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RESEARCH AND EDUCATION

Effect of different disinfection protocols on the surface properties of CAD-CAM denture base materials

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ABSTRACT

Statement of problem. Which disinfection protocol provides optimal water contact angle and microhardness for computer-aided design and computer-aided manufacturing (CAD-CAM) polymethyl methacrylate (PMMA) materials is unclear.

Purpose. The purpose of this in vitro study was to evaluate the effect of different disinfection protocols (1% sodium hypochlorite, denture cleanser gel, and effervescent tablet) on the water contact angle and microhardness of different CAD-CAM PMMA denture base materials by comparing them with a heat-polymerized PMMA.

Material and methods. Disk-shaped specimens (Ø10×2 mm) were fabricated from 3 different CAD-CAM PMMAs—AvaDent (AV), Merz M-PM (M-PM), and Polident (Poli)—and a heat-polymerized PMMA (Vynacron) (CV) (n=21). Three disinfection protocols (1% sodium hypochlorite [HC], denture cleanser gel [GEL], an effervescent tablet [TAB]) were applied to simulate 180 days of cleansing. The water contact angle and microhardness of specimens were measured before and after disinfection and compared by using a 2-way ANOVA (α=.05).

Results. For water contact angle, material (P=.010) and disinfection protocol (P=.002) had a significant effect. The material (P<.001), disinfection protocol (P=.001), and their interaction (P<.001) significantly affected the microhardness after disinfection. When the condition after disinfection was compared with that before disinfection, the water contact angle increased significantly in all material-disinfection protocol pairs ($P\leq$.025), and microhardness increased significantly in all material-disinfection protocol pairs ($P\leq$.040), except for GEL- (P=.689) or TAB-applied (P=.307) AV, HC-applied M-PM (P=.219), and TAB-applied Poli (P=.159).

Conclusions. The material and disinfection protocol affected the water contact angle of all tested PMMAs after disinfection, resulting in more hydrophobic surfaces for heat-polymerized or CAD-CAM PMMAs. The microhardness of heat-polymerized PMMA was less than that of all CAD-CAM PMMAs after disinfection, regardless of the protocol. (J Prosthet Dent 2021;■:■-■)

Heat-polymerized polymethyl methacrylate (PMMA) has been the material of choice for removable prostheses because of its good mechanical and physical properties.[1-5] However, monomer leaching is a drawback, which is responsible for water sorption and affects dimensional stability and surface properties.[1-8] Advances in digital dentistry and computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have led to the introduction of prepolymerized PMMA blocks.[8-15] Previous studies have reported improved surface properties, less porosity, and microbial adherence to CAD-CAM PMMAs, which may be attributed to the polymerization of blocks under high pressure and temperature.[9,10,12,16-20]

The porous surface of PMMA allows the accumulation of denture biofilm, predominantly composed of the *Candida* species and bacterial pathogens responsible for chronic atrophic candidiasis and halitosis.[21-27] Surface roughness, hardness, energy, and wettability play

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Clinical Implications

Clinicians may prefer 1% sodium hypochlorite, denture cleanser gel, or denture cleanser effervescent tablets for the disinfection of CAD-CAM PMMA denture base materials to minimize plaque accumulation and maintain the microhardness of the denture base.

essential roles in plaque accumulation, as rough surfaces are more susceptible to bacterial adhesion.[22,25-37] Biofilm can be mechanically or chemically eliminated, and the immersion of removable dentures in cleaning agents entails several disinfection processes.[38-47] Certain chemical denture cleansers can have a deleterious effect on the properties of heat-polymerized PMMA denture base materials, resulting in the dissolution of the surface, change in the morphology, and reduced hardness.[38-46,48-59] However, studies evaluating the effect of denture cleansers on recent CAD-CAM PMMA materials are necessary to better understand their effect on the physical and mechanical properties of CAD-CAM PMMAs. The aim of this in vitro study was to evaluate the effect of disinfection protocols (1% sodium hypochlorite, denture cleanser gel, or denture cleanser effervescent tablet) on the water contact angle and microhardness of different PMMA denture base materials (CAD-CAM and heat-polymerized). The null hypothesis was that the disinfection protocol would not affect the water contact angle and microhardness of CAD-CAM or heat-polymerized PMMAs.

