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Degradation of Computer-aided Design/Computer-aided Manufacturing Composites by Dietary Solvents: An Optical Three-dimensional Surface Analysis

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Clinical Relevance

Computer-aided design/computer-aided manufacturing (CAD/CAM) composite resins are susceptible to degradation by dietary solvents. Dietary counselling is prudent when placing such CAD/CAM restorations.

SUMMARY

This study determined the effect of dietary solvents on the surface roughness (Ra) of direct, indirect, and computer-aided design/computer-aided manufacturing (CAD/CAM) dental composites. The materials evaluated were a direct composite (Filtek Z350 XT [FZ]), an indirect composite (Shofu Ceramage [CM]), and four CAD/CAM composites (Lava Ultimate [LU], Shofu Block HC [HC], Cerasmart [CS], and Vita Enamic [VE]). Specimens (12×14×1.5 mm) of each material were prepared, measured for baseline Ra, ranked, divided into six groups (n=12), and conditioned in the following media for 1 week at 37°C: air (control), distilled water, 0.02 N citric acid, 0.02 N lactic acid, heptane, and 50% ethanol-water solution. The composite specimens were then subjected to postconditioning Ra testing using an optical three-dimensional surface analyzer (G4e, Alicona Imaging GmbH, Raaba, Austria). Inter-medium and inter-material comparisons were performed with one-way analysis of variance and *post hoc* Bonferroni test at a significance level of α=0.05. Mean Ra values ranged from 0.086 ± 0.004 μm to 0.153 ± 0.005 μm for

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the various material/medium combinations. For all materials, conditioning in air (control) and distilled water generally resulted in significantly lower mean Ra than exposure to other dietary solvents. Conditioning in citric acid presented the roughest surfaces for FZ, CM, and CS. For LU, HC, and VE, exposure to lactic acid, heptane, and ethanol solution resulted in the highest mean Ra. Regardless of conditioning media, FZ had the highest and VE the lowest mean Ra compared with other composites. The CAD/CAM composites remained susceptible to surface degradation by dietary solvents despite their industrial polymerization.

INTRODUCTION

Over the past decade, dental composites have evolved to meet increasing demands for esthetics, durability, and efficiency. Industrial polymerization, filler innovations, and digital dentistry are key drivers of dental composite development. Contemporary dental composites can be broadly categorized into direct, indirect, and computer-aided design/computer-aided manufacturing (CAD/CAM) materials.[1] Although direct composites are placed intraorally, indirect composites are fabricated extraorally in the laboratory before being cemented onto teeth. CAD/CAM dentistry, which was introduced in the 1970s,[2] involves the use of digitized optical scanners and chair-side or networked milling machines that fabricate single-unit restorations as well as multiple-unit bridges and frameworks.[3] The recent transition to open-access CAD/CAM systems allowed for greater data acquisition flexibility and increased choice of materials, design software, and manufacturing techniques. CAD/CAM dentistry has improved quality control, saves time, and is more cost effective than conventional dental laboratory processes.[4,5]

Ceramics and composites are the two main materials used for esthetic CAD/CAM restorations. CAD/CAM ceramics have traditionally been used because of their good mechanical and superior optical properties.[6] However, the advantages of CAD/CAM composites, such as ease in milling, better accuracy, reduced cost, simple polishing procedure, and intraoral repairability, have promoted their use over CAD/CAM ceramics.[7] Moreover, several studies found that CAD/CAM composites displayed superior fatigue or fracture resistance than glass ceramics and conventional composites.[8,9] Based on microstructure, CAD/CAM composite blocks can be divided into two subclasses: dispersed fillers and polymer-infiltrated ceramic network.[10] The first photopolymerized composite block introduced (Paradigm MZ100, 3M ESPE, St Paul, MN, USA) was composed of 85% weight-dispersed zirconia-silica fillers in a bisphenol A–glycidyl methacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA) matrix. Newer CAD/CAM composites in the dispersed fillers group, including Lava Ultimate (3M ESPE), Cerasmart (GC Corporation, Tokyo, Japan), and Shofu Block HC (Shofu Inc, Kyoto, Japan), use urethane dimethacrylate (UDMA), a highly viscous monomer that requires high-temperature polymerization, in their resin matrix.[10] Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany), the only material in the polymer-infiltrated ceramic network group, is composed of a pre-sintered glass-ceramic scaffold that is infiltrated with monomer and manufactured using high-temperature/high-pressure polymerization.

