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ORIGINAL RESEARCH

Effect of Dietary Simulating Solvents on the CAD-CAM Provisional Restorative Materials' Microhardness and Color Stability Properties: An in vitro Study

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Purpose: This in vitro study investigated the effects of dietary solvents on the microhardness and color stability of CAD/CAM provisional restorations compared to conventional materials.

Methods: Disc-shaped specimens (n=200) were fabricated from self-cured acrylic resin, two 3D-printing resins (FormLabs, NextDent), and a milled material (TelioCAD). Randomization assigned specimens (n=10/group) to immersion solutions: artificial saliva, citric acid, heptane, coffee, and tea. Microhardness and color stability were evaluated. One-way and three-way ANOVA with Tukey's post hoc test analyzed the data.

Results: Dietary solvents significantly reduced the surface microhardness of all tested materials ($p<0.05$). Unpolished surfaces exhibited greater color changes compared to polished ones ($p<0.05$) across all materials. Coffee and tea induced the most substantial reductions in hardness and the most significant color alterations ($p<0.05$), whereas saliva and citric acid had minimal effects.

Conclusion: Milled provisional restorations exhibited superior hardness and color stability. Dietary solvents significantly affected material properties over time, highlighting the importance of material selection for clinical applications.

Keywords: 3D-printed, color stability, food, microhardness, milled, self-cure resin

Introduction

Provisional restorations are indicated during prosthodontic treatments to preserve occlusion, pulp vitality, and aesthetics.[1] They are used for various purposes, including adjusting the vertical dimension, modifying occlusal plane abnormalities, planning gingivectomy and crown lengthening procedures, and promoting gingival inflammation healing before making final impressions for the definitive restorations.[2] These restorations are placed in the oral cavity for extended periods of time in some clinical scenarios, and they are subjected to various challenges, including masticatory forces and acidic and humid environments.[3] Therefore, understanding the mechanical properties of the provisional restoration materials is essential to survive the constant functional forces while they are in service.[4]

Polymethylmethacrylate (PMMA) is one of the most often used provisional restorative materials.[5] PMMA has several advantages over other provisional restorations, including excellent polishing capabilities, low cost, high coefficient of thermal expansion, and lightweight.[6] However, this material's limitations include poor color stability, unpleasant odor, excessive polymerization shrinkage, low durability, porosity, and high surface roughness.[7] The development of CAD-

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CAM (Computer-Aided Design and Computer-Aided Manufacturing) provisional restorations was introduced to dentistry as a solution to these issues.[8]

According to the fabrication process, CAD-CAM technology can be classified as Additive Manufacturing (AM) or Subtractive Manufacturing (SM).[9,10] When a long-term provisional is needed, CAD-CAM provisional materials are preferred because they have various advantages such as color stability, ease of production, accuracy, less material waste, and superior strength.[11] The immediate and long-term effects of 3D-printed provisional restorations are directly impacted by the manipulation and post-curing process information that many manufacturers choose not to adequately provide to clinicians.[12]

The oral environment influences the provisional restorations. When beverages, food components, and saliva come in contact with provisional restorations, they can cause significant damage, such as aging and degradation.[13] Organic acids, as well as a variety of liquid and dietary ingredients, can degrade dental composite resin matrices.[14] Additionally, dietary stimulating beverages have a negative impact on the hardness of provisional restorations manufactured with PMMA.[15] Another investigation discovered that the hardness of provisional materials made of bis-acryl resin composite degrades more quickly in aqueous ethanol solutions than methyl methacrylate and urethane methacrylate.[16] Color stability of resin provisional restorations is another mechanical property affected by beverages like tea and coffee.[17]

The impact of food-stimulating solvents on 3D-printed provisional restorations has not yet been the subject of previous studies. Therefore, this study aimed to investigate the hardness and color stability of two 3D-printed provisional restorative materials, NextDent C&B MFH (NextDent, Centurionbaan, The Netherlands) and FormLabs Temporary CB Resin (FormLabs, Somerville, MA), and compare them to milled provisional restoration (TelioCAD; Ivoclar Vivadent, Schaan, Liechtenstein) and a conventional cold-cured acrylic resin material (UNIFAST III self-cure acrylic resin; GC Corporation, Tokyo, Japan). The null hypothesis was that immersing various provisional restoration materials in food-stimulating solvents would not affect the microhardness and color stability of CAD-CAM provisional restorations.

