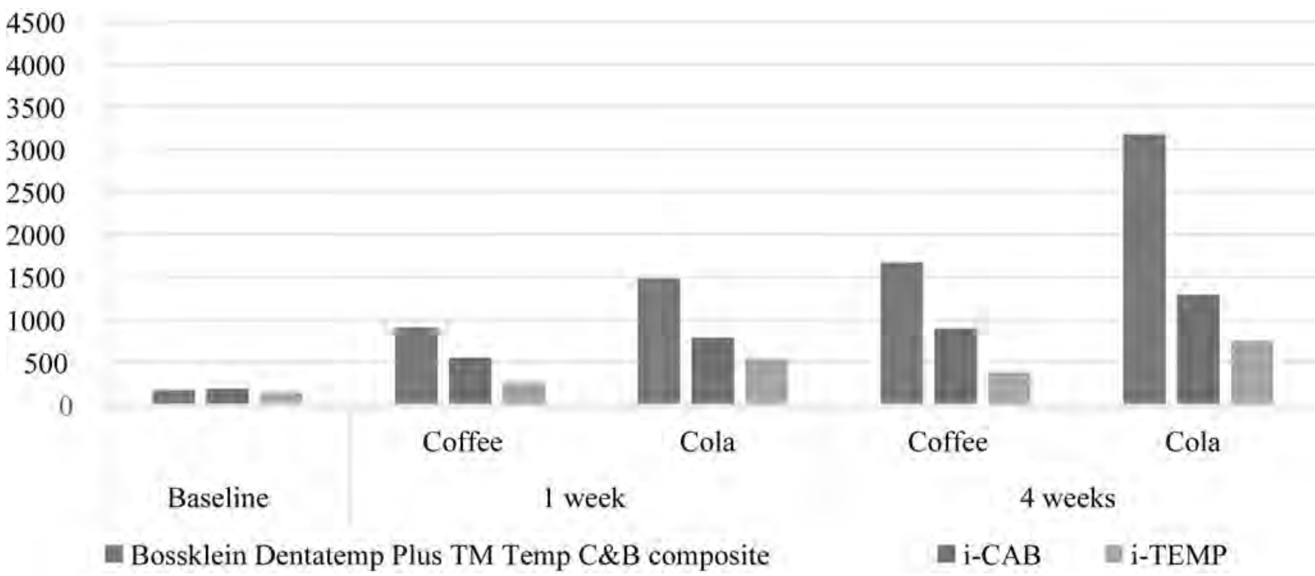

Fig. 3. Mean and Standard Deviation for the average roughness (Ra) of provisional restorative materials in nanometers (nm)

The highest ΔE values were observed in the coffee. After the 1 week of immersion in coffee, the Tukey analysis indicated that unpolished Bossklein Dentatemp Plus TM Temp C&B composite revealed the highest value (ΔE= 20.02) ($p<0.00$). Although unpolished material showed the worst results, but the results of polished bis-acryl based material were poor as well (ΔE=6.35) ($p<0.00$). At the second immersion period (4 week), unpolished Bossklein Dentatemp Plus TM Temp C&B composite in coffee had the highest ΔE value (ΔE=20.50) compared with other materials (Figure 2). There was no significantly bad material in 4 weeks period among polished materials.

According to Tukey HSD results it can be stated that the i-TEMP material had lowest or one of the least color changes in all the groups (in cola and coffee; polished and unpolished; both intervals) (Figure 2). The time factor had influence on the color stability of provisional materials ($p<0.01$).

There was statistical difference between polished and unpolished Bossklein Dentatemp Plus TM Temp C&B composite material in all subgroups (in cola and coffee; both intervals). But there was no statistical difference between polished and unpolished materials in a few i-CAB (1 week-cola; 4 weeks-coffee; 4 weeks-cola) and i-TEMP (1 week-coffee and 4 week-cola) subgroups.

Table 3 shows the results from the Tukey HSD test, mean and standard deviations of surface roughness values Ra recorded at baseline and after different immersion periods. At the baseline, materials' surface roughness was not statistically different ($p>0.05$).

