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SURFACE ROUGHNESS AND COLOR STABILITY OF MILLED VERSUS 3D PRINTED INTERIM RESTORATION AFTER IMMERSION IN TWO PH MEDIA (IN VITRO STUDY)

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ABSTRACT

Aim: To assess milling versus 3D printing construction technique and different pH media effect on the interim restorations surface roughness and color stability.

Materials and methods: Fourteen 3D-printed resin and 14 milled PMMA discs were divided into two groups (n=7) based on pH media (Coffee and Fanta) for immersion. At two-time immersion intervals (1 and 7 days), the surface roughness using a non-contact profilometer and color stability using a spectrophotometer were tested.

Results: Milled groups showed higher surface roughness at the baseline in both immersions and after 7 days immersion in coffee (0.2908±0.0015). After 7 days in Fanta, 3D printed group showed higher surface roughness (0.2921±0.0013). Considering color stability, after 1- and 7-days immersion, 3D printed group showed a higher color change (ΔE) in coffee (6.15±1.94) than milled group (3.97±1.24). Milled group showed a higher ΔE significance in Fanta (6.17±2.48) than 3D printed group (3.35±1.38).

Conclusion: The surface roughness and color stability of interim restorations were affected by the material, construction technique, and different pH beverage consumption. After seven days, Coffee increased the milled interim surface roughness, whereas Fanta increased it in 3D printed restorations. Coffee immersion induced more color change in the 3D printed interim restorations while Fanta immersion induced more color change in the milled interim restorations after one and seven days.

KEYWORDS: Interim restoration, 3D printing, CAD/CAM, Color stability, Surface roughness.

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INTRODUCTION

The interim restoration is crucial to fixed prosthesis treatment. It's used from tooth preparation to cementation [1]. In long-term treatment, especially rehabilitation, it protects restorations that are intended to last or when additional therapy is needed until rehabilitation is complete. Materials should meet biologic, esthetic, and mechanical requirements including strength and wear resistance. Thus, this interim restoration considerably affects fixed restoration prognosis [2].

Human mouths have a diverse, complex microbial and mechanical environment. Biologically, the oral environment is warm, rich in nutrients, constantly flowing saliva, and has a pH toward neutrality, making it ideal for biofilm growth [3]. Mastication causes intraoral wear processes as abrasion, adhesion, fatigue, and chemical dissolution that degrade interim restorations [4]. Oral pH also changes with the environment. Bacterial metabolic acids including acetic, propionic, and lactic acid change pH. Alkaline drinks like mineral water and staining solutions like tea, coffee, and acidic beverages can also modify pH. Thus, this community will affect interim restorations [5].

After manufacturing, provisional restorative materials should not change color or roughness. Rough surfaces shield bacteria from saliva and mastication, letting them adhere to interim restorations. This caused gingival irritation and tooth decay, and provisional restoration discolouration may dissatisfy patients and clinicians, therefore color stability is important, especially in esthetic areas [6].

Fixed interim prostheses are made directly and indirectly in the dental lab or clinic. It may be manufactured manually, but the worker's competence and multiple processing steps may be a drawback [1]. However, milling and 3D printing technology for prosthesis fabrication eliminate processing errors, resulting in more accurate interim restorations. CAD/CAM systems are fast, easy to use, and produce high-quality restorations, while 3D printing technology is passive and wastes little raw material [7].

The interim restoration surface roughness and color stability may be affected by manufacturing method (milled versus 3D printed) and oral cavity pH medium. Thus, this study examined how milling versus 3D printing and immersion in two pH oral media (coffee and carbonated orange juice) affected interim restoration surface roughness and color stability. This study's null hypothesis was that milled and 3D printed interim restorations surface roughness and color stability would not differ after immersion in two pH oral media (Coffee versus Fanta) for 1 and 7 days.

MATERIALS AND METHODS

Sample size calculation

A power analysis was designed to have adequate power to apply a statistical test. Based on a pervious study [8], sample size calculation was performed by adopting an alpha level of (0.05) a beta of (0.2) i.e. power=80% and an effect size (f) of (0.680) using G*Power version 3.1.9.7 [9].

A total of 28-disc samples (n=14 per group) with similar shade (A3) were used. Two provisional materials with different fabrication methods were evaluated, a 3D printed provisional resin **(Group D)** (Proshape temp resin,Proshape Dental Solutions, Turkey) and a milled provisional resin **(Group C)** (PMMA Disk, Yamahachi Dental Co., Japan) were used as shown in Table 1.

Each group was furtherly divided according to media of immersion (n=7 per supgroup); **Group (Dc)** Including 3D printed Proshape temp resin discs immersed in Turkish coffee solution, **Group (Df)** Including 3D printed Proshape temp resin discs immersed in Fanta Orange solution, **Group (Cc)** Including CAD/CAM PMMA discs immersed in Turkish coffee solution and **Group (Cf)** Including CAD/CAM PMMA discs immersed in Fanta Orange solution.

TABLE (1): Chemical compositions, manufacturer and batch No. of materials used in the present study

Material	Chemical composition	Manufacturer company	Batch No.
Proshape temp resin	405nm UV resin	Proshape Dental Solutions, Turkey	11914
PMMA Disk	Polymethyl methacrylate	Yamahachi Dental Co., Japan	1280119
Carbonated orange juice	Carbonated water, high fructose corn syrup, citric acid, sodium benzoate (to protect taste), natural flavors, modified food starch, sodium polyphosphates, glycerol ester of rosin, yellow 6, red 40.	Fanta Orange, Coca-Cola Co., Egypt	--
Coffee	Special plain,100% Arabica, Medium roast colors	Shaheen Coffee Co., Egypt	--

CAD/CAM and 3D printing samples design was carried out using Exocad software program (Exocad GmbH, Germany) to design a disc with a 10 mm diameter and 2 mm thickness.

