THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Influence of surface sealant agents on the surface roughness and color stability of artificial teeth

Onur Şahin, DDS, PhD,[a] Doğu Ömür Dede, DDS, PhD,[b] Ayşegül Köroğlu, DDS, PhD,[c] and Burak Yılmaz, DDS, PhD[d]

ABSTRACT

Statement of problem. Although various surface sealant agents are available and recommended for chairside polishing procedures, their effect on the surface roughness and color stability of denture teeth is not clear.

Purpose. The purpose of this in vitro study was to evaluate the effect of sealant agents on the surface roughness and color stability of various denture tooth materials.

Material and methods. Eighty disk-shaped specimens were prepared for each type of denture tooth material (SR Vivodent, PMMA; Vitapan, reinforced-PMMA; SR Phonares II, composite resin). The specimens were assigned to 4 groups according to the surface treatment used (n=20): surface sealant agents (Palaseal; Heraeus Kulzer GmbH, Optiglaze; GC Corp Biscover; Bisco Inc) and a conventional laboratory polishing technique (control group). A thermal cycling procedure was applied for half of the specimens (n=10). The surface roughness (R_a) values of thermocycled and nonthermocycled specimens were measured with a profilometer. The CIELab color parameters of both thermocycled and nonthermocycled specimens were measured with a spectrophotometer at baseline and after 7-day storage in a coffee solution. The color differences were calculated from the CIEDE2000 (ΔE_{00}) formula. Data were statistically analyzed with 3-way ANOVA and the Tukey HSD test (α=.05).

Results. The type of tooth material, surface treatment technique, and their interactions were significant for R_a values, and each variable and their interactions were also significant for ΔE_{00} values (P<.05). Thermal cycling had a significant effect only on ΔE_{00} values (P<.05).

Conclusions. Palaseal and Optiglaze sealant agents provided smoother and more color-stable denture tooth surfaces than the conventional polishing technique. The use of the Biscover agent with SR Vivodent and Phonares II teeth increased the R_a values. The color of conventionally polished SR Vivodent and Phonares II teeth changed more with thermal cycling. (J Prosthet Dent 2015;114:130-137)

Surface roughness and surface free energy are important predictors of the performance of dental restorative materials.[1-6] When the external surface of a dental restoration is rough, more plaque forms,[5] promoting tooth loss due to caries or periodontal disease as well as denture stomatitis.[1-4,6,7] In recent studies, a threshold level of surface roughness (R_a=0.2 μm) has been indicated for plaque accumulation. Although no further reduction in plaque accumulation was expected for the smooth surfaces below this borderline level, higher surface roughness resulted in a simultaneous increase in plaque accumulation.[4,8] Furthermore, dental restorations with rough surfaces are more prone to staining and discoloration, leading to reduced esthetics and acceptability of the restoration.[2,7]

Denture teeth are commonly used in complete and partial dental prostheses.[5,9-13] When the denture teeth are placed in direct contact with natural teeth or oral soft tissues, extensive plaque formation may contribute to caries or periodontal disease adjacent to the denture.[5] Plaque formation and discoloration can be reduced by polishing the denture teeth,[2,4] which has conventionally been done in the dental laboratory with aluminum oxide pastes or liquids.[4,14] Various chairside polishing kits and surface sealants are available if the prosthesis cannot be returned to the dental laboratory after grinding

[a]Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Bulent Ecevit University, Zonguldak, Turkey.
[b]Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Ordu University, Ordu, Turkey.
[c]Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Bulent Ecevit University, Zonguldak, Turkey.
[d]Associate Professor, Division of Restorative Sciences and Prosthodontics, College of Dentistry, The Ohio State University, Columbus, Ohio.