MATERIAL AND METHODS

Disk-shaped acrylic resin specimens (Ø10×2 mm) (n=21 for each resin material) were fabricated from 3 different brands of prepolymerized CAD-CAM PMMA denture base materials and a heat-polymerized PMMA denture base material to test the water contact angle and the microhardness before and after different disinfection procedures (Table 1). A Ø10-mm cylinder was virtually designed and converted to a standard tessellation language (STL) file to mill (Zenotec Mini; Wieland Dental) the CAD-CAM PMMA blocks, which were then wet sliced (Vari/cut VC-50; Leco Corp) to obtain disks with a final thickness of 2 ±0.02 mm. A polyvinyl siloxane mold (Elite HD; Zhermack SpA) was made from the fabricated CAD-CAM PMMA specimens to prepare wax patterns for the fabrication of heat-polymerized PMMA specimens. The wax patterns were then flasked and wax eliminated. Manufacturer recommendations were followed for mixing and packing the PMMA. Heat-polymerization was performed in a water bath for 8 hours at 74 °C.[5] The specimens were removed after cooling, and those without voids and porosity were trimmed before testing.

One surface of the specimens was smoothed with 1200# SiC papers (Leco; Leco Corp) under water, conventionally polished with pumice slurry (Pumice fine; Benco Dental) for 90 seconds at 1500 rpm (Red-Wing; Handler Mfg), and fine polished with a polishing paste (Fabulustre; Grobet) for 90 seconds.[37] Then, the final dimensions of each specimen were evaluated, and the specimens were stored in distilled water for 24 hours at 37 ±2 °C in an incubator (CIENLAB; Campinas) for hydration and residual monomer release.[41,42]

The specimens were then divided into 3 groups according to the disinfection protocols: 1% sodium hypochlorite group (HC), denture cleanser gel group (GEL), and denture cleanser effervescent tablet group (TAB) (n=7). These procedures were selected to represent standard hygiene recommendations for patients with complete dentures.[41]

In the HC and TAB groups, the specimens were immersed together in a 200-mL beaker with all specimen surfaces in contact with the immersion solution.[54] In the GEL group, the gel was applied only to the polished surfaces of the specimens as recommended by the manufacturer. Nine cleaning cycles were performed over a period of 20 days simulating 180 days of cleaning.[54] After each cleaning cycle, the specimens were removed from the disinfection solutions and rinsed under running tap water for 30 seconds.[41] A freshly prepared solution was applied in each cleaning cycle, and the cleaning process was repeated. When not being disinfected, the specimens were stored in distilled water at 37 ±2 °C in the same incubator.[41] To avoid operator variability, all disinfection procedures were performed by 1 operator (G.C.). After all disinfection cycles, the specimens were ultrasonically cleaned for 15 minutes before water contact angle and microhardness measurements and air dried.

In the HC group, a 250-mL beaker was filled with 1% sodium hypochlorite solution, and the specimens were immersed for 10 minutes.[41] In the GEL group, the specimens were washed under water because the manufacturer recommended applying the denture cleanser gel to a wet denture base surface for 2 minutes. Then, 2 droplets of disinfection gel were dropped onto the specimens' polished surface according to the manufacturers' recommendations. The cleaning gel covered all the polished surface for 2 minutes.

In the TAB group, a 200-mL beaker was filled with tap water at 40 °C, and an effervescent tablet was added. After the tablet had dissolved, the specimens were immersed for 15 minutes as recommended by the manufacturer.

The sessile drop method was used to evaluate the water contact angle.[22] First, the specimens were

Table 1. Denture base materials and disinfectant solutions used

Material	Composition	Code	Manufacturer
Pink AvaDent	Prepolymerized poly (methyl methacrylate)	AV	Global Dental Science
Pink M-PM Disc	Prepolymerized poly (methyl methacrylate)	M-PM	Merz Dental GmbH
Pink Polident CAD-CAM discs	Prepolymerized poly (methyl methacrylate)	Poli	Polident d.o.o
Vynacron	Heat-polymerized poly (methyl methacrylate)	CV	Vynacron Dental Resins Inc
Aktident denture cleanser gel	Sodium Laureth Sulfate, Aqua, Peg-4 Rapeseed Amide, Glycerol, Mentha Arvenis, Saccharin, Sodium Chloride	GEL	Aktident, AktiFarma
1% Sodium hypochlorite	Hypochlorous acid, sodium, and water	HC	Apothicario, Aracatuba
Polident antibacterial denture cleanser for smokers	Sodium Bicarbonate, citric acid, potassium monopersulfate, sodium percarbonate, sodium carbonate, TAED, sodium benzoate, PEG-180, sodium lauryl sulfoacetate, aroma, VP/VA copolymer, red 33, red 30, aluminum lake	TAB	GlaxoSmithKline

