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SURFACE ROUGHNESS AND COLOR STABILITY OF PROVISIONAL RESTORATIVE MATERIALS FABRICATED USING DIFFERENT METHODS AFTER IMMERSION IN VARIOUS STORAGE MEDIA

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ABSTRACT

Objectives: To investigate and compare the color stability and surface roughness of provisional restorative materials fabricated by 3D printing, milling and conventional techniques after immersion in different storage media.

Materials and methods: The 84-disc specimens were fabricated and divided into 3 groups according to the technique of fabrication (n=28), group C: Conventional techniques, group M: milled technique, group P: 3d printed technique. Each group was divided into 4 subgroups according to storage media (n=7), Subgroup D: distilled water, subgroup C: coffee solution, subgroup Co: cola, and subgroup O: orange juice. Baseline color was measured using spectrophotometer then measured after 2 and 4 weeks of immersion in different storage media. Color change (ΔE) was assessed using of the CIE L*a*b* system. Surface roughness was also measured using profilometer for all specimens before and after immersion in staining solutions. The data was then collected and statistically analyzed using two-way ANOVA. The significance level was set at $p<0.05$ within all tests.

Results: Two-way ANOVA showed that the fabrication technique and interaction between variables had a significant effect on surface roughness. There was a significant interaction between fabrication method, solution type and storage time on color stability.

Conclusions: The surface roughness of 3D printed materials was higher than milled and conventional groups. 3D printed and CAD-CAM milled materials had better color stability compared to conventional group.

KEYWORDS: Provisional materials, storage media, time of immersion, color stability, surface roughness.

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INTRODUCTION

The provisional restorative material is a valuable member in fixed prosthodontics work and represents very important step in crown and bridge fabricating flow work[1]. After preparation of the abutment teeth, they must be covered temporarily until the fabrication of the definite fixed prosthesis to maintain relationships of abutments, function, esthetics, and optimal periodontal health during this period. Additionally, temporary restorations are known to be effective diagnostic tools because they serve as a kind of aesthetic and functional trial run for permanent restorations, enabling the dentist to determine whether the intended prosthesis will adequately meet the patient's physiological, biomechanical, and aesthetic needs[2]. They can also be used to assess the prognosis of the teeth during periodontal therapy, to treat temporomandibular joint issues, and during the time following implant surgery when osteointegration is anticipated to occur[3].

Long-term provisional restorations need to be color stable and have a smooth surface in order to last longer in the patient's mouth without deteriorating their appearance or gingival health. This is particularly true when more complex prostheses call for treatment restorations during the procedure. The least amount of color stability possible should be considered while selecting materials and techniques. The color stability of the temporary materials is a problem when the temporary restoration is in the aesthetic zone to prevent discoloration in the oral cavity from various beverages and teeth-cleaning agents[4, 5]. The surface topography of temporary resin restorations has an impact on the neighboring gingival tissue's periodontal health. To prevent plaque and stains from adhering and causing gingival irritation, the provisional restoration surface must be smooth. This will preserve the gingival health. Besides that, The surface roughness can be a cause of changes in materials color, which might affect the aesthetic aspect of restorations[4]. Surface roughness of temporary crowns is influenced by material type, manufacturing method, and kind of surface polishing[5].

Materials used as temporary restoratives include Polyvinyl Methacrylate, Urethane Di Methacrylate, Polymethyl Methacrylate, Polyethylene Methacrylate, Bis-acrylic resin, and resin composites. These materials can either be polymerized chemically, optically, or simultaneously by both chemical and optical processes [6].