Materials and Methods

In this investigation, 200 (10 × 2 mm) discs were made using four different kinds of provisional restorative materials: two 3D-printed resin, one milled block, and a conventional cold-cured acrylic resin. Table 1 lists the names of the materials, manufacturers, and compositions. Sample size calculation was performed through power analysis by using an online calculator, "Power and Sample size.com".[18] A power analysis based on comparing two means ($\alpha = 0.05$, power = 80%, confidence interval = 95%) using data from previous studies determined a minimum sample size of 10 specimens per group.[15]

Specimen's Preparation

For conventional acrylic resin specimens, a mold was produced from a putty index (3M ESPE Dental Products; St Paul, MN, USA) with the disc's space dimensions of 10×2 mm and was used to fabricate the discs following previously published articles.[19] A Computer-Aided Design (CAD) program was used to create the 3D-printed specimens (Fusion 360 software; Autodesk, Rock Hill, SC, USA) with the exact standard dimensions and then printed with the corresponding printer (Formlabs Form 2, and NextDent 5100).[20] The 10 mm diameter cylinder was produced by trephining

Table 1 List of the Materials Used in the Study

Material	Composition	Manufacturer	Method of Fabrication	Sample Size (n)
NextDent C&B MFH	Methacrylic oligomers Phosphine oxides	NextDent, Centurionbaan, The Netherlands	3D printing by NextDent 5100	50
FormLabs Temporary CB Resin	Biocompatible Photopolymer Resin	Somerville, Massachusetts-based company, United States.	3D printing by Form 2	50
TelioCAD	Blocks consist of 99.5% Highly cross-linked PMMA and 0.5% pigment	Ivoclar Vivadent, Schaan, Liechtenstein.	Trimmed from a CAD-CAM block	50
UNIFAST III self-cure acrylic resin	Methyl methacrylate	GC Corporation, Tokyo, Japan	Cold-cured fabricated using a mold	50

TelioCAD discs. An Isomet-5000 precision saw from BUEHLER was then used to cut each cylinder into 2 mm thick discs (Buehler, Lake Bluff, IL, USA). Sectioning was carried out under running water with a blade speed of 1200 rpm, a blade thickness of 0.5 mm, and a load of 100 g. Fine grit (grits 300) sandpaper was installed on an AutoMet250 polishing machine disc (Buehler, Lake Bluff, IL, USA) to reduce the excessive thickness of the discs. One side of the specimens was polished with pumice and a rag wheel using WP-EX 3000 Polisher (Wassermann Dental, Hamburg, Germany) at 15,000 rpm for 15 s. After that, specimens were left to be dried for 24 hours prior to the testing.

Dietary Simulating Solvent Immersion Protocol

Specimens were kept in distilled water for a 24-hour at 37 °C. Each provisional restoration material was divided into five groups based on the immersion solutions: 1) artificial saliva group (n=10); 2) 0.02 N citric acid group (n=10); 3) heptane group (n=10); 4) coffee group (n=10); and 5) tea group (n=10).

Afterward, each test group was immersed in a 100 mL dietary stimulating solvent in the same container at 37 °C for one month inside an incubator (Heraeus Sanyo CO_2 Incubator; Thermo Scientific, Waltham, MA, USA). Every 7 days, freshly made immersion solutions replaced the dietary stimulation solvents. Regarding artificial saliva preparation, a buffer solution was prepared according to Fusayama et al from KH_2PO_4 and Na_2HPO_4. Each salt dissolved in 1 L of deionized distilled water.[21] The acidic solution (pH 5.7 ± 0.01) was prepared by mixing 500 mL of KH_2P0_4 in a graduated flask, and Na_2HPO_4 solution was added gradually to reach the required pH. Then, the remaining salts of artificial saliva were added till the volume reached 1 L.