Table 2. Summary of ANOVA of water contact angle and microhardness or after disinfection

Test	Effect	*df*	F	*P*
Water contact angle	Material	3	4.044	.010
	Disinfection protocol	2	7.105	.002
	Material×Disinfection protocol	6	1.503	.190
Microhardness	Material	3	52.187	<.001
	Disinfection protocol	2	8.055	.001
	Material×Disinfection protocol	6	9.138	<.001

df, numerator degrees of freedom.

ultrasonically cleaned for 15 minutes (Ultracleaner 07-08; Eltrosonic GmbH) and air dried. Then, a single 2.0-μL droplet of deionized water was placed on the center of the specimen, and the right and the left static contact angles were immediately measured (Olympus TGHM; rame-hart Inc) and averaged. This was repeated 3 times for each specimen both before and after disinfection procedures, and the arithmetic means were calculated.[20,22,34]

After the water contact angle measurements, the Knoop microhardness of the polished surfaces of the specimens was measured (M-400 Hardness Tester; Leco Corp). Five indentations were made for each specimen at 500 μm from each other under a 0.25-N load for 10 seconds[36] and averaged.[36] The measurements were repeated before and after disinfection.

The data were analyzed with a statistical software program (IBM SPSS Statistics v25.0; IBM Corp). Means and 95% confidence limits for water contact angle and microhardness values were calculated for each combination of material type and disinfection protocol both before and after disinfection. Two-way analysis of variance (ANOVA) was used to analyze the water contact angle and microhardness with the main effects of material type and disinfection protocol with the interaction included. A paired samples *t* test was used to evaluate the effect of disinfectant use (before and after comparison) on the surface microhardness and water contact angle of each material. Tukey HSD post hoc comparisons were used for any significant interactions (α=.05). After the initial analysis, it was observed that the sample size allowed the detection of statistically significant differences; therefore, the sample size was deemed sufficient.

RESULTS

According to the 2-way ANOVA, for the water contact angle after disinfection, the material (*P*=.010) and disinfection protocol (*P*=.002) had a significant effect, whereas no significant interaction was found between the material and the disinfection protocol (*P*=.190). For microhardness, the effects of the material (*P*<.001), disinfection protocol (*P*=.001), and their interaction (*P*<.001) were significant after disinfection (Table 2).

After disinfection, TAB resulted in the lowest water contact angle for AV material (*P*=.008), and GEL resulted in the highest water contact angle for CV ($P\leq$.008). For M-PM, GEL application resulted in a higher water contact angle than HC (*P*=.014). For Poli material, no significant difference was found between disinfection protocols after disinfection ($P\geq$.444). When the condition after disinfection was compared with that before disinfection, the water contact angle increased significantly in all material-disinfection protocol pairs ($P\leq$.025) (Table 3; Fig. 1).

After disinfection (Table 4; Fig. 2), TAB resulted in the highest microhardness for AV ($P\leq$.002). GEL resulted in lower microhardness than TAB for CV material (*P*=.026). For M-PM ($P\geq$.485) and Poli ($P\geq$.112), no significant difference was found among disinfection protocols. When the condition after disinfection was compared with that before disinfection, microhardness increased in all material-disinfection protocol pairs ($P\leq$.040), except for

Table 3. Mean ±standard deviation of water contact angle (degrees) of different denture base materials (CAD-CAM and heat-polymerized) and disinfection protocol pairs