Dental restoration production utilizing computer-aided design/computer-aided manufacturing (CAD/CAM) has recently grown in importance and mostly supplanted conventional methods. Due to technological advancements, the CAD/CAM system, which consists of optical scanners, CAD software, and production tools, is rapidly being employed in dental clinics[7]. These new methods are easier and more precise, and its processing precision is superior to the traditional dental restorative manufacturing technique. The design of the prosthesis may also be seen and communicated by dentists and dental technicians digitally, and the design data can be saved as a digital file. The popularity of three-dimensional (3D) printing or additive manufacturing is rising quickly along with the development of the CAD/CAM technology. With the development of 3D printing materials and advancements in 3D printers, 3D printing technology is becoming a modern technology that addresses the shortcomings of manufacturing methods in dentistry [7]. Furthermore, while milling has limitations due to parameters including bur size, milling bur tolerance, and motion range of the cutting equipment, 3D printed restorations were more precise than restorations made by milling techniques. Conversely, additive manufacturing technologies enable the construction of complicated designs using less time and material and, as a result, offer a more cost-effective manufacturing process than the milling approach [8,9] .Particularly, there is

a lack of evidence on the color stability of resins used in 3D printing when subjected to different colorants. The purpose of this study was to compare the surface roughness and color stability of CAD/CAM milled and 3D printing materials to conventional ones while exposed to staining solutions. The first null hypothesis was that the fabrication methods and storage media would not have significant effect on surface roughness of provisional material, second hypothesis was that the fabrication methods and storage media would not have significant effect on color stability of provisional materials.

MATERIALS

Material, manufacture, composition, and lot n. represented in table 1. Storage media, composition and pH represented in table 2.

METHODS

Study design

In this in vitro study, for comparing the color stability and surface roughness of three provisional restorative materials a sample size calculation was done. A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups. By adopting an alpha (α) and beta (β) levels of 0.05 (5%); i.e. power=95%, and an effect size (f) of (0.741) calculated based on the results of Mickeviciute et al. [10] ; the predicted sample size (n) was found to be a total of (84) samples i.e. (28) samples per group. A total of eighty-four specimens were fabricated and divided into three main groups according to fabrication methods of provisional materials; group C: conventional

TABLE (1) The materials used in the study, the manufacturers and composition.

Material names	Manufacture	Composition	Lot number
Tempofit®regular1:1 (Conventional fabricated)	DETAX, Germany.	Standard bis-acrylic-composite (Ethoxylated bisphenol A Di-methacrylate) self-curing	240302
YAMAHACHI (Milled CAD/CAM)	YAMAHACHI, Aichi, Japan.	Polymethyl methacrylate, plastics Carbon black Ferric Oxide Titanium dioxide	1280117
Next dent C&B MFH (3 D printing CAD/CAM)	Vertex Dental/ Dentimex, Zeist, Netherlands.	Micro Filled Hybrid (Methacrylic oligomers, methacrylate monomer, inorganic fillers phosphine oxide and pigments)	PAGCM1_20180

TABLE (2) Storage media, composition, and pH.

Storage Media	Composition	pH
Coffee	Caffeine, potassium, magnesium, calcium, sodium, iron, manganese, rubidium, amino acids, lipids, sugars, vitamin B complex and chlorogenic acids.	5.6
Orange juice (Sun top)	water, orange juice, acidity regulators (citric acid, potassium citrate), vitamin C, natural orange flavorings' color (beta-carotene), pasteurized sodium, carbohydrate.	3.2
Distelled water	H_2O	6.8
Coca cola	Carbonated water, Sugar, Caramel color, Phosphoric Acid, Caffeine and Natural flavors.	2.6

provisional material, group C: milled provisional material, Group P:3D printing provisional material (n =28). Each group was divided into 4 subgroups according to storage media; Subgroup D: distilled water, subgroup C: coffee solution, subgroup Co: cola, and subgroup O: orange juice.

Fabrication of samples:

The samples were fabricated in form of discs measuring 10 mm in diameter and 2 mm in thickness[11]. Split Teflon mold were made[12] for the conventionally fabricated materials (Tempofit® regular1:1, DETAX, Germany) with a disc space (dimensions 2 x 10 mm) in which the conventional fabricated provisional restoration material was injected. Then, the mold was covered and compressed by a glass slab to pack the mix and to help remove the excess material then the specimens were polymerized for 6 minutes at room temperature according to the manufacturer's instructions. The discs were removed from the mold space after complete and surgical blade was used to remove the flash material.