Surface roughness (Ra) of restorations can influence biofilm formation, which contributes to periodontal disease and/or recurrent caries.[11,12] The arithmetic mean of Ra is represented by a threshold Ra of 0.2 μm, above which bacterial retention may occur, proposed for restorative materials.[13] In addition, rough restoration surfaces may promote antagonist tooth wear[14,15] and are more susceptible to staining.[16] Restorations must be finished and polished properly to attain smooth surfaces,[17,18] and both laboratory and chair-side polishing of CAD/CAM composites are able to achieve Ra values below the critical threshold of 0.2 μm.[19]

Composite restorations are intermittently or constantly exposed to chemical agents in food and beverages.[20,21] The latter can occur when chemical agents are trapped around poorly finished/polished restorations, absorbed by adherent debris (calculus or food particles) at restoration margins, or produced by bacterial degradation of debris.[22,23] In research, dietary solvents or food-simulating liquids are used to simulate the diversity of ingredients in food and beverages.[24] They usually include heptane, citric acid, lactic acid, ethanol solution, and distilled water based on US Food and Drug Administration guidelines.[25]

Chemical degradation of dental composites is a clinical problem in the oral environment.[22,24] It is initiated by water absorption, which softens the resin matrix and causes hydrolytic degradation of silane couplers and fillers.[26] In addition, leaching of residual monomers, organic substances, filler particles, and ions also occurs.[27] The effects of chemical degradation on dental composites include decreased

Table 1: *Technical Profile and Manufacturers of Materials Investigated*

Material (Abbreviation)	Manufacturer	Manufacturing Process	Monomer Composition	Filler Composition	Filler % by Weight	Lot Number
Filtek Z350 XT (FZ)	3M ESPE, St Paul, MN, USA	Direct	Bis-GMA, Bis-EMA, UDMA, TEGDMA, PEGDMA	Silica nanoparticles and zirconia nanoparticles	78.5	N771467
Shofu Ceramage (CM)	Shofu, Kyoto, Japan	Indirect	UDMA (+ HEMA in opaque paste)	Silica-based glass	74	011605
Lava Ultimate (LU)	3M ESPE, St Paul, MN, USA	CAD/CAM	UDMA	SiO_2 (20 nm), ZrO_2 (4-11 nm), ZrO_2/SiO_2 clusters	79	N554839
Shofu Block HC (HC)	Shofu, Kyoto, Japan		UDMA + TEGDMA	SiO_2, Zirconium silicate	61	091501
Cerasmart (CS)	GC, Tokyo, Japan		UDMA + other DMA	SiO_2 (20 nm), barium glass (300 nm)	71	1410271
Vita Enamic (VE)	VITA Zahnfabrik, Bad Säckingen, Germany		UDMA + TEGDMA	86% glass-ceramic sintered network	86	20160422

Abbreviations: Bis-EMA, ethoxylated bisphenol-A-glycidyl methacrylate; Bis-GMA, bisphenol-A glycidyl methacrylate; CAD/CAM, computer-aided design/computer-aided manufacturing; DMA, dimethacrylate; HEMA, 2-hydroxyethyl methacrylate; PEGDMA, polyethylene glycol dimethacrylate; SiO_2, silicone dioxide; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate; ZrO_2, zirconium dioxide.

surface hardness and change in surface topography, resulting in an increase in roughness values.[26,28] The aforementioned effects can be detected in about a month *in vivo*.[28] However, exposure to dietary solvents allow chemical degradation of dental composites to be observed within a week *in vitro*[20,22] while taking into account processes like chemical affinity, elution, and/or bonding of filler-silane.[23]

Although the effect of dietary solvents on the surface degradation of direct and indirect composites has been previously reported,[20,21,29,30] their effects on CAD/CAM composites are still not widely researched. CAD/CAM composites are anticipated to be more resistant to the effects of dietary solvents in view of their industrial high-heat and high-pressure polymerization. The objective of this study was to determine the effect of dietary solvents on the Ra of direct, indirect, and CAD/CAM composites. The null hypotheses were as follows: 1) the Ra of CAD/CAM composites is not significantly affected by dietary solvents, and 2) there is no significant difference in Ra between composite types after exposure to the various dietary solvents.