Clinical Implications

Clinicians may use a surface sealant coupling technique to achieve smooth and color-stable denture tooth surfaces after chairside grinding procedures.

procedures.[4,15-18] The application of surface sealant agents onto the resin restoration is intended to fill in surface defects, increase wear resistance, and provide better stain resistance.[4,19-22] However, their long-term performance has not been fully reported. The purpose of this study was to evaluate the effect of sealant agents and thermal cycling on the surface roughness and color stability of different denture teeth. The first null hypothesis was that the application of different sealant agents would not affect the surface roughness and color stability of acrylic and composite resin teeth. The second null hypothesis was that the effect of sealant agents would not vary depending on the type of teeth. The third null hypothesis was that the effect of sealant agents would not vary depending on thermal cycling.

MATERIAL AND METHODS

A total of 240 standardized labial sections were cut from the labial surfaces of 3 different commercially available denture teeth: an unfilled PMMA (SR Vivodent PE, or SrVi), a microfiller reinforced PMMA (Vitapan, or Vita), and a nanofilled composite (SR Phonares II, or SrPh). Disk-shaped labial sections (6×2 mm) were prepared from the largest available A2 shade central incisors with minimal labial surface texture with a standardized template and trephine bur (Hager & Meisinger GmbH).[5] Before the polishing procedures, the specimens were ground-finished with 400-grit silicon carbide abrasive paper on a machine (Phoenix Beta; Buehler) under water cooling. Twenty specimens for each denture tooth group were polished with a conventional laboratory polishing technique (control group) and the other 60 specimens were divided and coated with 3 different surface sealant agents (n=20) (Table 1). Each sealant agent was applied with a soft brush in an even, thin layer in 1 direction without any agitation to avoid air bubble formation. Twenty seconds later, the Palaseal (Ps) and Optiglaze (Og) coated specimens were polymerized for 90 seconds in a light-polymerizing unit (Dentacolor XS; Heraeus Kulzer GmbH) and Biscover (Bc) coated specimens were polymerized for 30 seconds with an LED- polymerizing light (Elipar FreeLight 2; 3M ESPE) with an output of 750 mW/cm^2 at close range as recommended by the manufacturers.

Control specimens were initially polished with a slurry of coarse pumice (Pomza; Isler Dental) and a bristle brush (T.O.F.F Polishing brush; Artek's) on a polishing lathe (P1000; Zubler) for 90 seconds at a rate of 1500 rpm, then subjected to fine polishing with a paste (dental plaster plus pure alcohol) and lathe flannel wheel for 90 seconds.[4] All procedures were performed by 1 operator (D.O.D.) and according to the manufacturer's recommendations. After the polishing procedures, each specimen was ultrasonically cleaned (Hygosonic; Dürr Dental AG) for 10 minutes, then rinsed, and dried with oil-free air. One specimen for each group was chosen and examined with a scanning electron microscope (SEM) (Nova NanoSEM 450; FEI Europe). The acceleration voltage of the cathode was set to 15 kV and the working distance to 13.3 mm.

The surface roughness (R_a) was measured for 10 specimens of each test group with a contact profilometer (Perthometer M2; Mahr). The profilometer's resolution was 0.01 μm, the interval (cut-off length) was 0.25 mm, the transverse length was 1.75 mm, and the stylus speed was set at 1 mm/s. The arithmetic mean for the results of measurements in 3 different directions was calculated for each specimen. After the initial surface roughness measurements had been performed, the specimens were subjected to thermal cycling between 5°C and 55°C for 3000 cycles at 30 seconds in distilled water (n=120) and R_a measurements were repeated after thermal cycling.

The CIE (Commission International de l'Eclairage) L*a*b* color parameters of each specimen were measured with a digital spectrophotometer (VITA Easyshade; Vita Zahnfabrik).[22,23] The initial color measurements were repeated 3 times for each specimen, and the means were recorded as L_0*, a_0*, b_0*. Both thermocycled (TC) (n=120) and nonthermocycled (NT) specimens were then embedded into wax plates to cover the unpolished surfaces. The staining solution was prepared by adding 7.5 g of coffee (Nescafé Classic; Nestlé) to 500 mL of boiling distilled water. All specimens on the wax plates were immersed in the coffee solution in a stainless steel container and stored at 37°C in a dark environment for 7 days to simulate intraoral conditions. After the staining procedure, each specimen was washed under water and air-spray dried, and color measurements were made. Data were recorded as L_1*, a_1*, b_1*.