The highest Ra values were observed in the cola. At the 1 week immersion period, the Tukey analysis indicated that Bossklein Dentatemp Plus

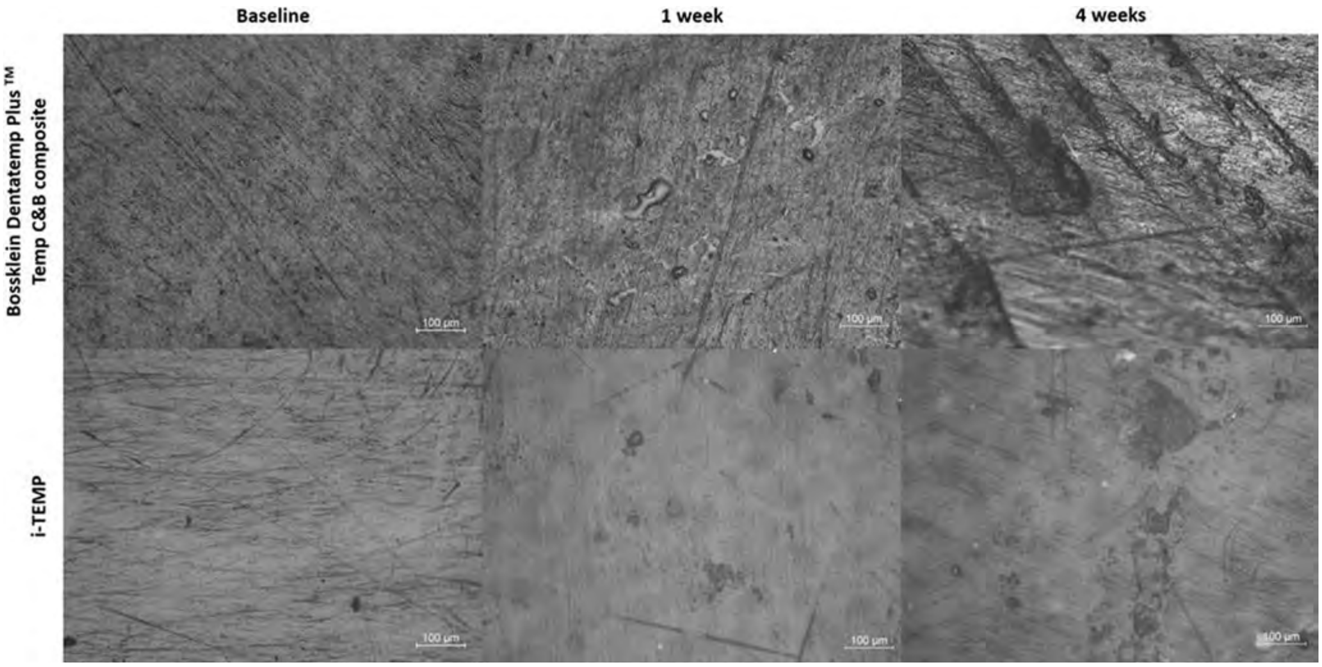

Fig. 4. Microscope images of flat areas of the specimens under 10X magnification in the beginning and after immersion in cola

TM Temp C&B composite – cola and coffee revealed the highest Ra value and i-TEMP showed the best result in coffee ($p<0.00$) and cola ($p<0.00$) (Figure 3). After the second immersion period (4 week) trends remained the same – Bossklein Dentatemp Plus TM Temp C&B composite – cola and coffee had the highest Ra value compared with other materials ($p<0.00$) and i-TEMP had lowest Ra values in coffee ($p<0.00$) and cola ($p<0.00$).

The Pearson Correlation test was carried out to find out if any statistically relationship exists between color change and surface roughness. Correlations have been studied in different provisional denture materials and solutions. The Pearson Correlation test showed a strong correlation in coffee (Bossklein Dentatemp Plus TM Temp C&B composite – 0.859; i-CAB – 0.814; i-TEMP – 0.769) and weak-moderate correlation in cola (Bossklein Dentatemp Plus TM Temp C&B composite – 0.404; i-CAB – 0.326; i-TEMP – 0.477).

DISCUSSION

Temporary restorations are intended for the period between tooth preparation, the fit and insertion of the final prosthesis. Even during the time when interim restorations are being present in the mouth, esthetics are important (2). Color stability is critical for the esthetics of long-term provisional restorations and has been previously studied in vitro for a variety of interim materials (10).