Material	DP	Mean ±SD Before DIS	Mean ±SD After DIS	Pairs	*P* After DIS	*P* Before-After DIS
AvaDent (AV)	HC	61.8 ±2.6*	74.6 ±2.0$^{E, †, a}$	HC-GEL	1.000	<.001
				HC-TAB	.008	
	GEL	59.7 ±2.6*	74.6 ±1.0$^{E, †, a}$	GEL-HC	1.000	<.001
				GEL-TAB	.008	
	TAB	61.0 ±2.1*	70.8 ±2.8$^{F, †, a}$	TAB-HC	.008	.001
				TAB-GEL	.008	
Conventional (CV)	HC	59.6 ±2.2*	70.2 ±1.2$^{G, †, b}$	HC-GEL	.003	<.001
				HC-TAB	.905	
	GEL	60.5 ±1.2*	74.8 ±1.5$^{H, †, a}$	GEL-HC	.003	<.001
				GEL-TAB	.008	
	TAB	60.5 ±0.9*	70.6 ±2.8$^{G, †, a}$	TAB-HC	.905	<.001
				TAB-GEL	.008	
Merz M-PM Disc (M-PM)	HC	59.1 ±1.3*	70.3 ±1.0$^{I, †, b}$	HC-GEL	.014	<.001
				HC-TAB	.499	
	GEL	58.5 ±0.8*	74.1 ±3.3$^{J, †, a}$	GEL-HC	.014	<.001
				GEL-TAB	.132	
	TAB	59.7 ±0.8*	71.7 ±1.7$^{IJ, †, a}$	TAB-HC	.499	<.001
				TAB-GEL	.132	
Polident (Poli)	HC	58.8 ±0.8*	71.2 ±2.8$^{K, †, b}$	HC-GEL	.986	<.001
				HC-TAB	.444	
	GEL	58.0 ±1.4*	70.8 ±2.1$^{K, †, b}$	GEL-HC	.986	<.001
				GEL-TAB	.538	
	TAB	58.6 ±1.4*	67.8 ±8.4$^{K, †, a}$	TAB-HC	.444	.025
				TAB-GEL	.538	

DIS, disinfection; DP, disinfection protocol; GEL, denture cleanser gel; HC, sodium hypochlorite; SD, standard deviation; TAB, denture cleanser effervescent tablet. Significant differences among disinfection protocol groups of same material indicated with different uppercase superscript letters in same column for after disinfection. Significant differences among same disinfection protocol groups of conventional heat-polymerized and CAD-CAM PMMAs indicated with different lowercase superscript letters in same column for after disinfection. Significant differences between before and after disinfection groups of same disinfection protocol group of same material indicated with different symbols in same row.

GEL- (*P*=.689) or TAB-applied (*P*=.307) AV, HC-applied M-PM (*P*=.219), and TAB-applied Poli (*P*=.159).

The water contact angle of CAD-CAM resins after disinfection when compared with the conventional PMMA varied depending on the disinfection protocol. After HC application, the water contact angle of AV was higher than that of CV (*P*=.001), and the water contact angle of other CAD-CAM resins was similar to that of CV (*P*>.05). After GEL application, only the values for Poli were smaller than those of CV (*P*=.036), and the values of other CAD-CAM resins were similar to those of CV (*P*>.05). After TAB application, the water contact angles of CAD-CAM resins and CV were similar (*P*>.05). The hardness of all CAD-CAM resins was higher than that of the conventional resin after all disinfection protocols (*P*<.001).

DISCUSSION

The disinfection protocols affected the water contact angle and microhardness of CAD-CAM PMMAs and a heat-polymerized PMMA. Therefore, the null hypothesis was rejected.

Even though the effect of denture cleansers on the physical properties of conventional PMMAs has been evaluated,[54,55] data regarding the effect of disinfection protocols on the surface properties of CAD-CAM PMMAs are sparse.[57-59] Fernandes et al[52] measured the water contact angle to calculate the surface free energy on heat-polymerized PMMA and polyamide resins, reporting that PMMA exhibited significantly higher surface free energy but a lower *Candida* colonization, with no correlation between surface free energy and *Candida* colonization. In the present study, all disinfection protocols increased the water contact angle in all material-disinfection protocol pairs (9.2 to 15.6 degrees). However, after disinfection, mean ±standard deviation water contact angle values of both heat-polymerized and CAD-CAM PMMAs ranged from 67.8 ±8.4 to 74.8 ±1.5 degrees, which were less than the 90-degree hydrophilicity distinction level.[35] The reduced contact angle values may be because PMMA denture base materials, depending on their formulation, contain some types of glycol functional cross-linkers (for example, ethylene glycol dimethacrylate),[18] which were reported to provide water compatibility.[60] The exposure to cleaners may hinder this functionality from the interpenetration of the content of the cleaners and the physicochemical interaction in between functional monomers and ingredients of the