For fabrication of specimens using CAD/CAM milling provisional material (YAMAHACHI, YAMAHACHI, Aichi, Japan), a block was design with dimensions of (16 mm x 98.5 mm) in 3Shape software, then it was milled using a CAD/CAM milling machine (CAM 5-S1 impression milling machine, Vhf, Baden-Württemberg, Germany). The block was attached to base then rounded to cylindrical shape by lathe machine (10 mm of diameter). Finally it was sectioned horizontally using low speed diamond saw (diamond disc in Isomet saw [13], Buehler, Lake Bluff, IL, USA) with rotation speed 2500 rpm and feeding rate 1mm/s with water cooling spray to obtain discs with 2 mm thickness and 10mm diameter.

For fabrication of specimens of the 3D printing provisional restoration material, Nextdent C&B printing resins (Vertex Dental/ Dentimex, Zeist, Netherlands) and EPAX 3D3D printing machine (North Carolina, USA) were used. The discs were designed in Standard Tessellation Language STL format file imported into 3shape program with the same dimensions 2m thickens and 10 m diameter. The support structures were designed attached to the lateral side of the disc specimens and 3D printing parameters established as thickness of each printing layer was set to 100 μm and all other parameters were set automatically by the software upon resin selection. After printing was complete, specimens were cleaned in 91% Isopropyl alcohol in an ultrasonic unit for 5 minutes, carefully dried, and placed into the LED post-curing equipment (bre. Lux power unit 2, Bredent, Senden, Germany) for 30 minutes. Then, support structures were removed from the printed specimens, and the remaining irregular structures on the surface were removed.

The Samples were examined for voids using a magnifying glass (2X) and any defective specimens were discarded. The samples were finished using wet sandpaper (1500) grit by placing the surface to be measured against the sandpaper twice with gentle pressure for all specimens to standardize the finishing protocol for all specimens. Then the polishing kit (KENDA DENTAL POLISHERS for Composite, Kenda, Liechtenstein) was used, firstly with white, green and finally pink tip of rubber wheel mounted in low-speed hand piece operating at 5000 rev/min for 30s with a circular movement and light pressure for all specimens, then using polishing cup with Prisma Gloss fine pastes was applied for 15s. Specimens were rinsed with water for 10s and air dried for five seconds between and after polishing paste application. Finally, specimen dimensions were verified with a digital caliper. All finishing and polishing procedures were carried out by the same investigator to minimize variability and achieve standardization.

Preparation of storage Media

1. Commercially available orange juice as acidic media (Sun-top, Soudan Coro. Port Said, Egypt) used at room temperature and pH was measured.
2. The coffee media was Prepared of 1.8 g of coffee (Nescafe, Nestle Egypt) was poured into 150 ml of boiled water. The media were stirred every 5 min for 10 s until they cooled down to room temperature and then filtered through a filter paper and pH was measured.
3. For cola solution, commercially available brand of cola (Pepsi) was used, and pH was measured.
4. For distilled water, commercially available purified water (ADWIC, El Nasr pharmaceutical chemicals co., Egypt) was used and pH was measured.

Samples were randomly divided into subgroups and placed into 20 ml of each storage media and kept in the above-mentioned solutions for 30 days at 37°C in incubator (PS, Advanced Technology, Cairo, Egypt) which were freshened once every 24 hours and stirred twice a day throughout whole experimental time (4 weeks) to reduce the precipitation of particles in the storage media.

Surface roughness measurements

Surface roughness measurements were done for all specimens at base line and after 4 weeks of immersion in storage media using USB digital surface profile gauge profilometer (Elcometer 224/2, Elcometer Instruments, Great Britain). The data was recorded using a computer software of roughness tester supplier (Elcomaster 2, Elcometer Instruments). The mean roughness value (Ra, μm) represented by the arithmetic mean between the peaks and valleys registered, after the needle of the profilometer had scanned a stretch of 2 mm in length, with a cut-off of 0.25mm to maximize the filtering and the undulation on the surface. Each surface was assesed three times, always with the needle scanning the geometric center of the specimen, starting from three different points. The mean value of the three readings yielded the mean value of the roughness of each specimen. Initial roughness values were subtracted from the roughness values after immersion to obtain the delta Ra values ΔRa (Ra_2-Ra_1), which were then entered into a spreadsheet for calculating descriptive statistics for surface characterization [14].