Additionally, the basic saliva (pH 8.3 ± 0.01) was prepared by inserting 500 mL of Na_2HPO_4 in a flask, and KH_2PO_4 was added until reaching the required pH. Moreover, the neutral saliva solution was prepared as mentioned, and the pH was adjusted to pH 7 by adding the Na_2HPO_4 solution. The pH of all immersion solutions was checked and evaluated using a digital pH meter (Thermo Scientific Orion Star A211; Thermo Fisher Scientific, Waltham, MA, USA).

Heptane is a solution that simulates vegetable oils, fatty meat, and butter. While citric acid simulates fruit like oranges and vegetables like lemons according to FDA guidelines.[22] Regarding Citric acid solution preparation, 2.0 g of Citric Acid Monohydrate was dissolved in 10 mL of water and mixed in a beaker. While Heptane was commercially available from Scharlab (Scharlab, Barcelona, Spain) (Table 2). A sealed glass container was used for the Heptane group to minimize its evaporation property.[23]

For the coffee group, 300 mL of boiled distilled water was mixed with 3.6 g of coffee (Nescafé Classic; Nestlé, São Paulo, Brazil) and mixed for 10 min. Once it was ready, a filter paper was used to filter the solution before the specimens were immersed. For the tea group, two commercial tea leave bags (2 × 2 g) (Yellow Label Tea; Lipton, Dubai, United Arab Emirates) were immersed in a boiled 300 mL of distilled water and left for 10 minutes. Following immersion, the specimens' color parameters and surface microhardness values were measured. Figure 1 summarizes the sample preparation and tests conducted.

Microhardness Test

Initially, the specimens' microhardness was measured for both polished and unpolished surfaces in two intervals, one as a baseline (T0) and the other after a one-month conditioning period (T1). After the immersion phase, the specimens were

Table 2 List of the Dietary Solvents Used in the Study

Dietary Solvent	Composition	Manufacturer
Artificial saliva	Na_2HPO_4, KH_2PO_4, and deionized distilled water	Analytical grade, freshly prepared
Citric acid	CITRIC ACID PURE (MONOHYDRATE) 99.5% 500GM/BTL (C6H8O7.H2O, 2-HYDROXY-1,2,3-PROPANETRICARBOXYLIC ACID MONOHYDRATE)	2860 Loba Chemie, India
Heptane	N-HEPTANE 99% EXTRA PURE 1LIT/BTL (C7H16, N-DIPROPYLMETHANE, N-HEPTYLHDRIDE, 1-METHYL HEXANE)	Scharlab, Barcelona, Spain, He01251000
Coffee	100% Pure Coffee	Nestlé, Araras, São Paulo, Brazil
Tea	Black Tea	Lipton, United Arab Emirates by Unilever Gulf FZE, P.O Box 17055, Dubai.