Proprietary variations in chemistry, such as size distribution of the PMMA particles, polarity of the monomers, pigment stability, and efficiency of the initiator system for provisional resins may lead to different degrees of polymerization, water sorption, and consequently, color stability (10).

This study has been designed to evaluate the color stability of three commercially available temporary restorative materials in two different solutions the different time periods (2).

Discoloration can be evaluated visually and with instrumental techniques (spectrophotometer and colorimeter) (2, 8). The results of this study revealed that PMMA-based (i-TEMP and i-CAB) is more color stable in both cola and coffee solutions than bis-acryl-based (Bossklein Dentatemp Plus TM Temp C&B composite). In addition to these results, cold-polymerization (i-TEMP) material had the lowest or one of least color changes in all the groups (in cola and coffee; polished and unpolished; both intervals). According to Jalali *et al.*, autopolymerization materials (Duralay and Tempron) were more color stable than heat-polymerization ones (Acropars) (10).

It should be pointed out that in addition to monomers such as bisphenol A-diglycidyl dimethacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA) the bis-acrylic resins have an organic matrix and inorganic filler particles. Monomers and their derivatives tend to provide better mechanical properties, unsignificant changes in temperature, reduction in polymerization shrinkage, and excellent polishing properties. Thereby monomers increase the practicality of temporary dental prostheses fabrication (7, 11).

However, as highlighted by Mazaro *et al.* (11), the mixture of monomers may be harmful to color stability, considering that the majority of bis-acrylic resin polymers are more polar than the acrylic resin polymers. These chemical characteristics increase the affinity of bis-acrylic resins for polar liquid molecules, and consequently, facilitates greater sorption of substances that interfere in the color stability of the materials.

Similar results have been found in previous studies – greater susceptibility to color change of bis-acrylic resins when in contact with pigmenting solutions was also observed. Moreover, studies conducted by Gujjari *et al.* (12) and Mazaro *et al.* (11), found that PMMA is more color stable than bis-acryl composite resin, as PMMA showed lower color change values as compared to bis-acrylic resin for cola and coffee solutions. This occurs because the PMMA-based materials have a more homogeneous composition, and consequently the capacity to absorb and adsorb solutions may have a direct influence on color stability. Due to the heterogeneity of bis-acrylic resins, the pigmenting solution is capable to infiltrate into the midst of the small particles of material, thus causing a greater level of pigmentation (1, 11, 13).

In this study, the time factor had influence on the color stability of provisional materials ($p < 0.01$). The longer period discoids were immersed, the greater color change it presented, particularly in coffee solution. Possible explanation for the staining capacity of cola is that it is a low pH medium which affects the surface integrity of the resins (12).

Other factors like surface roughness, thickness, wear and polishability can also affect color stability (4, 8, 13). There are many reasons why the surface of a restoration should be made as smooth as possible. This study revealed that color stability of provisional prosthetic materials was significantly influenced by the roughness of surface provisionals. After the 1 week and 4 week immersion period it was found that polished Bossklein Dentatemp Plus TM Temp C&B composite-cola revealed the highest Ra values and i-TEMP showed best result in coffee ($p < 0.00$) and cola ($p < 0.00$) (Figure 4). Rutkunas *et al.* (14), also reported many reasons why the surface of a restoration should be made as smooth as possible. It serves to ensure long-term esthetic success – including color stability, and it is also noteworthy that prosthetic material wear is partly determined by surface finishing (polishing). For these reasons, adequate finishing and subsequent polishing are key to fortifying a restoration against plaque accumulation, possible adsorption of stains, and increased material wear which could compromise the clinical performance of the whole restoration (14).

CONCLUSIONS

The higher color stability of polished and unpolished specimens was shown by polymethylmethacrylate-based than bis-acryl based resins. The better results shown by PMMA cold-polymerization than hot-polymerization materials.

All polished specimens shown better color stability properties than unpolished except for the hot polymerization provisional materials.

The better results of average roughness of polish materials shown by PMMA than bis-acryl based resins. Cold-polymerization PMMA shown better results than hot-polymerization PMMA.

This study has shown a strong correlation between color change and surface roughness of provisional restorative materials in coffee and weak-moderate correlation in cola. Also coffee is more coloring solution and cola mostly influenced the roughness.

STATEMENT OF CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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