Color measurements:

The color parameter at baseline of all specimens was measured before immersion in storage media using the spectrophotometer (Spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). The color of the specimens was assessed in the Commission International de' l'Èclairage (CIE) L*a*b* color system [15]. L* is lightness; white to black, a* is red-green axis; positive value indicates red, negative value indicates green and b* is yellow-blue axis; positive value indicates yellow, negative value indicates blue. The measurements were repeated 3 times for each sample, and the mean values of L*, a*, b* were calculated. Prior to the color measurement, the spectrophotometer was calibrated according to the manufacturer's recommendation.

Second and third color measurements were after 2 weeks and 4 weeks of immersion in storage media, the specimens were rinsed with distilled water for 5 min and blotted with tissue paper and, the color values of each specimen were remeasured with the same protocol of baseline measurement to obtain (L, a, b,) values, and the color change value ΔE after 2 weeks and 4 weeks of immersion was calculated [16,17].

$$\Delta E_{CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$$

Where: L =* lightness (0-100), a=*change the color of the axis (red/green) and b=* color variation axis (yellow/blue).

The collected data was analyzed using two-way ANCOVA for surface roughness and three-way mixed model ANOVA for color change. Comparison

of main and simple effects were done utilizing one-way ANOVA followed by Tukey's post hoc test for independent samples and repeated measures ANOVA followed by Bonferroni post hoc test for paired samples. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. The significance level was set at $p \leq 0.05$.

RESULTS

For surface roughness measurements

Two-way ANCOVA showed that fabrication methods and interaction between fabrication method and storage media had a significant ($p<0.001$) effect on Δ Ra while storage media had no significant effect ($p > 0.05$). Mean, Standard deviation (SD) values of surface roughness (Δ Ra) for different fabrication methods within other variables were presented in table 3. In All storage media, the 3D printed provisional material had significantly higher surface roughness to conventional and milled provisional materials. However, in Conventional materials the highest value of surface roughness was found in cola (0.2902±7e-04), followed by orange (0.2891±0.0010), then distilled water (0.2883±0.0014), while the lowest value was found in coffee (0.2839±0.0038). Post hoc pairwise comparisons showed coffee to have significantly lower value than other groups ($p<0.001$). While in 3d printed material, there was no significant difference in surface roughness between different storage media ($p=0.181$). In milled materials, the highest value of surface roughness was found in coffee (0.2925±0.0043), followed by orange (0.2887±0.0020), then distilled water (0.2885±0.0011), while the lowest value was found in cola (0.2863±0.0039). Post hoc pairwise comparisons showed coffee to have significantly lower value than cola ($p<0.001$).

Color measurements

Three-way mixed model ANOVA for color change showed that fabrication method, media type and storage time and interaction between variables had significantly affected on ΔE ($p<0.001$). Regardless of other variables there was a significant difference between different method of fabrication in color change ($p<0.001$). The highest value was found in conventional samples (5.94±3.02), followed by milled samples (4.48±1.71), while the lowest value was found in 3D printed samples (4.14±2.01) (Figure 1). Post hoc pairwise comparisons showed conventional samples to have a significantly higher value than other groups ($p<0.001$). While in storage

TABLE (3) Mean, Standard deviation (SD) values of surface roughness (Ra) for different fabrication methods within other variables

Storage Media	Surface roughness (Ra) (mean±SD)			p-value
	Conventional	3D printed	Milled	
Cola	$0.2902±7e\text{-}04^{B\,a}$	$0.2926±0.0034^{A\,a}$	$0.2863±0.0039^{B\,b}$	0.004*
Coffee	$0.2839±0.0038^{B\,b}$	$0.2907±0.0013^{A\,a}$	$0.2925±0.0043^{A\,a}$	<0.001*
Orange	$0.2891±0.0010^{B\,a}$	$0.2932±0.0022^{A\,a}$	$0.2887±0.0020^{B\,ab}$	<0.001*
Distilled water	$0.2883±0.0014^{B\,a}$	$0.2913±0.0018^{A\,a}$	$0.2885±0.0011^{B\,ab}$	0.002*
p-value	<0.001*	0.181ns	0.010*	