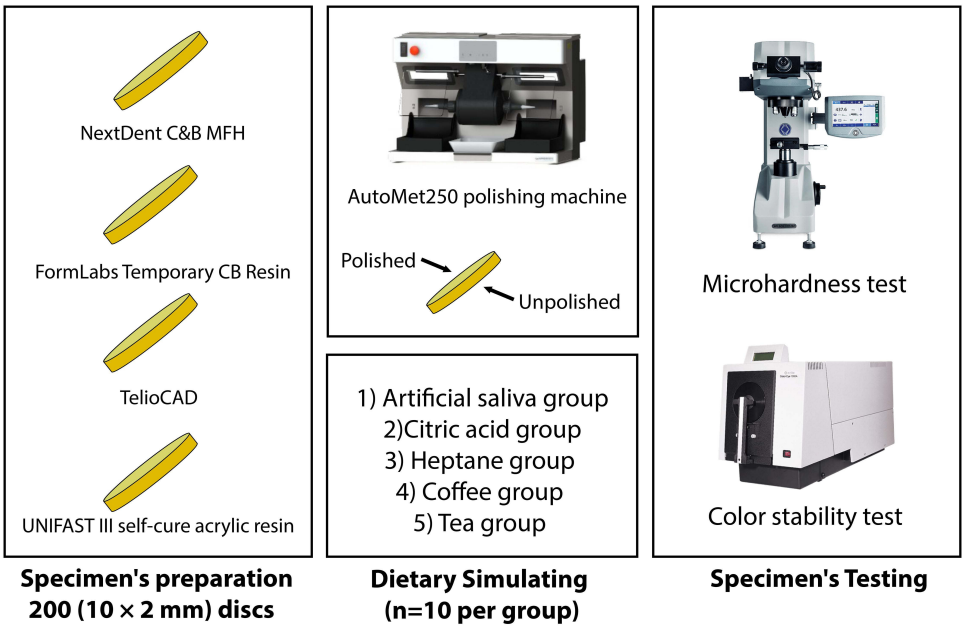

Figure 1 Summary of the specimen preparation and study protocol.

taken out of the storage containers, dried, and placed directly underneath the indenter of a digital microhardness tester (Wilson Hardness; ITW Test & Measurement, Shanghai, China). The indenter was subjected to a 100-gf load with a 15-second dwell period.

Color Stability Test

The initial color of the specimens was measured to evaluate the color change following the ISO 7491:2000 standard.[24] Two intervals were measured: baseline (T0) and one after a one-month conditioning period (T1). The specimens' color change was measured using a spectrophotometer (Color- Eye 7000A; X-rite, Grand Rapids, MI, USA), which helps in comparing the amount of illuminating light and the amount of reflected light. The spectrophotometer was calibrated using white and black ceramic tiles per the manufacturer's instructions. Moreover, the color values were measured from the center and on each side of the specimens using the color system CIE L*A*B. To assess color stability, the following equation $\Delta E* = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{1/2}$ were used to calculate color differences (ΔE) and color variables (ΔL*, Δa*, Δb*). Moreover, the color difference (ΔE) was converted into the National Bureau of Standards (NBS) units to mimic the clinical situation by using the NBS formula (NBS units = ΔE × 0.92). The following classification: indicial (NBS = 0.0–0.5); slight (NBS = 0.5–1.5); noticeable (NBS = 1.5–3.0); considerable (NBS = 3.0–6.0); very (NBS = 6.0–12.0); and excessive (NBS = +12.0).24 identified the clinically acceptable color changes.

Statistical Analysis

The data was analyzed using SPSS version 23 (IBM-SPSS; IBM, Chicago, IL, USA). For the descriptive data analysis, mean values and standard deviations were calculated. Kruskal–Wallis test was performed to determine whether there was a detectable difference in average hardness caused by various solvents. The impact of time on the hardness of the tested materials was investigated using the Wilcoxon Signed Ranks Test. The interacting effect of solvent, surface, and time on the hardness of the study's test materials was examined using the generalized linear models. A p-value of 0.05 or less was regarded as statistically significant.

Results

Microhardness Test

The microhardness of polished surfaces varied significantly across materials and solvent exposure times (Table 3). At the initial time point (T0), the conventional material exhibited significant differences in hardness between solvents, with citric acid showing the greatest effect compared to tea (p=0.040). In TelioCAD, significant differences in hardness due to solvent were observed at (T1) time point (p=0.0001). Post-hoc analysis revealed that saliva, citric acid, coffee, and tea all significantly affected TelioCAD hardness at both time points (p=0.005).

Table 3 Mean, Standard Deviations, and Significance Level of Hardness Values Among Tested Material of the Polished Surface