The color change values of TC and NT denture teeth after different surface treatments were calculated with the following CIEDE2000 (ΔE_{00}) color difference formula[24-27]:

$$\Delta E_{00}=\sqrt{\left(\frac{\Delta L*}{KLSL}\right)^2+\left(\frac{\Delta C*}{KcSc}\right)^2+\left(\frac{\Delta H*}{KHSH}\right)^2+\mathrm{RT}\left(\frac{\Delta C*}{KCSL}\right)\left(\frac{\Delta H*}{KHSH}\right)},$$

where ΔL*, ΔC*, and ΔH* are the differences in lightness, chroma, and hue for a pair of specimens in ΔE_{00}, and where RT is a function that accounts for the interaction between chroma and hue differences in the blue

Table 1. Materials used

Material	Code	Type	Component	Manufacturer	Batch No.
SR Vivodent PE	SrVi	Acrylic resin denture teeth	PMMA	Ivoclar Vivadent AG	018795
Vitapan	Vita	Microfiller reinforced polyacrylic resin denture teeth	PMMA, TiO_2	Vita Zahnfabrik	R5
SR Phonares II	SrPh	Nanofilled composite resin denture teeth	Urethane dimethacrylate matrix (TMX-UDMA), PMMA, silanized SiO_2	Ivoclar Vivadent AG	SP0345
Palaseal	Ps	Surface sealant agent	Methyl methacrylate, 2-hydroxyethyl isocyanuratetriacrylate, acrylized epoxy oligomer and polysiloxane	Heraeus Kulzer GmbH	531
Optiglaze	Og	Surface sealant agent	PMMA, methyl methacrylate, silica filler, photo inhibitor	GC Corp	1211121
Biscover LV	Bc	Surface sealant agent	Dipentaerythritolpentaacrylate, ethanol	Bisco Inc	130000-1098

Table 2. Three-way ANOVA results of surface roughness R_a and ΔE_{00} values

Parameter	Source	SS	*df*	MS	F	*P*
R_a						
	Tooth type (A)	0.090	2	0.045	4.919	.008
	Surface treatment (B)	1.086	3	0.362	39.371	<.01
	Thermal cycling (C)	9.882E-5	1	9.882E-5	0.011	.918
	A×B	0.668	6	0.111	12.108	<.01
	A×C	0.001	2	0.001	0.058	.944
	B×C	0.009	3	0.003	0.310	.818
	A×B×C	0.006	6	0.001	0.107	.996
ΔE_{00}						
	A	10.362	2	5.181	19.531	<.01
	B	25.895	3	8.632	32.538	<.01
	C	7.121	1	7.121	26.843	<.01
	A×B	2.912	6	0.485	1.830	.095
	A×C	1.995	2	0.998	3.760	.025
	B×C	3.010	3	1.003	3.782	.011
	A×B×C	1.139	6	0.190	0.715	.638

P<.05 indicates significant difference.

Table 3. Mean, standard deviation (SD), and Tukey multiple-comparison test of denture tooth specimen surface roughness R_a (μm)

Denture Tooth	Surface Treatment	NT		TC	
		Mean	SD	Mean	SD
SR Vivodent	Control	0.114	(0.080)[a]	0.107	(0.063)[a]
	Palaseal	0.099	(0.087)[a]	0.123	(0.063)[a]
	Optiglaze	0.084	(0.040)[a]	0.083	(0.035)[a]
	Biscover	0.309	(0.145)[bc]	0.278	(0.148)[bc]
Vitapan	Control	0.173	(0.080)[ab]	0.153	(0.037)[ab]
	Palaseal	0.069	(0.028)[a]	0.079	(0.054)[a]
	Optiglaze	0.121	(0.044)[a]	0.127	(0.069)[a]
	Biscover	0.103	(0.085)[a]	0.112	(0.051)[a]
SR Phonares	Control	0.187	(0.038)[abc]	0.174	(0.032)[ab]
	Palaseal	0.043	(0.018)[a]	0.067	(0.027)[a]
	Optiglaze	0.066	(0.034)[a]	0.071	(0.019)[a]
	Biscover	0.344	(0.258)[c]	0.355	(0.231)[c]