Different uppercase superscript letters indicate a statistically significant difference within the same horizontal row, and lowercase superscript letters indicate a statistically significant difference within the same vertical column, *; significant ($p \leq 0.05$).

media, post hoc pairwise comparisons showed coffee to have significantly higher value than other groups ($p<0.001$) (Figure 2). Besides that, regardless of other variables Baseline Vs 4 weeks (5.67±2.60) had significantly higher value than baseline Vs 2 weeks (4.04±1.96) ($p<0.001$) (Figure 3).

Mean, Standard deviation (SD) values of color change (ΔE) for different fabrication methods, storage media and storage times within other variables and interactions were presented in table 4,5,6.

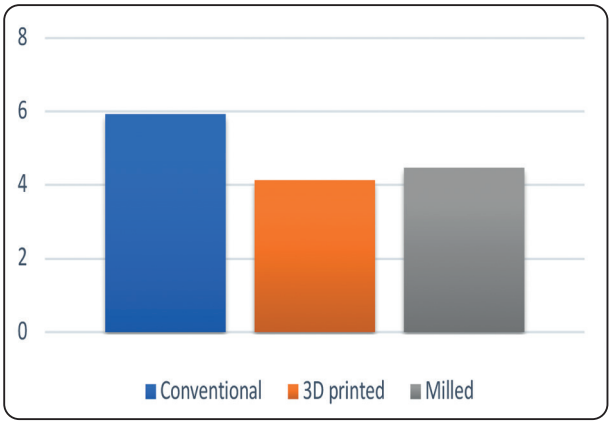

Fig. (2): Bar chart showing average color change (ΔE) for different storage media

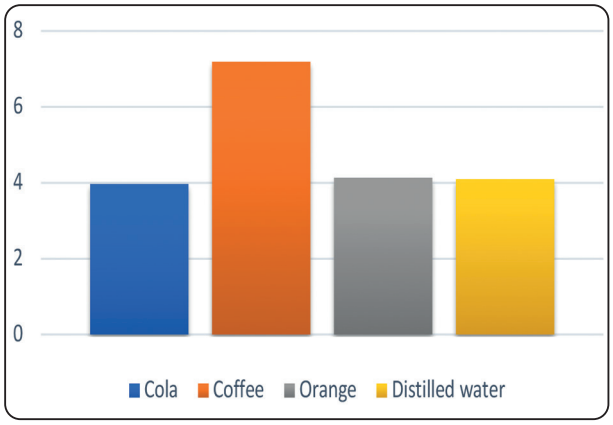

Fig. (1): Bar chart showing average color change (ΔE) for different fabrication methods.

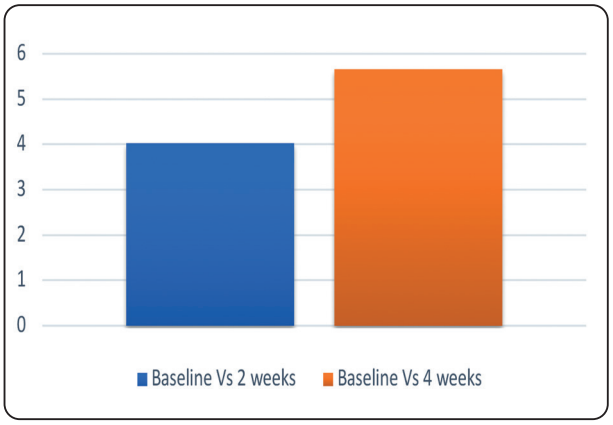

Fig. (3): Bar chart showing average color change (ΔE) for different storage times

TABLE (4) Mean, Standard deviation (SD) values of color change (ΔE) for different fabrication methods within other variables