For CAD/CAM provisional discs fabrication, the design was sent as Standard Tessellation Language (STL) file to computer aided manufacturing (CAM) DENTALCAM software (vhf, vhf camfacture AG, Germany), where nesting placement of the samples within PMMA disc was done and three supporting structures were placed on the outer surface of the disc. The milling was accomplished using five-axis dry K5 Milling Machine (vhf, vhf camfacture AG, Germany).

Afterwards, the interim disc samples either by CAD/CAM or 3D printing technique, and for the purpose of standardization, the samples were handled by a single operator. All supporting structures attached to the discs were removed, and then they were finished and polished using a polishing kit (visio.lign tool kit, bredent.co.uk, Germany) according to the manufacturer's instructions. All specimens were polished using 600-grit silicon carbide abrasive paper at 300 rpm for one minute under water cooling for initial roughness standardization [8,10]**.** The final thickness of all samples was measured using a HOLEX digital caliper (Holex Digital External Micrometer, HOLEX, Japan) at different points to assure discs thickness.

The identical design STL file was transferred to a 3D printing machine using Exocad to make tentative discs. Stereolithography machine (X-Rite, model RM200QC, Neu-Isenburg, Germany) was used. The resin liquid (Proshape temp resin, Proshape Dental Solutions, Turkey) was poured in a special container of the 3D printer machine (EPAX X1-4K Mono printer, 3DGence America, Inc. Dallas, Texas, USA). Following the manufacturer's instructions, the printer began printing with 20 layers of 0.02-0.1 mm thickness and a 30-minute partial curing cycle. The 3D-printed discs were removed from the printer to begin post-processing curing by Denstar Light Zone II - DS310 (Denstar, South Korea). 30-minute post-curing cycle. After that, all samples were polished as forementioned previously.

Before immersion, all samples surface roughness was evaluated. Quantitative surface topography characterization without contact is possible with optical profilometry [11]**.** USB Digital microscope with a built-in camera (Scope Capture Digital Microscope,Guangdong, China) connected to an IBM compatible PC photographed samples at 120X. Images were captured at 1280 × 1024 pixels, cropped to 350 x 400 pixels using Microsoft Office Picture Manager, then analyzed using WSxM software [12]. Pixels represent all limitations, sizes, frames, and measurable metrics in WSxM. Therefore, system calibration converted pixels into absolute real-world units. The calibration process involved comparing a ruler to a software-generated scale to calculate the average height (Ra) in µm, which is a good indicator of surface roughness [13].

Additionally, the samples shade was measured before immersion using a reflective spectrophotometer (X-Rite, model RM200QC) (Neu-Isenburg, Germany). The aperture size was set to 4 mm and the samples were exactly aligned with the device. A white background was selected and measurements were made according to the CIE L*a*b* color space relative to the CIE standard illuminant D65. The color changes (ΔE) of the specimens were evaluated using the following formula:

$$\Delta E\ CIELAB = (\Delta L^*2 + \Delta a^*2 + \Delta b^*2)\ ½$$

Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue) [14].

For immersion, the coffee solution was prepared according to manufacture instruction, 2 gm of Turkish coffee (special plain,100% Arabica, Medium roast colors) (Shaheen Coffee Co., Egypt) were poured into 100 ml of boiled water and ready-made carbonated Fanta orange (250 ml) (Coca-Cola Co., Egypt) was placed in a container. Then testing of the solutions pH was carried out using the PH-108 pen device (Sinotester CO., China), the pH recorded was 4.5-5 for the coffee and was 2.7 for Fanta.

Samples were immersed individually in closed vials containing 5 ml of each immersion solutions and stored in an incubator (CBM.Torre Picenardi (CR), Model 431/V, Italy) at 37ºC for 1 and 7 days. The solutions were freshened daily to avoid yeast or bacterial contamination and to reduce the precipitation of particles in the staining solutions [15], the solutions were also stirred twice a day to prevent solution accumulation at the bottom of the vials.

Color changes were measured at 1 and 7 days after storage in the colorants. It is known that a 24-hour in-vitro incubation in the colorants simulates conditions similar to exposure to the colorants during food intake over ~30 days [16,17]. The maximum storage period of 7 days that was evaluated in the present study is equivalent to approximately 7 months; this simulates the use of interim restorations in rehabilitation cases [16,17].

By the end of the immersion period, samples were rinsed with distilled water and wiped with gauze to clean and remove the residual solution from the surface before re-immersion. After the immersion periods (1 and 7 days) were attained, a reassessment of the surface roughness and color was conducted in a similar manner as in the previously mentioned procedures.

Statistical analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. Data showed parametric distribution so one-way ANOVA followed by Tukey's post hoc test was used for intergroup comparisons and repeated measures ANOVA followed by Bonferroni post hoc test was used for intragroup comparisons. Correlation analysis was done utilizing Spearman's rank order correlation coefficient. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows [18].