Results of Tukey HSD post hoc comparisons are shown as superscripts, and values having same letters are not significantly different (*P*>.05).
Lowercase letters indicate differences between denture tooth/surface treatment combinations in NT and TC groups.

region. Weighting functions, SL, SC, and SH adjust the total color difference for variation in the location of the color difference pair in L_0, a_0, b_0 coordinates, and the parametric factors, K_L, K_C, K_H are correction terms for experimental conditions.[18] In this study, the parametric factors were set to 1.0. The perceptibility and acceptability thresholds for CIEDE2000 color differences were evaluated and determined by recent studies.[25,26] In the present study, the perceptibility threshold was set at $\Delta E_{00} \leq 1.30$ units, and the clinical acceptability threshold was set at $\Delta E_{00} \leq 2.25$ units.

The R_a and ΔE_{00} data were statistically analyzed. First, the Levene test of homogeneity was used to evaluate the normal distribution of the variables. Secondly, the R_a and ΔE_{00} results were separately analyzed by 3-way ANOVA to evaluate the effects of denture tooth type, surface treatment techniques, thermal cycling, and their interactions. Finally, the mean R_a and ΔE_{00} values were also separately compared by using the Tukey HSD multiple comparison test. Significance was evaluated at *P*<.05 for all tests. All the computational work was performed with statistical software (SPSS v17.0; SPSS Inc).

RESULTS

According to the 3-way ANOVA, the type of denture teeth, surface treatment technique, and their interactions were significant for R_a values (Table 2) (*P*<.05). The mean R_a values and standard deviations for denture tooth/surface treatment combinations for the NT and TC groups are listed in Table 3 (Fig. 1).

Only the SrVi_Bc and BC (SrPh_Bc) specimens had higher R_a values (0.278 to 0.355 μm) than the plaque accumulation threshold level (0.20 μm). While the highest R_a value was determined for the TC_SrPh_Bc group (0.355 μm), the lowest R_a value was determined for the NT_SrPh_Ps group (0.043 μm).The Bc sealant agent coupling significantly increased the R_a of SrVi and SrPh denture teeth compared with the other sealant agents and control groups (*P*<.05). However, Vita denture tooth groups had decreased R_a values when the Bc sealant agent coupling was used. The coupling of each denture tooth with Ps and Og agents resulted in smoother surfaces than with conventional polishing; however, no statistically significant differences were found among them. SEM images of SrVi, Vita, and SrPh denture teeth surfaces after surface treatments are shown in