Materials	Solvent	Time		P-value
		T0	T1	
Conventional	Saliva	41.5(5.5)	40.38(3.9)	0.445
	Citric Acid	39.3(5.2)[a]	41.3(4.0)	0.386
	Heptane	48.5(14.0)	42.8(3.7)	0.445
	Coffee	44.1(3.9)	42.4(2.6)	0.114
	Tea	50.36(10.7)[a]	42.8(2.2)	0.028*
P-value		0.040*	0.36	
TelioCAD	Saliva	79.3(13.2)	53.4(4.8)[a]	0.005*
	Citric Acid	80.9(17.7)	48.7(3.6)[b,c,d]	0.005*
	Heptane	67.2(5.7)	66.3(5.6)[a,b,e,f]	0.575
	Coffee	81.4(28.3)	54.4(4.6)[c,e]	0.005*
	Tea	84.3(35.6)	56.3(1.8)[d,f]	0.005*
P-value		0.224	0.0001*	
NextDent	Saliva	59.5(17.7)	58.4(16.9)[a]	0.009*
	Citric Acid	65.7(13.7)	39.5(5.9)[b,c]	0.005*
	Heptane	64.9(32.6)	57.04(12.5)[a,b,d]	0.575
	Coffee	54.8(9.6)	47.8(6.7)[c]	0.009*
	Tea	49.2(10.4)	42.5(8.1)[d]	0.005*
P-value		0.109	0.001*	
FormLabs	Saliva	60.4(17.7)	58.4(16.9)[a]	0.262
	Citric Acid	61.9(16.8)	61.2(15.8)	0.575
	Heptane	65.8(13.1)	73.4(15.4)[a,b,c]	0.008*
	Coffee	57.9(18.7)	55.9(14.7)[b]	0.333
	Tea	55.3(16.6)	57.8(14.7)[c]	0.386
P-value		0.558	0.042*	

Notes: *Statistically significant at 0.05 level of significance. The same small alphabets in each column showed a significant difference between the pairs.

Following a similar trend, NextDent and FormLabs displayed significant variations in hardness due to solvent exposure at T1 (p=0.001 and p=0.042, respectively). Post-hoc analysis in NextDent revealed significant differences between saliva/heptane, citric acid/heptane, citric acid/coffee, and heptane/coffee. In FormLabs, saliva/heptane, heptane/coffee, and heptane/tea showed statistically distinct hardness values.

Time also affected the hardness of some materials. In the conventional material, only tea showed a significant effect on polished surfaces, while citric acid and tea impacted unpolished surfaces (Table 3). TelioCAD displayed time-dependent changes for all solvents on both surfaces. NextDent exhibited significant effects of time for saliva, citric acid, coffee, and tea on polished surfaces, while only saliva, citric acid, heptane, and coffee affected unpolished surfaces. FormLabs showed a time effect solely for heptane on polished surfaces, whereas citric acid, heptane, and coffee significantly altered hardness on unpolished surfaces.

Unpolished surfaces of the conventional material exhibited significant differences in hardness across solvents at both time points (p=0.008 and p=0.003) (Table 4). Notably, tea had the greatest impact on hardness at T0, while at T1, tea differed significantly from saliva and citric acid.

Unpolished surfaces in TelioCAD showed significant solvent effects only at T1 ($p \leq 0.05$). In contrast, NextDent displayed no significant solvent influence at either time point. FormLabs exhibited solvent-dependent changes in hardness at T1, with saliva/citric acid, citric acid/heptane, citric acid/tea, and heptane/tea showing distinct values.

Table 4 Mean, Standard Deviations, and Significance Level of Hardness Values Among Tested Material of Unpolished Surface

Materials	Solvent	Time		P-value
		T0	T1	
Conventional	Saliva	44.4(4.8)[a]	42.1(4.9)[a]	0.241
	Citric Acid	43.6(5.9)[b]	37.7(4.1)[b]	0.013*
	Heptane	45.4(7.3)[c]	44.2(6.2)	0.878
	Coffee	47.3(4.1)[d]	44.2(4.9)	0.059
	Tea	54.63(5.9)[a,b,c,d]	49.1(5.7)[a,b]	0.005*
P-value		0.008*	0.003*	
TelioCAD	Saliva	76.1(11.2)	53.1(6.5)[a,b]	0.005*
	Citric Acid	77.9(17.4)	48.6(3.9)[c,d]	0.005*
	Heptane	66.8(6.8)	69.3(3.9)[a,c,e,f]	0.445
	Coffee	70.7(18.2)	61.1(7.5)[b,d,e]	0.022*
	Tea	70.64(17.0)	54.9(2.3)[f]	0.005*
P-value		0.180	0.0001*	
NextDent	Saliva	16.9(18.0)	52.8(14.8)	0.022*
	Citric Acid	48.0(24.9)	28.7(11.7)	0.007*
	Heptane	29.8(15.4)	43.6(16.2)	0.005*
	Coffee	43.0(17.4)	38.1(12.7)	0.028*
	Tea	45.3(8.9)	44.5(7.3)	0.878

(*Continued*)

Table 4 (Continued).