RESULTS

Surface roughness

Regarding construction technique effect after immersion in coffee solution at two-time intervals, the milled interim group (Cc) had significantly higher mean values than the 3D printed interim group (Dc) at baseline. After 1 day, there was no statistically significant difference between Cc group and Dc group. While after 7-days, Cc groups showed a highly significant mean value compared to Dc groups as presented in Table (2).

After immersion in Fanta solution, the baseline milled interim discs (Cf) had a significantly higher surface roughness value than the 3D printed interim discs (Df). While there was no statistically significant difference between both groups after 1 day. After 7-days, Df group had a significantly higher value than Cf group as presented in Table (2).

Regarding the effect of immersion solution on surface roughness of milled interim discs, there was no statistically significant difference between coffee samples and Fanta samples at the baseline. Also, after 1 day, no statistically significant difference was found between coffee samples and Fanta samples. While samples of coffee solution showed a higher significant mean value than Fanta solution after 7-days as shown in Table (2).

In 3D printed interim group at the baseline, the difference was not statistically significant between coffee samples and Fanta samples But they were statistically significant at 1 day and 7-days. In 1 day, samples immersed in coffee showed a statistically significant higher mean value than those in Fanta at ($p<0.001$). While after 7-days samples immersed in Fanta showed a significantly higher value than those in coffee as shown in Table (2).

TABLE (2) Results of the effect of construction technique (Milling versus 3D printing) and immersion solution (Coffee versus Fanta) on surface roughness at two-time intervals.

Results of the effect of construction technique (Milling versus 3D printing) on surface roughness

Interval	Immersing solution	Surface roughness (Ra) (mean±SD)		p-value
		3D printed	**Milled**	
Baseline	**Coffee**	0.2890±9e-04	0.2913±0.0024	**0.002***
	Fanta	0.2875±0.0030	0.2901±0.0011	**0.004***
1 Day	**Coffee**	0.2898±3e-04	0.2902±0.0018	**0.373ns**
	Fanta	0.2887±8e-04	0.2894±0.0043	**0.535ns**
7-days	**Coffee**	0.2881±0.0037	0.2908±0.0015	**0.016***
	Fanta	0.2921±0.0013	0.2888±0.0033	**0.001***

Results of the effect of immersion solution (Coffee versus Fanta) on surface roughness

Interval	Restoration	Surface roughness (Ra) (mean±SD)		p-value
		Coffee	**Fanta**	
Baseline	**Milled**	0.2913±0.0024	0.2901±0.0011	**0.084ns**
	3D printed	0.2890±9e-04	0.2875±0.0030	**0.067ns**
1 Day	**Milled**	0.2902±0.0018	0.2894±0.0043	**0.492ns**
	3D printed	0.2898±3e-04	0.2887±8e-04	**<0.001***
7-days	**Milled**	0.2908±0.0015	0.2888±0.0033	**0.043***
	3D printed	0.2881±0.0037	0.2921±0.0013	**<0.001***

; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

Results of the profilometry assessment

The obtained 3D images of 3D printed interim discs after immersion in coffee solution revealed that the surface roughness pattern at baseline consisted of scratches and a uniform pattern of micro-irregularities. After 1 day, 3D images showed scratches that were characterized by broader peaks and shallow valleys. However, after 7-days, it showed a uniform pattern of micro irregularities with deep valleys, as presented in Figure (1). While the obtained 3D images of milled interim discs revealed that the surface roughness pattern at baseline consisted of broader peaks and shallow valleys. After 1 day, 3D images showed uniform pattern of micro irregularities with crater like appearance and deep valleys. However, after 7-days, it showed a high peaks and shallow valleys, as presented in Figure (2).

3D printed interim discs after immersion in Fanta solution 3D images revealed that the surface roughness pattern at baseline consisted of scratches and uniform pattern of micro irregularities. After 1 day, 3D images showed uniform pattern of micro irregularities characterized by high peaks and deep valleys. However, after 7-days, it showed a crater like appearance with shallow valleys, as presented in Figure (3). While milled interim discs 3D images revealed that the surface roughness pattern at baseline consisted of crater like appearance with shallow valleys. After 1 day, 3D images showed crater like appearance with shallow valleys. However, after 7-days, it showed a uniform pattern of micro irregularities characterized by high peaks and deep valleys, as presented in Figure (4).

Color stability

Regarding the effect of construction technique (milling versus 3D printing) on color stability after immersion in coffee solution, 3D printed interim discs showed significantly higher mean values of color change than milled interim discs at 1 and 7 days respectively as shown in Table (3).

When the color stability of the milled interim discs was compared to 3D printed interim ones after immersion in Fanta solution, they showed significantly higher mean color change values than 3D printed discs at 1 day. While, at 7-days, milled discs showed significantly higher mean values than 3D printed discs as shown in Table (3).

Regarding the effect of immersion solution on color stability of milled interim discs at two-

TABLE (3) Results of the effect of construction technique (milling versus 3D printing) and immersion solution (Coffee versus Fanta) on color stability at two-time intervals.