METHODS AND MATERIALS

Specimen Preparation and Conditioning

The materials investigated and their technical profiles are shown in Table 1. The materials consisted of one direct (Filtek Z350 XT [FZ]), one indirect (Shofu Ceramage [CM]), and four CAD/CAM dental composites (Lava Ultimate [LU], Shofu Block HC [HC], Cerasmart [CS], and Vita Enamic [VE]). All materials were shade A2. Sample size was calculated using the G*Power Software version 3.1.9.3[31] based on an analysis of variance (ANOVA) test with effect size of 0.5[20], alpha error of 0.05, and power of 80% for six materials. In total, 72 specimens were prepared for each material with provision for a 20% specimen rejection. The FZ and CM specimens were fabricated by using a customized stainless steel mold with a recess of 12×14×1.5 mm. The direct and indirect composites were placed in one increment, covered with a transparent cellulose acetate strip, and compressed between two glass slides. Excess materials were extruded, and a 1000 g load was applied for 15 seconds through the top glass slide. The FZ specimens were then cured with four overlapping irradiations of 20 seconds each using a light-emitting diode (LED) curing unit (Demi Plus, Kerr, Orange, CA, USA). The LED curing unit had an 8-mm-diameter light guide, output irradiance of 1330 mW/cm^2, and a wavelength range of 450-470 nm. Irradiance was measured using a LED radiometer (Demetron LED Radiometer, Kerr) to ensure consistency of light output for full depth cure. The CM specimens were irradiated using a calibrated Solidilite V (Shofu Dental, Kyoto, Japan) laboratory curing unit that had 4 halogen lamps with a total power of 600 W and wavelength range of 400-550 nm. After an initial cure for 1 minute on the turntable, CM specimens were removed from their molds and further cured for another 3 minutes. Both FZ and CM specimens were left in an incubator at 37°C for 24 hours to allow post-cure after photopolymerization. For LU, HC, CS, and VE, CAD/CAM blocks of 12×14 mm were sectioned into 1.5-mm-thick specimens using a high-speed diamond saw under water coolant (Micracut 176, Metkon, Bursa, Turkey).

The direct, indirect, and CAD/CAM composite specimens were examined for defects and replaced where needed. The specimens were then polished sequentially on both sides using a twin variable-speed grinding and polisher machine (Buehler, Lake Bluff, IL, USA) with a series of silicon carbide abrasive paper discs from P600 to P1200 at 250 rpm for 30 seconds.[32,33] They were subsequently measured with a digital micrometer (Mitutoyo Corporation, Kawasaki, Japan) to ensure dimensional uniformity (±0.15 mm) after polishing. The polished specimens were ultrasonically cleaned in distilled water and washed with isopropanol to remove any impurities. Baseline Ra of the 72 specimens of each composite were measured and ranked from smallest to largest before being divided into six groups (n=12) to ensure equal distribution of specimens with varying Ra and to minimize sampling bias. The six groups were conditioned for 1 week at 37°C in the following media: air (control), distilled water, 0.02 N citric acid (pH 2.6), 0.02 N lactic acid (pH 2.6), heptane, and 50% ethanol-water solution. Ten milliliters of each dietary solvent was used for each group. At the end of the conditioning period, the specimens were rinsed with distilled water, gently blotted dry with absorbent paper, and subjected to postconditioning Ra measurement.

Ra Testing and Scanning Electron Microscopy Observation

Ra was measured using the Infinite Focus Optical 3D Measurement G4e machine (Alicona Imaging GmbH, Raaba, Austria). The magnification of the three-dimensional (3D) surface analyzer was set at 20× with vertical and lateral resolutions of 325.66 nm and 2.93 μm, respectively. Images from five standardized areas of each specimen were captured, and the average Ra was determined using IFM version 3.5 software (Alicona Imaging GmbH, Raaba, Austria). The measurements were subsequently tabulated, and mean values for each material/medium combination were computed. Representative control and postconditioning samples with the highest mean Ra value were examined with scanning electron microscopy (SEM) (Quanta FEG 250, Thermo Fisher Scientific, Brno, Czech Republic), at 5000× magnification and 10 kV to ascertain microstructural changes.