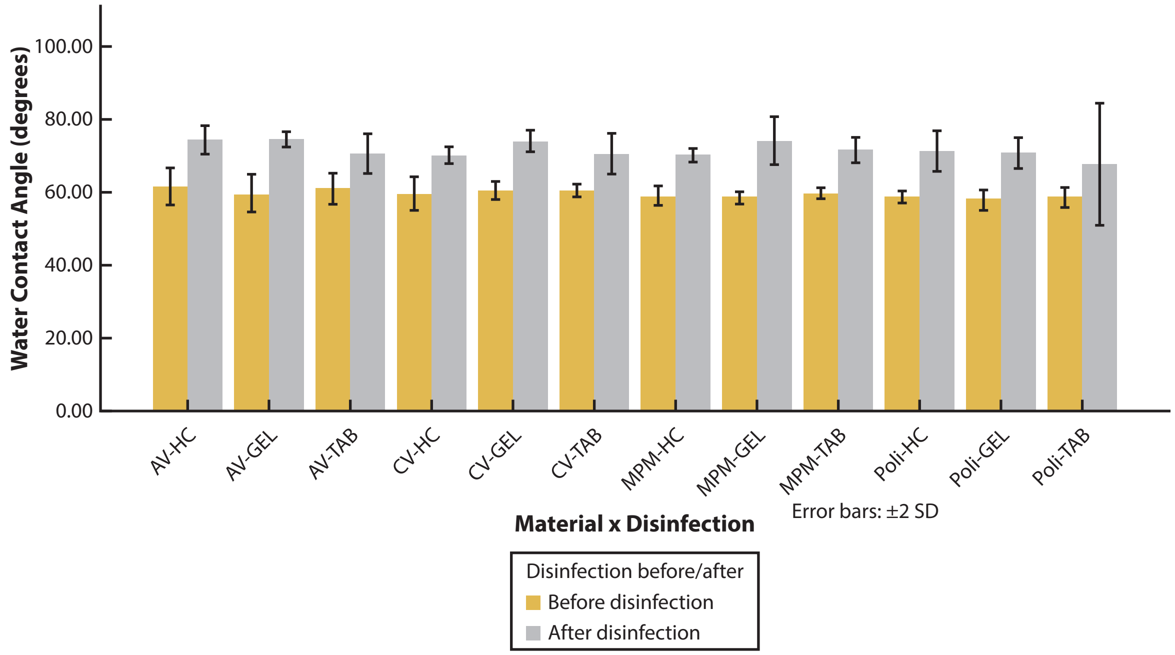

Figure 1. Mean and 95% confidence limits of water contact angle (degrees) of different disinfection protocol groups before and after disinfection. AV, AvaDent; CV, conventional; GEL, denture cleanser gel; HC, sodium hypochlorite; M-PM, Merz M-PM Disc; Poli, Polident; SD, standard deviation; TAB, denture cleanser effervescent tablet.

cleansers, resulting in an increase in the water contact angle.

Arslan et al[17] compared the surface properties of CAD-CAM PMMAs with those of heat-polymerized PMMA and reported similar water contact angle values, as in the present study. The highest values were observed with CAD-CAM PMMAs, suggesting that CAD-CAM polymers may be more hydrophobic. The increased hydrophobic nature may be from the minimal residual monomer, as the CAD-CAM PMMAs are prepolymerized under high pressure and temperature, which alters the polarity of the molecules and changes the wettability.[17,47,53] A positive correlation has been reported between surface hydrophobicity and the detachment of adhered cells or biofilm, and the removal of adhered bacteria from hydrophobic surfaces has been reported to be easier than it is from hydrophilic ones.[24,29,31-33] Therefore, the tested disinfection procedures may have facilitated cell or biofilm clearance from the tested CAD-CAM and heat-polymerized PMMAs because surface hydrophobicity increased slightly (9.2 to 15.6 degrees) after disinfection.