Results of the effect of construction technique (milling versus 3D printing) on color stability				
Interval	Immersing solution	Color stability (ΔE) (mean±SD)		p-value
		3D printed	**Milled**	
1 Day	**Coffee**	5.77±1.27	2.61±0.51	**<0.001***
	Fanta	3.57±1.59	6.18±1.93	**<0.001***
7-days	**Coffee**	6.15±1.94	3.97±1.24	**<0.001***
	Fanta	3.35±1.38	6.17±2.48	**<0.001***
Results of the effect of immersion solution (Coffee versus Fanta) on color stability				
Interval	Restoration	Color stability (ΔE) (mean±SD)		p-value
		Coffee	**Fanta**	
1 Day	**Milled**	2.61±0.51	6.18±1.93	**<0.001***
	3D printed	5.77±1.27	3.57±1.59	**0.003***
7-days	**Milled**	3.97±1.24	6.17±2.48	**0.005***
	3D printed	6.15±1.94	3.35±1.38	**0.015***

; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

time intervals, after 1 day, there were statistically significant difference between samples immersed in Fanta solution and coffee solution. As well, at 7-days samples immersed in Fanta solution showed higher statistically significant mean values than those in coffee solution as shown in Table (3).

Regarding the color stability of the 3D printed interim discs after immersion in coffee and Fanta solutions after 1 day, there were statistically significant difference between samples immersed in coffee solution and Fanta solution. As well, at 7-day samples immersed in coffee solution showed higher statistically significant mean values than in Fanta solution samples as shown in Table (3).

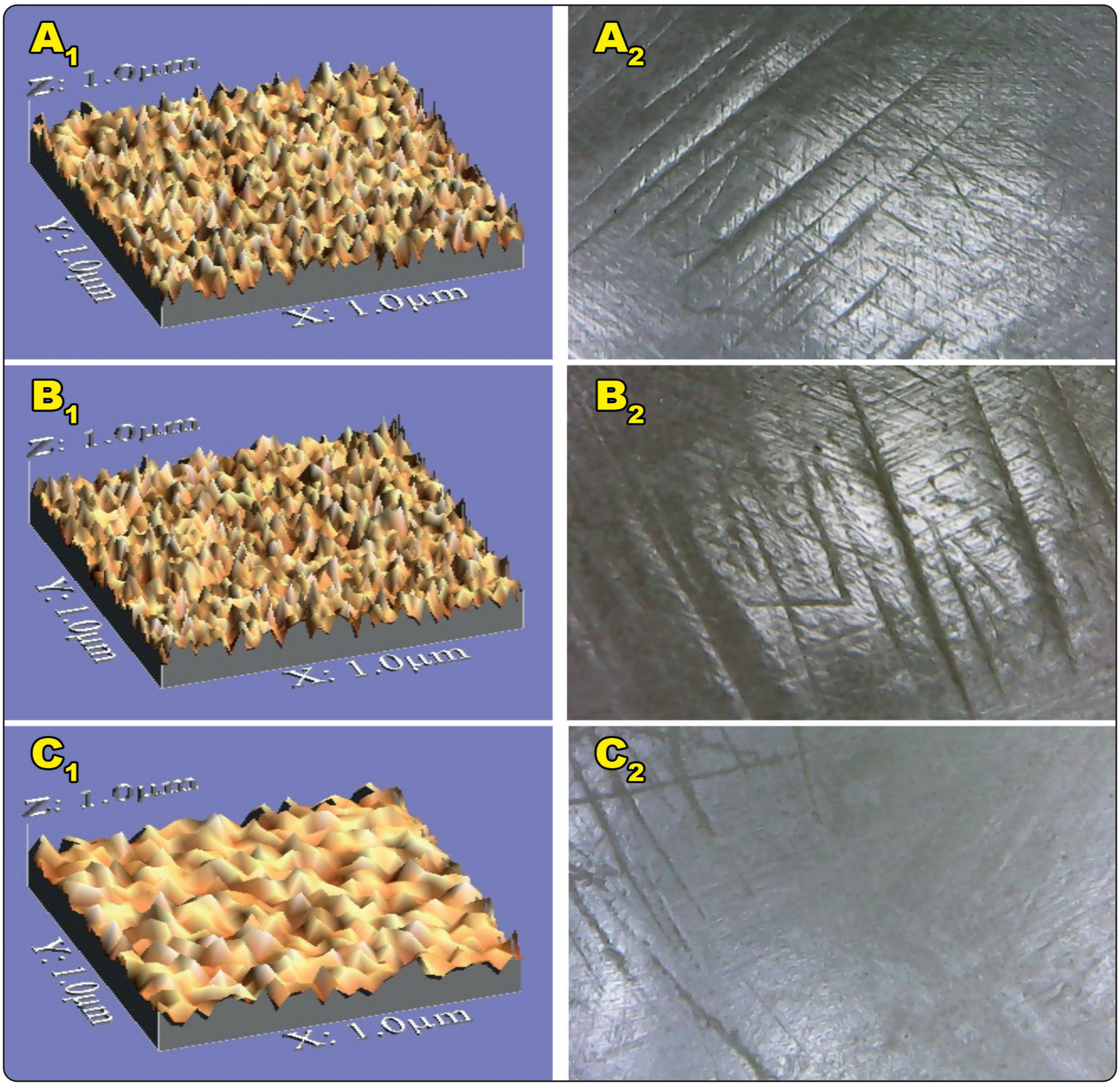

Fig. (1) (A1) 3D digital profilometry image showing surface roughness (Ra) of 3D Printed samples before immersion in coffee solutions under Scope Capture Digital Microscope (Baseline). (A2) Microscopic image of 3D Printed samples before immersion in coffee solutions. (B1) 3D digital profilometry image showing surface roughness (Ra) of 3D Printed samples immersion in coffee solutions under Scope Capture Digital Microscope (1 Day). (B2) Microscopic image of 3D Printed samples immersion in coffee solutions. (C1) 3D digital profilometry image showing surface roughness (Ra) of 3D Printed samples immersion in coffee solutions under Scope Capture Digital Microscope (7-days). (C2) Microscopic image of 3D Printed samples immersion in coffee solutions.