Solution	Storage time	Color change (ΔE) (mean±SD)			p-value
		Conventional	3D printed	Milled	
Cola	**Baseline Vs 2 weeks**	3.19 ± 1.24^{AB}	2.31 ± 0.86^{B}	3.82 ± 0.52^{A}	**0.022***
	Baseline Vs 4 weeks	3.70 ± 1.37^{B}	6.54 ± 1.34^{A}	4.34 ± 0.47^{B}	**<0.001***
Coffee	**Baseline Vs 2 weeks**	9.02 ± 0.89^{A}	4.60 ± 1.85^{B}	3.06 ± 0.09^{B}	**<0.001***
	Baseline Vs 4 weeks	11.83 ± 1.23^{A}	6.97 ± 1.47^{B}	7.71 ± 2.60^{B}	**<0.001***
Orange	**Baseline Vs 2 weeks**	4.95 ± 1.67^{A}	2.66 ± 0.61^{B}	4.11 ± 1.00^{AB}	**0.006***
	Baseline Vs 4 weeks	5.11 ± 1.39^{A}	3.54 ± 0.84^{B}	4.44 ± 0.14^{AB}	**0.020***
Distilled water	**Baseline Vs 2 weeks**	4.57 ± 0.66^{A}	2.87 ± 0.80^{B}	3.34 ± 0.65^{B}	**<0.001***
	Baseline Vs 4 weeks	5.17 ± 1.31^{A}	3.62 ± 1.32^{A}	5.03 ± 1.07^{A}	**0.058ns**

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$).

TABLE (5) Mean, Standard deviation (SD) values of color change (ΔE) for different storage media within other variables

Fabrication method	Storage time	Color change (ΔE) (mean±SD)				p-value
		Cola	Coffee	Orange	Distilled water	
Conventional	**Baseline Vs 2 weeks**	3.19±1.24^{C}	9.02±0.89^{A}	4.95±1.67^{B}	4.57±0.66^{BC}	<0.001*
	Baseline Vs 4 weeks	3.70±1.37^{B}	11.83±1.23^{A}	5.11±1.39^{B}	5.17±1.31^{B}	<0.001*
3D printed	**Baseline Vs 2 weeks**	2.31±0.86^{B}	4.60±1.85^{A}	2.66±0.61^{B}	2.87±0.80^{B}	0.005*
	Baseline Vs 4 weeks	6.54±1.34^{A}	6.97±1.47^{A}	3.54±0.84^{B}	3.62±1.32^{B}	<0.001*
Milling	**Baseline Vs 2 weeks**	3.82±0.52^{AB}	3.06±0.09^{B}	4.11±1.00^{A}	3.34±0.65^{AB}	0.026*
	Baseline Vs 4 weeks	4.34±0.47^{B}	7.71±2.60^{A}	4.44±0.14^{B}	5.03±1.07^{B}	<0.001*

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

TABLE (6) Mean, Standard deviation (SD) values of color change (ΔE) for different storage times within other variables

Solutions	Fabrication method	Color change (ΔE) (mean±SD)		p-value
		Baseline Vs 2 weeks	Baseline Vs 4 weeks	
Cola	**Conventional**	3.19±1.24	3.70±1.37	**0.466ns**
	3D printed	2.31±0.86	6.54±1.34	**<0.001***
	Milling	3.82±0.52	4.34±0.47	**0.034***
Coffee	**Conventional**	9.02±0.89	11.83±1.23	**0.002***
	3D printed	4.60±1.85	6.97±1.47	**0.017***
	Milling	3.06±0.09	7.71±2.60	**0.003***
Orange	**Conventional**	4.95±1.67	5.11±1.39	**0.842ns**
	3D printed	2.66±0.61	3.54±0.84	**0.014***
	Milling	4.11±1.00	4.44±0.14	**0.398ns**
Distilled water	**Conventional**	4.57±0.66	5.17±1.31	**0.321ns**
	3D printed	2.87±0.80	3.62±1.32	**0.198ns**
	Milling	3.34±0.65	5.03±1.07	**0.012***

****; significant (p ≤ 0.05) ns; non-significant (p>0.05)***

DISCUSSION

To obtain and maintain aesthetic results for short- and long-term periods, it is essential to evaluate the surface roughness and stability of tooth-colored materials based on various environmental changes in the oral cavity [18]. To enhance the biological, mechanical, and physical qualities of temporary resin materials, several methods were conducted. Modifying the fabrication process from conventional manufactured to CAD/CAM resin block milling is one method to enhance[18,19]. 3D printing technology is devolved to overcome the limitations of milling systems in dentistry like curing resin materials under optimal conditions to increase their mechanical strength and higher reproducibility than the milling machine [8]. This study was conducted to measure color stability and surface roughness of three temporary crown materials with three different manufacturing techniques (conventionally, CAD/CAM milling blank, and 3D printed) after immersion in different storage media.