Materials	Solvent	Time		P-value
		T0	T1	
P-value		0.055	0.086	
FormLabs	Saliva	57.2(18.0)	52.8(14.9)[a]	0.508
	Citric Acid	45.1(30.7)	28.7(14.8)[a,b,c]	0.013*
	Heptane	48.2(24.5)	65.9(8.9)[b,d]	0.009*
	Coffee	48.4(19.9)	43.8(17.6)	0.009*
	Tea	48.5(23.9)	50.7(24.4)[c,d]	0.878
P-value		0.674	0.0001*	

Notes: *Statistically significant at 0.05 level of significance. The same small alphabets in each column showed a significant difference between the pairs.

Combined effects analysis revealed significant interactions ($p<0.05$) only for TelioCAD and NextDent (Tables 5 and 6). This suggests that hardness in these materials is most influenced by the complex interplay of solvent, surface, and time, compared to a simpler additive effect.

Table 5 Generalized Linear Model Results for TelioCAD

Source	Type III Sum of Squares	df	Mean Square	F-value	P-value
Intercept	873,379.361	1	873,379.361	4464.878	0.0001*
Solvent-conventional	286.538	4	71.634	0.366	0.832
Surface	274.014	1	274.014	1.401	0.238
Time	17,847.272	1	17,847.272	91.239	0.000*
Solvent-conventional*surface	405.812	4	101.453	0.519	0.722
Solvent-conventional*time	5683.931	4	1420.983	7.264	0.0001*
Surface*time	742.280	1	742.280	3.795	0.053
Solvent-conventional*surface*time	453.978	4	113.495	0.580	0.677
Error	35,209.983	180	195.611		
Total	934,283.170	200			

Note: *Statistically significant at 0.05 level of significance.

Table 6 Generalized Linear Model Results for NextDent

Source	Type III Sum of Squares	df	Mean Square	F-value	P-value
Intercept	434,843.402	1	434,843.402	1955.835	0.0001*
Solvent-conventional	360.291	4	90.073	0.405	0.805
Surface	5891.551	1	5891.551	26.499	0.0001*

(*Continued*)

Table 6 (Continued).

Source	Type III Sum of Squares	df	Mean Square	F-value	P-value
Time	3922.322	1	3922.322	17.642	0.0001*
Solvent-conventional*surface	3361.670	4	840.418	3.780	0.006*
Solvent-conventional*time	4021.290	4	1005.323	4.522	0.002*
Surface*time	1090.912	1	1090.912	4.907	0.028*
Solvent-conventional*surface*time	553.661	4	138.415	0.623	0.647
Error	40,019.649	180	222.331		
Total	494,064.750	200			

Note: *Statistically significant at 0.05 level of significance.

Color Stability Test

Regarding the color stability results, all materials exhibited significant solvent-induced color changes ($p<0.05$) (Table 7). Post-hoc analysis revealed significant differences ($p<0.05$) in color stability between specific solvent pairs for each material. Notably, tea consistently caused substantial color changes across all materials. Unpolished surfaces also displayed significant solvent-induced color changes ($p<0.05$) for all materials.