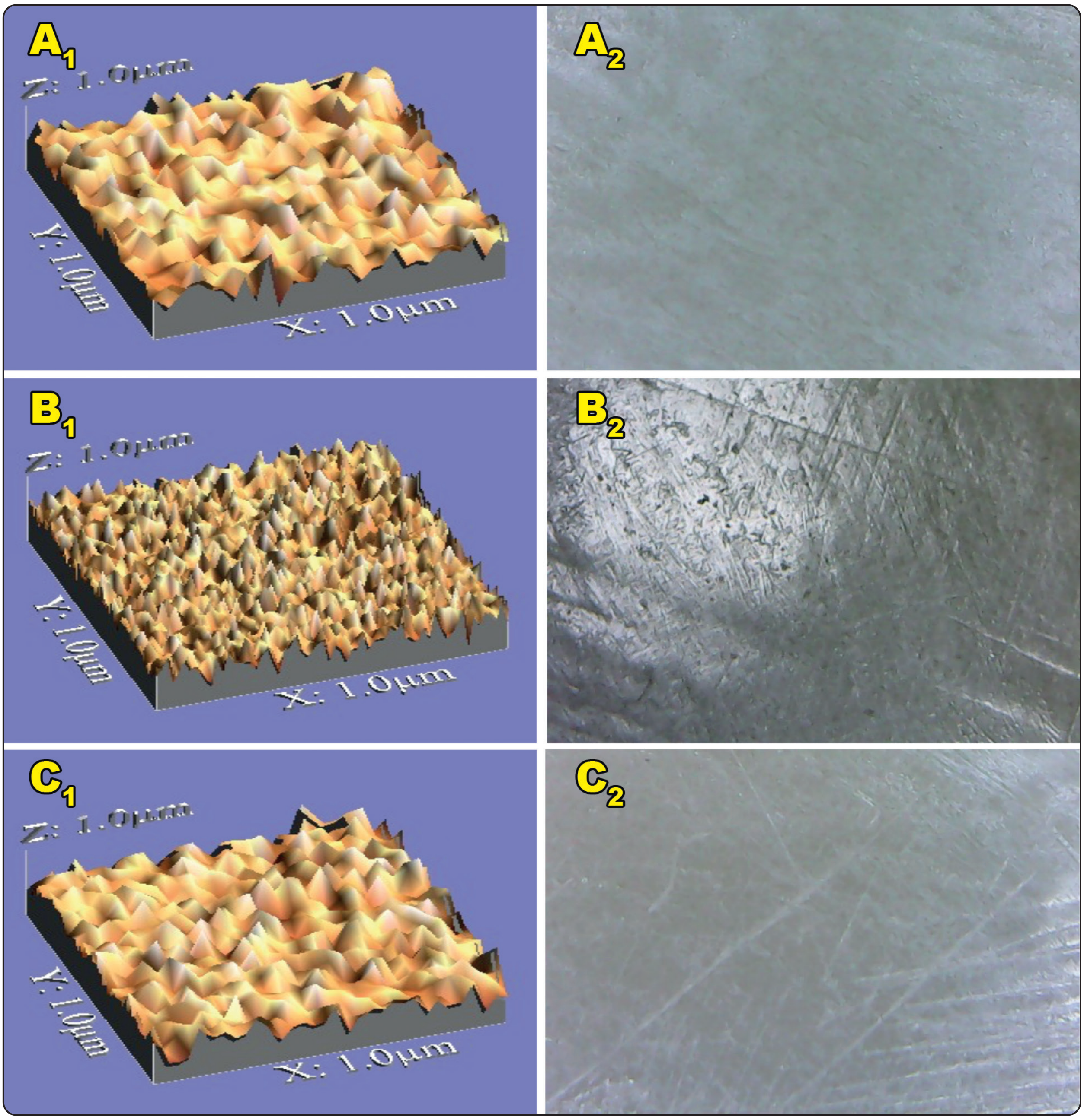

Fig. (2) (A1) 3D digital profilometry image showing surface roughness (Ra) of milled samples before immersion in coffee solution under Scope Capture Digital Microscope. (A2) Microscopic image of milled samples before immersion in coffee solutions. (B1) 3D digital profilometry image showing surface roughness (Ra) of milled samples immersion in coffee solutions under Scope Capture Digital Microscope. (B2) Microscopic image of milled samples immersion in coffee solutions. (C1) 3D digital profilometry image showing surface roughness (Ra) of milled samples immersion in coffee solutions under Scope Capture Digital Microscope. (C2) Microscopic image of milled samples immersion in coffee solutions.