Statistical Analysis

Statistical analysis was performed using the SPSS Statistic 24.0 software (IBM, Chicago, IL, USA). Parametric analysis was used as data was found to be normally distributed with the Kolmogorov-Smirnov test. Two-way ANOVA was performed to determine interactions between materials and conditioning media. Inter-medium and inter-material comparisons were performed with one-way ANOVA and *post hoc* Bonferroni test**.** Statistical analyses were conducted at a significance level of $\alpha = 0.05$.

RESULTS

Mean Ra values of the composite materials after conditioning in the various media are shown in Table 2. Mean Ra ranged from 0.086 ± 0.004 μm to 0.153 ± 0.005 μm for VE exposed to air or distilled water and for FZ conditioned in citric acid, respectively. Tables 3 and 4 showed inter-medium comparisons for the different materials and inter-material comparisons after exposure to the various conditioning media. Two-way ANOVA revealed significant interactions between materials and conditioning media ($p<0.05$).

For all composites, the smoothest surfaces were observed after exposure to air or distilled water, and mean Ra values were mostly significantly lower than the other dietary solvents (Table 3). With the exception of CS and VE, conditioning in citric acid, lactic acid, heptane, and ethanol solution resulted in significantly rougher surfaces than the control. No significant difference in mean Ra was observed between lactic/citric acid and the control for CS/VE, respectively. Conditioning in citric acid presented the roughest surfaces for FZ, CM, and CS. Significant differences in mean Ra values were observed between exposure to citric acid and heptane for FZ. Conditioning in lactic acid presented the roughest surface for LU. Significant differences in mean Ra values were observed between exposure to the two acids and heptane as well as ethanol solution. For HC and VE, conditioning in heptane and ethanol solution resulted in the roughest surfaces, respectively. VE, however, appeared to be less susceptible to degradation by citric acid.

For all conditioning media, mean Ra of FZ was the highest while that of VE was the lowest compared with other composites investigated (Table 4). When exposed to air (control) and distilled water, mean Ra ranking and significant differences between materials were alike. Conditioning in citric acid presented similar results, with the exception of the lack of significant inter-material difference between CM and CS. No significant differences in mean Ra values were observed between FZ, LU, and CM after conditioning in lactic acid. They were, however, still significantly rougher than CS, HC, and VE. For

Table 2: *Mean (Standard Deviation) Ra Values for the Various Materials*

Dietary Solvents	Mean Ra values (μm)					
	FZ	CM	LU	HC	CS	VE
Control (air)	0.136 (0.006)	0.125 (0.006)	0.120 (0.005)	0.105 (0.006)	0.116 (0.008)	0.086 (0.004)
Distilled water	0.137 (0.005)	0.125 (0.006)	0.120 (0.006)	0.106 (0.006)	0.117 (0.008)	0.086 (0.004)
0.02 N citric acid	0.153 (0.005)	0.140 (0.008)	0.140 (0.008)	0.122 (0.006)	0.134 (0.006)	0.087 (0.005)
0.02 N lactic acid	0.147 (0.008)	0.138 (0.007)	0.142 (0.008)	0.121 (0.004)	0.124 (0.009)	0.096 (0.004)
Heptane	0.144 (0.006)	0.137 (0.006)	0.132 (0.005)	0.125 (0.006)	0.131 (0.008)	0.103 (0.007)
50% ethanol-water	0.146 (0.006)	0.137 (0.009)	0.131 (0.004)	0.123 (0.006)	0.131 (0.009)	0.107 (0.007)

Abbreviations: CM, Shofu Ceramage; CS, Cerasmart; FZ, Filtek Z350 XT; HC, Shofu Block HC; LU, Lava Ultimate; Ra, surface roughness; VE, Vita Enamic.

heptane, FZ was only significantly rougher than the CAD/CAM composites. In addition, CM was also considerably rougher than HC and VE. The mean Ra of FZ was significantly higher than that of the other composites after conditioning in ethanol solution. CM was, again, notably rougher than HC and VE.