The dimension of the provisional restoration material discs was 2x10 mm following Specification No.27 of the American Dental Association (ADA) [20]. This size is approximately 2.0 mm, nearly the maximum facial or occlusal thickness of a provisional crown[10]. The spectrophotometer used in our study which can measure all of the spectral wavelengths that reflect off a material, so provide more exact and systematic results, unlike the colorimeter which can only detect the amount of blue, red, and green wavelengths [21].

Although various methods are available for surface roughness evaluation, profilometry is arguably the most extensively used and acknowledged [22,23], for that, we used USB digital surface profile gauge.

The result of this study showed that fabrication technique had significant effect on surface toughness while storage media had no effect on surface roughness. Although the interaction between variables was significant so the first null hypothesis was partial rejected. According to previous in vivo research, plaque formation can be predicted to stop decreasing below a certain degree of surface roughness (Ra = 0.2 μm). Nevertheless, a rise in plaque formation was accompanied by a rise in surface roughness above this critical level[24].

All studied materials showed an increase in Ra while 3D printed Next Dent C&B MFH showed statistically significant higher values. This can be explained by the presence of a large number of variables related to the fabrication and curing of 3D printed samples. Besides, the slicing process of samples being fabricated at 90 degree leads to loss of geometry occurring in the vertical direction, called the staircase effect and it's based on the angular edges of the slicing layer, which cause wave-like elevation on the surface [25] . Several studies have analyzed the impact of the layer orientation on the mechanical properties and surface roughness of the additive manufacturing interim materials[7,9,26]. Moreover, the setting parameters for 3D printing could also affect the surface quality during specimen fabrication [27, 28] . This was agreement with Atria et al. [29] reported high surface roughness of 3D-printed hybrid resins compared to conventional and CAD/CAM-printed PMMA resins. In contrast, Ta sn et al. [30] discovered that 3D-printed hybrid resins had smoother surfaces than traditional and CAD/CAM PMMA resins. They claimed that additional surface flaws that might heighten the surface roughness could result from the milling and polishing procedure.

The Ra value of disc samples immersed in different oral media had no statistically significant effect on 3Dprinted material while the conventional one showed statistically significantly lowest surface roughness with coffee. This may be due to the high affinity of bis-acrylic-composite to polar materials. The coffee modifies the surface properties due to changing the characteristics of materials as a result of acidity and low polarity which cause more diffusion inside bis-acrylic-composite [31, 32] , which led to brushing of the samples so decrease the surface roughness by removing the stains and the peaks and valleys of the material itself which make it smoother.

In this study the method of fabrication and storage media had significant effect on color stability of provisional materials, so the second null hypothesis was rejected. The conventional provisional material had statistically significant highest color change. As the provisional material is bis-acrylic-composite which has high water sorption values as result of incomplete polymerization process[36]. Moreover regardless of the chemical characteristics using auto mixing for bis-acrylic-composite may increase porosities that may provoke water sorption [30] .While CAD/CAM PMMA blocks are industrially polymerized under optimum manufacturing conditions such conditions offer those interim restoration better mechanical and physical properties than those that are manually fabricated [33] . Proprietary variations in chemistry, such as size distribution of the polymethyl methacrylate particles, polarity of the

monomers, pigment stability, and efficiency of the initiator system for provisional resins may lead to differing degrees of polymerization, water sorption, and, consequently, color stability [33]. Most bis-acryl polymers are more polar than PMMA polymers and therefore have a greater affinity towards water and other polar liquids. The heterogeneity of The bis-acryl resins result of greater susceptibility to color change when in contact with pigmentation media [32] . The higher staining resistance of the PMMA material either milled or printed may be a result of the lower polarity of PMMA and fabrication process as polymerized under optimum conditions in comparison to conventional methods[33, 34] . These findings are consistent with the study of Haselton et al [33]. Furthermore, the present findings accord with those of studies where more color stability was obtained in PMMA than in bis-acryl materials [35, 36] . On the other hand, this was disagreed with the findings of Sham et al [37] who reported minimum color change for the materials containing bis-acryl methacrylate. This may be due to different storage duration.