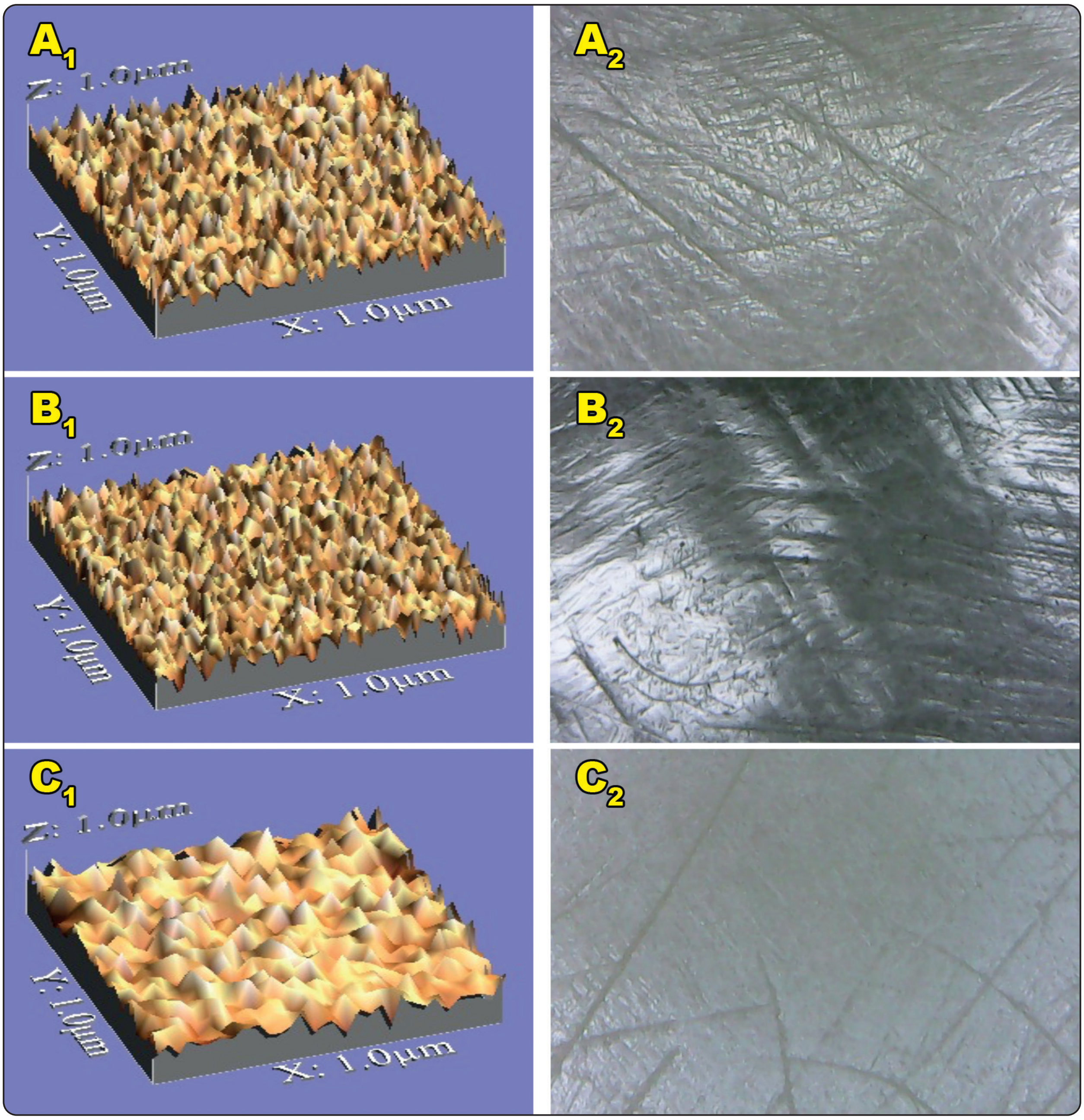

Fig. (3) (A1) 3D digital profilometry image showing surface roughness (Ra) of 3D Printed samples before immersion in Fanta solutions under Scope Capture Digital Microscope (Baseline). (A2) Microscopic image of 3D printed samples before immersion in Fanta solutions. (B1) 3D digital profilometry image showing surface roughness (Ra) of 3D Printed samples immersion in Fanta solutions under Scope Capture Digital Microscope (1 Day). (B2) Microscopic image of 3D printed samples immersion in Fanta solutions. (C1) 3D digital profilometry image showing surface roughness (Ra) of 3D Printed samples immersion in Fanta solutions under Scope Capture Digital Microscope (7-days). (C2) Microscopic image of 3D printed samples immersion in Fanta solutions.