Table 7 Mean, Standard Deviations, and Significance Level of Color Change (ΔE) Values Among Tested Material of Polished and Unpolished Surfaces

Materials	Solvent	Polished Surfaces			Unpolished Surfaces		
		Mean (SD)	NBS	P-value	Mean (SD)	NBS	P-value
Conventional	Saliva	4.07(0.4)^{a}	3.748	0.001	3.89(0.5)^{a}	3.582	0.001*
	Citric Acid	4.09(0.3)^{b}	3.766		5.16(1.3)	4.748	
	Heptane	3.57(2.3)^{c}	3.287		3.85(1.6)^{b}	3.225	
	Coffee	4.52(0.9)	4.157		5.12(0.6)	4.708	
	Tea	5.04(0.3)^{a,b,c}	4.635		5.4(1.3)^{a,b}	4.966	
TelioCAD	Saliva	1.01(1.3)	0.719	0.0001	0.45(0.4)^{a,b}	0.411	0.0001*
	Citric Acid	0.43(0.2)^{a,b}	0.391		0.43(0.2)^{c,d}	0.400	
	Heptane	0.62(0.3)^{c,d}	0.572		0.71(0.3)^{e}	0.658	
	Coffee	1.26(0.6)^{a,c}	1.161		1.2(0.5)^{a,c}	1.114	
	Tea	1.09(0.5)^{b,d}	1.005		1.5(0.8)^{b,d,e}	1.412	
NextDent	Saliva	0.30(0.2)^{a,b}	0.280	0.0001*	0.64(0.2)^{a,b}	0.588	0.0001*
	Citric Acid	0.56(0.2)^{c,d}	0.538		1.09(0.6)^{c,d}	1.008	
	Heptane	0.54(0.2)^{e,f}	0.499		0.93(0.6)^{e,f}	0.857	
	Coffee	3.37(1.5)^{a,c,e}	3.102		15.6(2.9)^{a,c,e,g}	14.400	
	Tea	3.22(1.5)^{b,d,f}	2.959		8.44(3.0)^{b,d,f,g}	7.773	

(*Continued*)

Table 7 (Continued).

Materials	Solvent	Polished Surfaces			Unpolished Surfaces		
		Mean (SD)	NBS	P-value	Mean (SD)	NBS	P-value
FormLabs	Saliva	0.31(0.2)[a,b]	0.290	0.0001*	1.6(1.0)[a,b,c]	1.474	0.0001*
	Citric Acid	1.78(0.9)[c]	1.643		2.69(0.9)[d,e,f]	2.479	
	Heptane	2.14(0.9)[d]	1.974		11.1(3.3)[a,d,g]	10.221	
	Coffee	5.49(3.5)[a,c,d,e]	5.057		19.03(5.6)[b,e,g,h]	15.913	
	Tea	2.89(0.6)[b,e]	2.660		11.78(3.8)[c,f,h]	10.839	

Notes: *Statistically significant at 0.05 level of significance. The same small alphabets in each column showed a significant difference between the pairs.

Similar to polished surfaces, unpolished surfaces exhibited significant differences in color stability between specific solvent pairs for most materials ($p<0.05$) (Table 7). Notably, tea and coffee again caused the most prominent changes.

Discussion

Dietary solvents significantly impacted the microhardness and color stability of CAD-CAM provisional restorations compared to conventional materials ($p<0.05$), thus rejecting the null hypothesis. Considering the established detrimental effects of the oral environment on provisional restorations due to saliva, beverages, and food components,[25] this study employed a standardized protocol using FDA-recommended food simulants: saliva, citric acid, heptane, coffee, and tea.[22] An immersion period of one month was chosen based on previous research demonstrating its effectiveness in altering provisional material properties like hardness and water sorption.[17,26] While in-use of provisional restorations exposure may be more intermittent, factors like poorly finished restorations or trapped debris at the margins can lead to prolonged contact with these dietary components, potentially amplifying their effects.[16,27]