Denture PMMA should be sufficiently hard to withstand physical alteration after chemical applications. Hardness measurements can be correlated with polymeric matrix degradation, which increases the possibility of fracture, diminishing the longevity of the denture base.[15] Adverse effects of chemical disinfection methods and solutions on heat-polymerized PMMAs have been reported.[34,36,38-46,50] The observed changes were a decrease in microhardness, an increase in surface roughness, and a color change; some changes were significant depending on the material, disinfection protocol, and their concentration. Disinfectants in different concentrations, including water, vinegar, ethanol, alkaline peroxide, sodium hypochlorite, glutaraldehyde, and commercial disinfectant agents, have been used.[38,40,42-46,50] Kurt et al[43] evaluated the effect of cleaning solutions (alkaline peroxide, 1% sodium hypochlorite, and 0.1% polymeric-guanidine solution) on heat-polymerized PMMA and reported a decrease in the Vickers hardness, which was significantly higher in sodium hypochlorite. Similar results have been reported in studies[39,40,44,46] where the hardness of heat-polymerized PMMAs decreased. Darwish[57] reported that alkaline peroxide effervescent tablets (Corega [GlaxoSmithKline] and Polident) had a negative effect on the hardness of heat-polymerized PMMA but did not affect the Vickers hardness of CAD-CAM PMMAs. Dayan[58] reported that exposure to 5% sodium hypochlorite decreased the surface hardness of heat-polymerized PMMAs; however, disinfection methods (2% glutaraldehyde, 5% sodium hypochlorite, and microwave) had no effect on the Vickers surface hardness of CAD-CAM PMMAs. Acrylic resins absorb water, which interferes with the polymer chains, causing swelling of the resin network, which affects the material's physical properties.[8,11,13,19,22,38] Residual monomer content may adversely affect the mechanical properties of PMMAs because of a reduction in the interchain forces or the plasticizing effect that leads

Table 4. Mean ±standard deviation of microhardness (KHN) of different denture base materials (CAD-CAM and heat-polymerized) and disinfection protocol pairs

Material	DP	Mean ±SD Before DIS	Mean ±SD After DIS	Pairs	*P* After DIS	*P* Before-After DIS
AvaDent (AV)	HC	10.8 ±0.8*	$11.6 \pm 0.7^{F, \dagger, a}$	HC-GEL	.612	.002
				HC-TAB	.002	
	GEL	11.0 ±0.6*	$11.2 \pm 0.8^{F, *, a}$	GEL-HC	.612	.689
				GEL-TAB	<.001	
	TAB	12.2 ±2.4*	$13.3 \pm 0.9^{G, *, a}$	TAB-HC	.002	.307
				TAB-GEL	<.001	
Conventional (CV)	HC	8.6 ±0.2*	$10.5 \pm 0.5^{HJ, \dagger, b}$	HC-GEL	.234	<.001
				HC-TAB	.484	
	GEL	8.9 ±0.5*	$10.1 \pm 0.4^{H, \dagger, b}$	GEL-HC	.234	.002
				GEL-TAB	.026	
	TAB	8.9 ±0.3*	$10.7 \pm 0.4^{J, \dagger, b}$	TAB-HC	.484	<.001
				TAB-GEL	.026	
Merz M-PM Disc (M-PM)	HC	11.8 ±1.0*	$12.2 \pm 0.6^{K, *, a}$	HC-GEL	.620	.219
				HC-TAB	.972	
	GEL	11.3 ±0.5*	$12.5 \pm 0.4^{K, \dagger, a}$	GEL-HC	.620	.007
				GEL-TAB	.485	
	TAB	11.4 ±0.7*	$12.2 \pm 0.6^{K, \dagger, a}$	TAB-HC	.972	.040
				TAB-GEL	.485	
Polident (Poli)	HC	11.5 ±0.3*	$12.0 \pm 0.4^{L, \dagger, a}$	HC-GEL	.768	.005
				HC-TAB	.346	
	GEL	10.9 ±0.3*	$12.1 \pm 0.2^{L, \dagger, a}$	GEL-HC	.768	<.001
				GEL-TAB	.112	
	TAB	11.4 ±0.5*	$11.7 \pm 0.2^{L, *, a}$	TAB-HC	.346	.159
				TAB-GEL	.112	