Representative postconditioning samples with the highest mean Ra values were subjected to SEM examination and compared with the control group. SEM micrograph of FZ after conditioning in 0.02 N citric acid showed formation of surface voids and exposure of filler particles (Figure 1). Erosion of resin matrix with appearance of filler particles was also seen in CM after conditioning in 0.02 N citric acid (Figure 2). LU displayed accompanying filler/matrix interfacial failure after conditioning in 0.02 N lactic acid (Figure 3). HC showed sizeable areas of matrix erosion and localized porosity with some protrusion of fillers after exposure to heptane (Figure 4). SEM micrograph of CS showed nano-sized filler particles. Matrix erosion occurred with exposure to 0.02 N citric acid, but surface damage was not as apparent (Figure 5). For VE, considerable matrix erosion occurred after conditioning in 50% ethanol-water solution, revealing the glass-ceramic network (Figure 6).

Table 3: *Comparison of Mean Ra Values Between Dietary Solvents Based on Materials*[a]

Materials	Differences Between Dietary Solvents
FZ	Citric acid, lactic acid, 50% ethanol-water, heptane > Control (air); Citric acid, lactic acid, 50% ethanol-water > Distilled water; Citric acid > Heptane
CM	Citric acid, lactic acid, heptane, 50% ethanol-water > Control (air) and distilled water
LU	Lactic acid, citric acid, heptane, 50% ethanol-water > Control (air) and distilled water; Lactic acid, citric acid > Heptane and 50% ethanol-water
HC	Heptane, 50% ethanol-water, citric acid, lactic acid > Distilled water and control (air)
CS	Citric acid, heptane, 50% ethanol-water > Control (air) and distilled water
VE	50% ethanol-water, heptane, lactic acid > Control (air); 50% ethanol-water, heptane > Lactic acid, citric acid, and distilled water; Lactic acid > Citric acid and distilled water

Abbreviations: CM, Shofu Ceramage; CS, Cerasmart; FZ, Filtek Z350 XT; HC, Shofu Block HC; LU, Lava Ultimate; Ra, surface roughness; VE, Vita Enamic

[a] *Results of one-way analysis of variance and post hoc test ($p < 0.05$); > indicates statistically significant differences in mean Ra values between conditioning in different dietary solvents for each material.*

DISCUSSION

The effect of dietary solvents on the Ra of direct, indirect, and CAD/CAM composites was examined in this study. As the Ra of CAD/CAM composites was affected and significant differences existed between composite materials after conditioning in the various dietary solvents, both null hypotheses were rejected. Significant two-way interactions (ANOVA) between materials and conditioning media were observed, indicating that the effect of dietary solvents on Ra of the composites was material dependent. This finding corroborated those of earlier literature.[27]

For all composite materials evaluated, no significant difference in mean Ra was observed between conditioning in air (control) and distilled water. The polymer network in dental composites may contain porosity and intermolecular spaces that allow water or solvents to diffuse.[34] Two important factors that influence water sorption in dental composites are degree of conversion and amount of residual monomers remaining in the polymer network.[35] When matrix polymer is subjected to high temperature or a combination of high temperature and high pressure polymerization, the degree of conversion is increased. The higher cross-linked network reduces the diffusion of water/solvents and amount of leachable unreacted monomers.[36,37] The solubility parameter describes a solvent's ability to dissolve a

Table 4: *Comparison of Mean Ra Values Between Materials Based on Dietary Solvents*[a]

Dietary Solvents	Differences Between Materials
Control (air)	FZ > CM, LU, CS > HC > VE; CM > CS
Distilled water	FZ > CM, LU, CS > HC > VE; CM > CS
Citric acid	FZ > CM, LU, CS > HC > VE
Lactic acid	FZ, LU, CM > CS, HC >VE
Heptane	FZ > LU, CS, HC > VE; CM > HC, VE
50% ethanol-water	FZ > CM, LU, CS, HC > VE; CM > HC, VE

Abbreviations: CM, Shofu Ceramage; CS, Cerasmart; FZ, Filtek Z350 XT; HC, Shofu Block HC; LU, Lava Ultimate; Ra, surface roughness; VE, Vita Enamic