Microhardness is a property used for definite indentation penetration prevention by predicting the material's resistance to wear and abrasion of dental structures opposing them. Strength, Ductility, and proportional limit are properties related to hardness.[20] In the present study, hardness was significantly reduced in all the solvents with time intervals. This is because the solvent solubility parameter can lead to permanent deformations to the composite material subsurface, and the damage depends mainly on the organic matrix and fillers' interfacial bonding and the amount of solvent component penetration to the provisional material.[28,29] In our study, for the conventional group, hardness showed an insignificant change in all solvents except tea. This finding is consistent with a study by Rajaee et al[30] who reported that no significant effect was observed for cold-cure methyl methacrylate after immersion in heptane. This could be due to the ability of heptane to inhibit the leaching out of Silica in the fillers and combine the filler particles with the metal in an organic solvent such as heptane.[31] In addition, the same study reported insignificant change after immersion in citric acid for 7 days. However, a more extended immersion period could have significant effects.[30] In this study, artificial saliva and citric acid did not show a significant result in the conventional group, which disagrees with Muley et al, who reported a significant reduction in their samples following immersion in artificial saliva and citric acid. However, the disagreement could be due to the different chemical compositions of the conventional material used in their research.[15]

The study's findings revealed statistically significant hardness differences across the tested groups, which the composition of the materials may have influenced. According to several studies, the chemical composition and presence of inorganic fillers would alter the mechanical characteristics of the provisional material.[32]

One of the essential criteria for selecting the provisional restoration is color stability.[33] Oral hygiene, incomplete polymerization, and smoothness of the provisional surface are related to the causes of color change.[34] In addition, there are multifactorial reasons for color alteration like food dies, chemical reactions, and the solvent type and immersion time.[35] This study employed a spectrophotometer for color change evaluation due to its superior accuracy compared to

a colorimeter, as previously reported.[36] Spectrophotometers offer more reproducible shade determination compared to visual assessment, which can be prone to variation and bias towards darker shades.[37]

In the present study, a significant change was observed with all unpolished surfaces compared to polished ones despite the type of material used. This could be because of topographical irregularities, which trigger more colorant and plaque than polished surface.[35] All CAD-CAM specimens, either polished/unpolished, had "extremely slight change" to "perceivable change" after immersion in saliva and citric acid, while immersion of the conventional group in the exact solutions resulted in a "marked color change". This current study showed that the highest color change was observed with 3D-printed provisional restorations (NextDent, Formlabs) after immersion in Coffee and Tea, which ranged from "extremely marked change" to "change to another color". This is attributed to the fact that 3D printing has a weak contact link between printed layers.[38] The reason behind the maximum effect of coffee and tea is the present colorant agent, which is tannic acid.[39] Similar to a previous study, coffee showed higher color change than the tea group, mainly due to the water absorption property and the smaller molecular size of the material tested.[40] Colorant particles are not present in the artificial saliva, which results in minimal color change in all artificial saliva groups regardless of the tested materials.[41] On the other hand, the lowest effect was observed with the TelioCAD group in all immersing solutions, which ranged from "extremely slight" to "slight change". This result is due to the higher monomer conversion, fewer preparation errors, and pre-polymerization in CAD-CAM restorations.[42]

This in vitro study highlights the potential impact of dietary factors on the microhardness and color stability of provisional restorations. While clinical translation is limited, these findings suggest that patients with long-term provisional restorations may benefit from limiting the consumption of coffee and tea to minimize staining and degradation.

This in vitro study investigated the effects of dietary simulants on provisional restoration materials. However, in vitro evaluations may not fully translate to complex clinical scenarios in the oral cavity. Additionally, disc-shaped specimens do not replicate the intricate geometry of dental restorations with cusps and grooves. Fabrication challenges can also influence material properties. For instance, controlling homogeneity, porosity, and stress release during the finishing and polishing of conventional materials can be difficult.[15] Similarly, sample preparation for CAD-CAM restorations is influenced by factors like printing technology, build orientation, layer thickness, and post-curing time.[43] Future research in vivo could explore the performance of these materials under more realistic clinical conditions.

Conclusion

Dietary solvents significantly affected the surface hardness of CAD-CAM and conventional materials over time. Unpolished surfaces exhibited greater color changes compared to polished ones. Coffee and tea had the strongest impact on color stability, while saliva and citric acid had minimal effects. Milled restorations demonstrated superior hardness and color stability compared to 3D-printed and conventional alternatives.

Disclosure

The authors report no conflicts of interest in this work.

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