DIS, disinfection; DP, disinfection protocol; GEL, denture cleanser gel; HC, sodium hypochlorite; SD, standard deviation; TAB, denture cleanser effervescent tablet. Significant differences among disinfection protocol groups of same material indicated with different uppercase superscript letters in same column for after disinfection. Significant differences among same disinfection protocol groups of conventional heat-polymerized and CAD-CAM PMMAs indicated with different lowercase superscript letters in same column for after disinfection. Significant differences between before and after disinfection groups of same disinfection protocol group of same material indicated with different symbols in same row.

to material deformation.[4,7,14] The decrease in the hardness of heat-polymerized PMMAs has been attributed to a continuing polymerization reaction, monomer release, and combinations of these monomers with free active radicals by bonding with oxygen.[3,40] The damaging factor for heat-polymerized PMMAs in high-alkaline solutions may be a high peroxide content and level of oxygenation.[3,40] Considering previous findings,[3,36] a decrease in microhardness can be expected for tested materials, especially for heat-polymerized PMMAs after disinfection. Contrary to the findings in previous studies,[39,40,44,46,57,58] in the present study, microhardness increased in all disinfection protocol pairs of heat-polymerized PMMA and increased in all material-disinfection protocol pairs of CAD-CAM PMMAs except for some material-disinfection protocol pairs (AV-GEL, AV-TAB, M-PM-HC, POLI-TAB). The divergence of the results of the present study for CAD-CAM PMMAs from those in published heat-polymerized PMMA studies[39,40,44,46,57,58] may be attributed to different manufacturing processes, the composition of CAD-CAM PMMAs, and the disinfection protocols involving different cleanser types, immersion periods, and solution concentrations. CAD-CAM PMMAs have less water sorption and are expected to have less residual monomer release.[9,12,16] Therefore, disinfectants may be absorbed in lesser amounts, and their chemical reaction may affect the loss of plasticizers and interchain forces, which may alter the surface properties and the hardness. The residual monomer release and sorption of tested CAD-CAM materials should be evaluated further to confirm these assumptions.

The difference in microhardness between the heat-polymerized PMMA tested in the present study and those in previous studies[44,48,56-58] may be because of the difference in polymerization process and the brand. Heat polymerization can affect the residual monomer release and the mechanical and physical properties of PMMAs. In the present study, heat polymerization (74 °C for 8 hours) may have decreased the residual monomer. However, in a previous study,[42] which reported lower microhardness values for heat-polymerized PMMAs after disinfection, heat polymerization was performed by using different temperatures and duration. In addition, different immersion periods have been previously applied.[44,48,56] In the present study, 180 cleaning cycles simulated 180 days of cleaning,[54] and, previously,[46] 10-minute disinfection was repeated only 4 times. Immersion time may affect the microhardness and water contact angle.