[a] *Results of one-way analysis of variance and post hoc test ($p < 0.05$); > indicates statistically significant differences in mean Ra values between different materials after conditioning in each dietary solvent.*

substance.[30] Together with polymer network density, the solubility parameter affects the extent and rate of solvent uptake.[30,35] Degradation of dental composites is greater when the solubility parameter mismatch between polymers and solvent is small.[35] The type of polymer, filler load and composition, as well as surface treatment of filler particles also influence hydrolytic degradation.[38] Notwithstanding the higher degree of conversion of indirect and CAD/CAM composites, the direct composite FZ also displayed no significant difference in Ra between air (control) and distilled water. The resistance of FZ to hydrolytic degradation may be attributed in part to the use of spherical shaped nanoparticle fillers. These nanoparticles form nanoclusters that improve packing and reduce stresses that commonly occur on irregularities of filler/matrix interfaces.[39,40] Furthermore, water uptake is a diffusion-controlled process and may take a minimum of one week to show significant effect on surface properties of composites.[41,42]

Dietary solvents used in this study included heptane, which simulates butter, fatty meats, and vegetable oils as well as citric acid, lactic acid, and ethanol, which mimic certain alcohols, vegetables, fruits, candy, and syrup.[22] Distilled water simulates nonacidic foods with pH more than 5 and models the wet oral environment.[21] Alcohol and acidic/basic solvents exhibit hygroscopic and hydrolytic effects on dental composites, and the degree of degradation is influenced by the chemistry of the solvents.[30,43] This was in accordance with our findings, where conditioning in citric acid, lactic acid, heptane, and 50% ethanol-water resulted in significantly greater postconditioning mean Ra values than with air (control) and distilled water. Acids such as citric and lactic acids are known to have softening effects on polymers through chemical degradation of the resin matrix and silane agent as well as hydrolytic breakdown of the filler particles.[44,45] The aforementioned effects are supported by SEM micrographs of FZ, CM, CS in citric acid, and LU in lactic acid, respectively. VE was not significantly degraded by citric acid, and this may be ascribed to the filler composition (interpenetrated resin matrix) that differed from the other composites investigated.

Previous studies have reported superior and stable surface characteristics when dental composites are stored in heptane as it can prevent leaching of silica and combined metal from filler particles.[20,38] Interestingly, conditioning in heptane presented the roughest surface for HC in our study. This may be attributed partly to the relatively low filler loading of HC (61%) compared with the other materials (71% to 86%) and higher monomer composition accordingly. Moreover, TEGDMA in HC has been reported to cause a plasticizing effect and solvent susceptibility.[46] The latter effect is supported by changes in surface morphology, including considerable areas of resin matrix erosion observed under SEM. Degradation of the polymer matrix and filler-silane bond by ethanol-water solution is influenced by the composition and chemical structure of the polymer networks.[23,47] In this study, 50% ethanol-water solution was selected because it mimicked food and beverages consumed by people and allowed composite degradation to be observed.[20,21,44,48] The solubility parameter of pure ethanol approximated that of Bis-GMA resin, whereas TEGDMA resin absorbed higher amounts of 50% ethanol-water solution than water or pure ethanol.[49] Since FZ contains both Bis-GMA and TEGDMA, the aforementioned may explain the significantly roughened surfaces of FZ after conditioning in 50% ethanol-water solution. In this study, it was observed that for VE, conditioning in 50% ethanol-water solution presented the highest Ra. The SEM micrograph of VE showed irregular preinfiltrated porous ceramic[50] for the control sample and obvious volume defects after conditioning in 50% ethanol-water solution. The microstructural changes may be attributed to the degradation and loss of the infiltrated polymer, leading to exposure of the porous ceramic network.

The chemical degradation of dental composites can be assessed by changes in Ra. Moreover, Ra of restorations is found to affect clinical performance as adhesion of plaque on rough surfaces could promote caries and periodontitis.[51] The baseline Ra values for