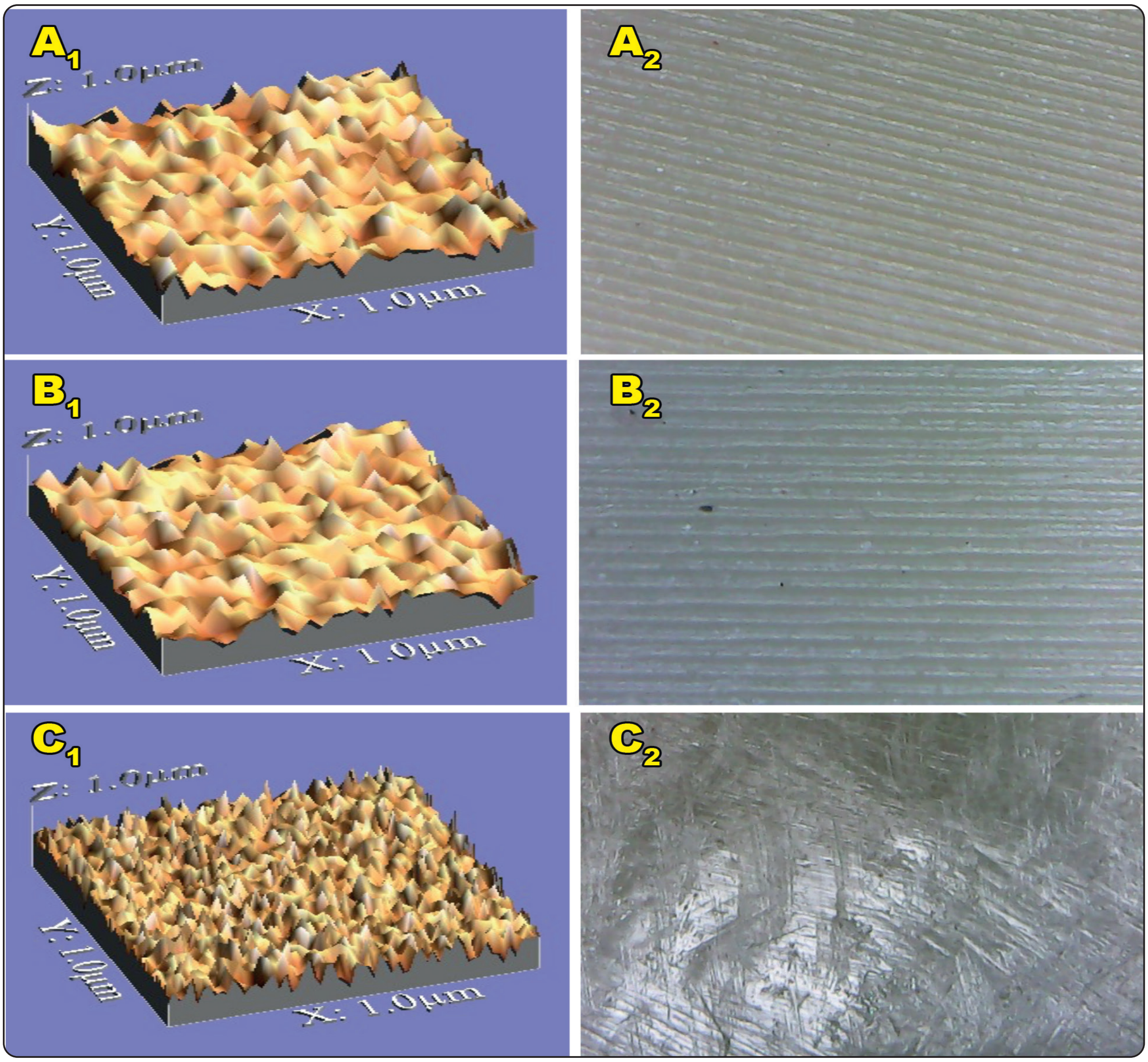

Fig. (4) (A1) 3D digital profilometry image showing surface roughness (Ra) of milled samples before immersion in Fanta solutions under Scope Capture Digital Microscope (Baseline). (A2) Microscopic image of milled samples before immersion in Fanta solutions. (B1) 3D digital profilometry image showing surface roughness (Ra) of milled samples immersion in Fanta solutions under Scope Capture Digital Microscope (1 Day). (B2) Microscopic image of milled samples immersion in Fanta solutions. (C1) 3D digital profilometry image showing surface roughness (Ra) of milled samples immersing in Fanta solutions under Scope Capture Digital Microscope (7-days). (C2) Microscopic image of milled samples immersion in Fanta solutions.

Correlation

There was no significant correlation between the surface roughness and color stability as presented in Table (4) and Figure (5).

TABLE (4) Results of the correlation test between surface roughness and color stability

Variables	Correlation coefficient (95% CI)	P-value
Surface roughness-color stability	-0.092 (-0.267:0.089)	**0.318ns**

; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

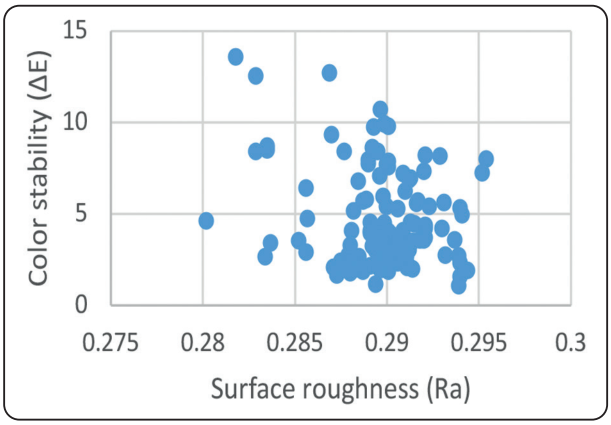

Fig. (5) Scatter plot showing the correlation between surface roughness and color stability

DISCUSSION

Interim restorations are essential for fixed prosthesis treatment. From tooth preparation to final cementation, interim restorations use numerous techniques and materials [(1)]. Recently, subtractive (milling) or additive (3D) manufacturing are used [(7)]. Environment influences oral pH. Additionally, Acetic, propionic, and lactic acids modify pH. Mineral water, tea, coffee, and acidic beverages can also change pH. Thus, this community impacts interim restorations [(5)].

In the current study, CAD/CAM provisional material (PMMA Disk) were used to construct disc samples. It is characterized by 21 Hv hardness and 110 MPa bonding strength and highest mean fracture toughness value when compared to other PMMA materials and manufacturing techniques [(19)].

3D printed provisional material (Proshape temp resin) was used to construct disc samples. It is characterized by exceptional breakage and wear resistance for daily use and is perfectly compatible with syringe composites in the event of modification or repair. Furthermore, its flexural strength is 62–70 MPa, and its linear shrinkage is 0.11%-0.15%.