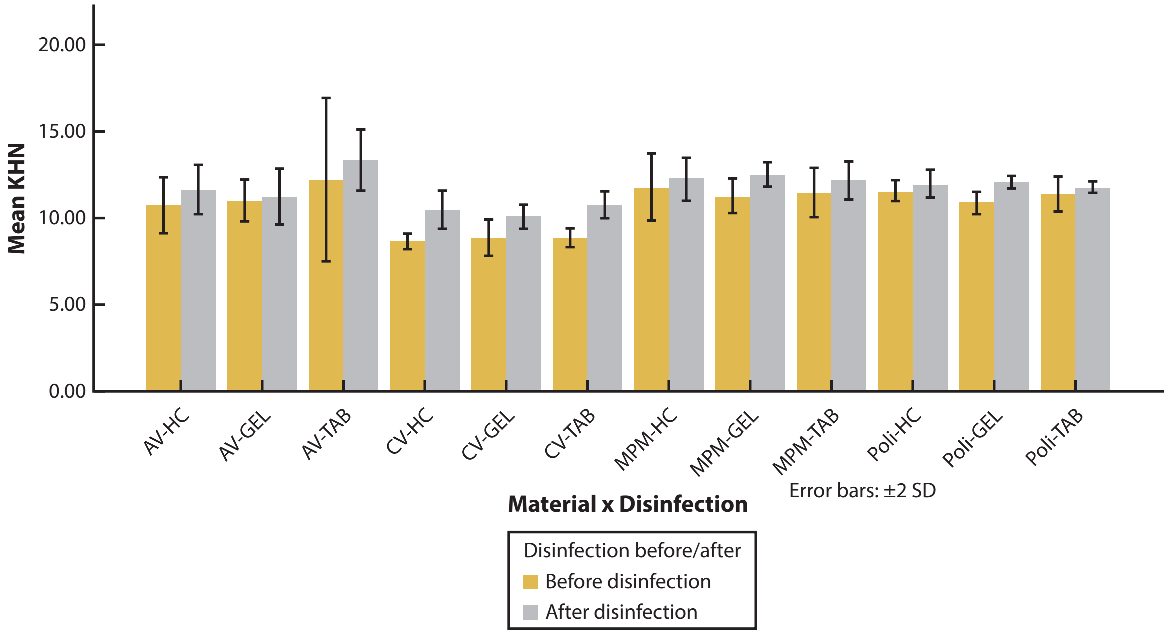

Figure 2. Mean and 95% confidence limits of microhardness (KHN) of different disinfection protocol groups before and after disinfection. AV, AvaDent; CV, conventional; GEL, denture cleanser gel; HC, sodium hypochlorite; M-PM, Merz M-PM Disc; Poli, Polident; TAB, denture cleanser effervescent tablet.

Consistent with the present study, increased hardness has been observed in previous studies after soaking heat-polymerized PMMA in water for 1- and 2-month periods after disinfection, a behavior related to monomer release.[6,7,46] Increased hardness after storage in water for 15, 30, and 60 days has been reported. [6,7,46] Braun et al[7] demonstrated that the leaching of residual monomer from denture base material contributed to the higher hardness observed after storage in water.

Denture cleanser gel is an alcohol-free mouth rinse-type cleaner and includes detergent, surfactants, and glycerol. This cleaner may be considered mild because of the lack of a mechanical cleaning mechanism that effervescent-type cleansers contain, that is, bleaching ingredients such as sodium percarbonate, potassium persulfate, and tetraacetylethylenediamine. In addition, effervescent tablets have sodium carbonate as abrasives and polyvinylpyrrolidone/vinyl acetate copolymer as a film-forming resin. These tablets are referred to as chemical soak-type materials and transform into an alkaline peroxide solution when immersed in water at a certain temperature.[51] This solution further releases oxygen, generating a mechanical cleaning action by means of the oxygen bubbles. One percent sodium hypochlorite (NaOCl) is a chlorine-based compound with hypochlorous acid, sodium, and water and is used as a disinfectant.[61] The difference in water contact angle and microhardness within the same denture base material when different disinfection protocols are used may be attributed to the difference in the composition of disinfectants and the varied chemical reaction of PMMAs. The specimens were washed under water[41] and ultrasonically cleaned before the water contact angle and microhardness measurements. Therefore, depending on the disinfectant's chemical composition, the residual surfactants may have remained on the surface, changing the surface free energy, wettability, and mechanical properties, and may have increased the water contact angle.

Considering the increase in microhardness and water contact angle observed in the present study, tested PMMAs may be recommended with the tested disinfection protocols, as the surface properties were favorable after a 6-month cleansing simulation. The results should be interpreted with caution as they are limited to the materials and the disinfection protocols evaluated. The microbial adhesion and surface roughness were not investigated. Future studies are needed to evaluate the performance of CAD-CAM PMMAs to determine the optimal disinfection method without adverse alterations to PMMA's surface properties.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The material and disinfection protocol affected the water contact angle of all tested PMMAs after disinfection.
2. Disinfection protocols resulted in more hydrophobic surfaces for heat-polymerized and CAD-CAM PMMAs than there were before disinfection.

3. The microhardness of heat-polymerized PMMA increased with all disinfection protocols and increased in most of the material-disinfection protocol pairs of CAD-CAM PMMAs.
4. The effect of disinfection on the water contact angle of heat-polymerized and CAD-CAM PMMAs depended on the disinfectant material type; however, the water contact angle was mostly similar among the PMMAs.
5. The microhardness of heat-polymerized PMMA was smaller than all CAD-CAM PMMAs after disinfection, regardless of the disinfection protocol.

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