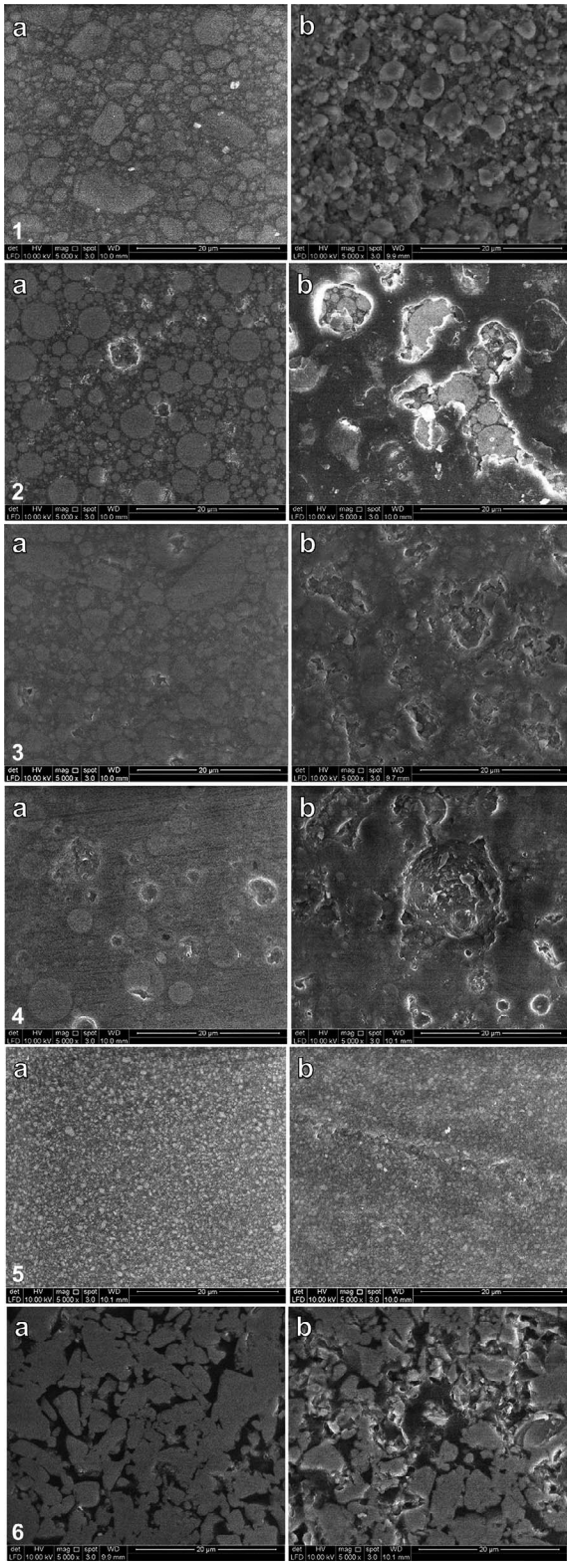

Figure 1. *Scanning electron micrograph of Filtek Z350 XT (a): air (control) and (b): after conditioning in 0.02 N citric acid.*

Figure 2. Scanning electron micrograph of Shofu Ceramage (a): air (control) and (b): after conditioning in 0.02 N citric acid.

CAD/CAM composite blocks were significantly lower than those of the direct composite FZ and consistent with findings of a previous study where laboratory-based polishing of CAD/CAM composites presented Ra values between 0.06 μm and 0.16 μm, while chair-side polishing achieved values between 0.11 μm and 0.13 μm.[19] After conditioning in dietary solvents, the mean Ra of all composites tested were below the threshold Ra of 0.2 μm. The performance of the composites was thus acceptable for the duration of dietary solvent exposure in this study. Chemical degradation observed with one week of conditioning may actually take a few months or years to occur intraorally, depending on exposure time and the patient's oral condition.[21] A recent study found that elution of unreacted components from conventional resin-based materials can occur up to one year and is influenced by composition of composite, degree of conversion, solvent type, size, and the chemical nature of released components.[52] This warrants further investigation via chemical analysis, and longer storage periods are needed to assess progressive chemical degradation of the CAD/CAM dental composites.

CONCLUSIONS

Within limits of this study, the following can be concluded:

1. Ra of dental composites, including CAD/CAM materials, was significantly affected by dietary solvents, with the exception of distilled water.
2. For CAD/CAM composites, conditioning in citric acid, lactic acid, heptane, and 50% ethanol-water solution presented the roughest surface for CS, LU, HC, and VE, respectively.
3. Differences in Ra between composite types were both material and solvent dependent.

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Figure 3. Scanning electron micrograph of Lava Ultimate (a): air (control) and (b): after conditioning in 0.02 N lactic acid.

Figure 4. Scanning electron micrograph of Shofu Block HC (a): air (control) and (b): after conditioning in heptane.

Figure 5. Scanning electron micrograph of Cerasmart (a): air (control) and (b): after conditioning in 0.02 N citric acid.

Figure 6. Scanning electron micrograph of Vita Enamic (a): air (control) and (b): after conditioning in 50% ethanol-water solution.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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