The disc samples were 2 mm thick for standardization since the provisional crown's maximum facial or occlusal thickness is 2 mm [(8,20)]. The discs were 10 mm in diameter to accommodate spectrophotometer color measurement according to window dimensions [(21)]. Surface residues and discolouration were reduced during finishing and polishing [(22)]. Coffee and orange Fanta as immersion media were selected as they are the most commonly consumed beverages. Carbonated orange juice has a low pH value about (2.82), while coffee shows high staining potential [(21, 23)].

All samples were immersed 1 and 7 days. The 24-hour (1-day) incubation in the solutions mimics the exposure to colorants during food consumption over ~30 days [(16,17)]. In rehabilitation and implant-supported restoration scenarios, 7 days (1 week) is similar to 7 months because several months represent long-term provisional restoration periods [(24)]. Additionally, Immersion solutions were freshened daily to eliminate yeast or bacterial contamination and mixed twice a day to reduce particle accumulation in staining solutions [(15)].

Rough surfaces increase the initial attachment of bacteria to the interim restoration that cause tissue inflammation and play a major role in restoration staining. Moreover, a rough surface can lead to the initiation of cracks, which cause a shorter restoration life and poor optical characteristics [(6)]. In the current study, non-contact optical profilometry was used to assess the roughness because it avoids damage from contact profilometry with the stylus, which may alter the surfaces tested [(25)].

Color stability is crucial for interim restorations in the esthetic zone when used for long periods [(26)]. Due to its high-precision sensor and capacity to estimate spectral reflectance at each wavelength, spectrophotometers were used to investigate color stability in this work [(27)]. Therefore, it suits complicated color analysis. As a popular space for measuring object and uniform color, CIELAB was utilized [(14)].

The null hypothesis was rejected for surface roughness since the milled groups showed a higher statistically significant difference than the 3D printed groups at baseline in both immersion media and after 7 days of coffee immersion. This may be because milling burs may cause more surface flaws and lower interim restoration material quality. 3D printing improves surface smoothness through composition and polymerization [16]. Current study results are consistent with a study that compared the surface roughness of 3D printed interim crowns before and after polishing to conventional crown materials and found that stereolithography-fabricated crowns had the lowest surface roughness [28].

After 7 days of immersion in Fanta, the 3D printed group showed statistically significant higher values of surface roughness than the milled group. This could be attributed to the acidity of the Fanta solution that led to hydrolytic degradation of the resin surface. This deterioration of the resin materials can be increased by long-term consumption of low-pH beverages. The results of the current study are consistent with the findings of a study reported that increased consumption of low-pH beverages (carbonated orange juice) led to increased surface roughness of 3D-printed materials [21,29].

The threshold surface roughness that can eliminate bacterial accumulation and plaque adherence is below 0.2μm and could be considered a smooth surface, and it can be detectable by the tongue if it is more than 0.5 μm. Therefore, all the surface roughness values of the current study were below the roughness threshold detectable by the tongue (0.5μm) [6,30].

The null hypothesis of color stability was rejected, as both groups noted changes in color parameters (ΔE) after immersion. 3D printed groups had significantly higher values than milled groups after 1 and 7 days in coffee solution. The low polymerization rate of 3D-printed resins impaired mechanical strength and surface integrity and caused leftover monomers to discolor and deteriorate the surface [16]. 3D-printing remained an uncured layer after curing, reducing color stability [8]. This may be due to the greatest discoloration of the yellow colorants in the coffee. Coffee had the highest color alterations after long-term storage of all aesthetic restorative products and exceeded the therapeutic limit regardless of composition [31,32]. Also, due to the absorption and adsorption of polar colorants incorporated into or onto the organic phase of resin materials [20]. After immersion in Fanta solution for 1 and 7 days, milled groups had statistically significant higher color change than 3D printed groups. Milled interim restorations composition may require more examination. However, the amount of color change in groups were above the level of clinical acceptability (ΔE=3.3) indicating that it is simple to distinguish the difference in color between the observed objects as determined by Jeong-Yol Lee [19].

These results came in agreement with other studies reported that coffee caused more discoloration than other solution types [21,32,33]. Furthermore, the used colorant type, the immersion time, and the composition of the material had an impact on the color stability of the material [33].

However, the results of the present study did not coincide with a study reported that no significant difference was showed in color change between milled and printed groups. Furthermore, it was recommended that 3D-printed composite resins could be a promising interim material with good stain resistance. The difference in the results may be attributed to the different finishing and polishing used system [20].

Surface roughness and color stability were not statistically correlated in this investigation. Contrary to a study that linked surface roughness to color stability [21]. This may be due to the study's limited sample size [34]. Correlation cannot be implemented as causality [35]. Even when variables are strongly correlated, we cannot determine their causes.

In this study, in-vitro experiments do not imitate all oral variables and do not include an artificial saliva control group. Further, in vivo studies should replicate clinical and oral conditions. To define interim restoration materials, X-ray diffraction and EDX are indicated.

CONCLUSIONS

The material construction technique, and different pH beverage consumption have an influence on the surface roughness and color stability of fixed interim restorations. After seven days, Coffee immersion increased the surface roughness of milled interim restorations, whereas Fanta immersion increased the surface roughness of 3D printed restorations. Coffee immersion induced more color change in the 3D printed interim restorations while Fanta immersion induced more color change in the milled interim restorations after one and seven days.

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