In the present study the media had significant effect on the color stability of different provisional materials. The specimens were stored in distilled water, cola, coffee, and orange juice and the mean ΔE values were significantly higher in coffee. This may because the coffee has pH 5 and contained higher stains than other medias , possibly because of its high content of yellow pigment molecules [9,30] .Beside that the smaller molecular size of coffee combine with water absorption characteristic of provisional materials [38]. The media such coffee contain yellow colorants, which have lower polarities so the lower polarity of the media promotes a high penetration of pigments into the organic phase due to adsorption and absorption processes[39]. This was agreement with study conducted by Tasin et al [30]and Bitencourt et al [40]. In the current study the storage time significantly affected color change (ΔE) which increased, so time plays a role in the staining of provisional resin materials. This may be due to precipitation of stains over time which agreed with Radwan et al [41] and Bastos et al [42] . Where the ΔE increased progressively over time, regardless of material and media that may be due to increased water sorption over time. Color change of 3D printed was the less than milling after immersed in cola after 2 weeks While after 4 weeks of immersed it was higher in Next Dent C&B MFH (3D printed) than milling when it immersed in cola this may be due to, the low polymerization rate of 3D printing resins compared to other materials is another causative factor of low color stability[1] . The CAD/CAM PMMA materials are made by polymerizing in a high-temperature and high-pressure environment. Therefore, the polymerization rates in these materials are high, and their structures are compact. In the other hand, although 3D printing resins undergo post-curing processes after printing, their polymerization rates are relatively low [43]. A low polymerization rate may affect mechanical strength and biological processes as well as increase the possibility of discoloration due to poor surface integrity and affect surface deterioration due to the presence of residual monomers [44]. In the current study distilled water showed increase in color change ΔE after 4 weeks of immersion of milled provisional material. This may be due to that the immersion of resin in water for a prolonged period may irreversibly affect their color due to high affinity of PMMA to water resins can absorb water at a higher rate because of a high diffusion coefficient [40] .These findings were disagreement with Cevik et al [45] and Alghamdi et al [46] who found that water showed the statistically significant lowest color change due to water does not contain colorant particles. There was a strategically different color change between the study groups; the conventional one shows the highest color change in coffee, followed by orange, distilled water, and the lowest was found to be in cola after 2 weeks of immersion, while after 4 weeks of immersion there was no statistically different color change between cola and orange. This could be explained by the

fact that cola has the lowest pH range (2.7), which could damage the surface integrity of the materials, and it does not produce as much discoloration as coffee, which could be due to cola's lack of a yellow colorant [42] . On top of that, it has been suggested that the phosphate ions in cola can play a role in preventing dissolution [47].

CONCLUSION

Under the conditions of this research, the following conclusions were drawn:

1- The surface roughness of 3D printed materials was higher than milled and conventional groups.

2- Different storage media did not affect the surface roughness of different provisional materials.

3- 3D printed and CAD-CAM milled provisional materials had better color stability compared to conventional group.

4- Coffee produced the greatest color change in all manufacturing techniques of provisional restoration materials.

5- Color stability of 3D printed provisional materials is highly affected by exposure time to cola.

Clinical recommendation:

The degree of discoloration increased with time or has been associated with drinks that have pigments that can stain, especially 3D-printing materials showed more rapid change in discoloration after 4 weeks so decreasing consumption of beverage is recommend when using provisional material for long term.

Recommendations for future studies:

The ideal parameters for 3D printing of provisional restoration materials are still not clear Thus, additional studies on ways to improve printing methods, post-curing processes, and the materials themselves, are essential.

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