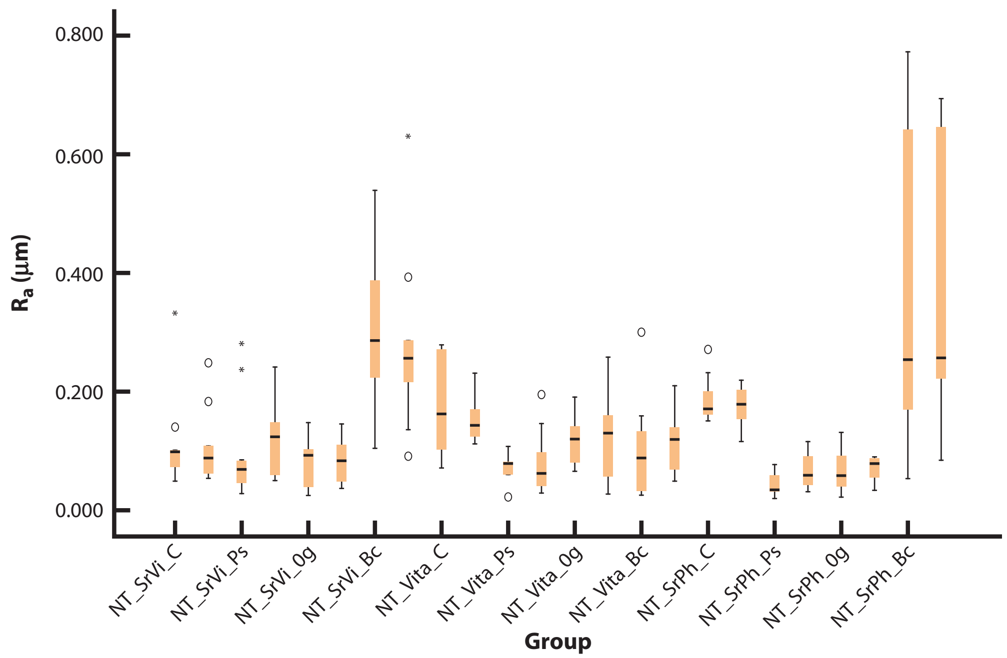

Figure 1. Means, standard deviations (SD), and significant interactions for R_a (µm) values.

Figs. 1-4. The SEM images show that the sealant-coupled specimens had smoother surfaces than the control groups. Additionally, topographical changes, including micropores, cavities (Figs. 2D, 4D), and microcracks (Fig. 2D), were observed for Bc agent-coupled SrVi and SrPh specimens. An irregular surface was also observed for Vita_C (Fig. 3A).

The 3-way ANOVA results showed that each variable and their interactions (except the interaction between tooth type and surface treatment) were significant for color difference values (Table 2) ($P<.05$). The mean ΔE_{00} values and standard deviations for denture tooth/surface treatment combinations for the NT and TC groups are listed in Table 4. The mean color differences for each control group (NT SrVi_Og, SrVi_Bc, and SrPh_Bc tooth groups; TC Vita_Ps, SrPh_Ps, and SrPh_Og tooth groups) were above the acceptability threshold level ($\Delta E_{00} \leq 2.25$). Even though all other ΔE_{00} values were within the clinically acceptable limits ($1.30 < \Delta E_{00} \leq 2.25$), they were in the range of visual perceptibility. While the highest ΔE_{00} was observed for the TC_SrVi_C group (3.46), the lowest was observed for the TC_Vita_Og group (1.59). In general, conventional polishing produced the highest ΔE_{00} for each tooth group. A statistically significant difference was found between the conventionally polished and other surface treatment groups for TC_SrPh, NT_Vita (except Vita_Bc), and TC_Vita (except TC_Vita_Ps) teeth ($P<.05$). Sealant agent coupling techniques reduced the ΔE_{00} values.

Thermal cycling application significantly increased the ΔE_{00} values of SrVi and SrPh tooth groups ($P<.05$). When denture tooth types were compared for each surface treatment and thermal cycling procedure, the highest ΔE_{00} values were obtained for the SrVi tooth groups. However, Vita teeth were the most stain-resistant group. A statistically significant difference was found between the thermocycled Og/Bc sealant agent coupled SrVi and Vita groups ($P<.05$). Regression analysis found the coefficient of correlation between R_a and ΔE_{00} values to be statistically significant ($P=.011$, $r^2=.165$) (Fig. 5).

DISCUSSION

All null hypotheses were rejected, because surface treatment techniques and tooth type significantly affected both surface roughness and color stability, and thermal cycling had a significant effect on color stability ($P<.01$). Significant differences were found in R_a and ΔE_{00} values among the groups ($P<.05$). Thermal cycling had no effect on surface roughness.

All teeth coated with Ps and Og had smoother surfaces than those in conventionally polished groups. Similarly, previous studies have found that surface-penetrating sealant or glaze materials result in significantly lower R_a values than conventional polishing techniques (aluminum oxide abrasive disks or silicone wheel systems).[15,21] However, in this study, when Bc was used, only the surfaces of Vita teeth were smoother than the control group. The Bc sealant agent caused significantly rougher surfaces for SrVi and SrPh tooth groups than for their control groups. In addition, the R_a values were higher than the 0.2 µm threshold level. This unexpected result may be explained by surface irregularities caused by the removal of unpolymerized or nonadhered

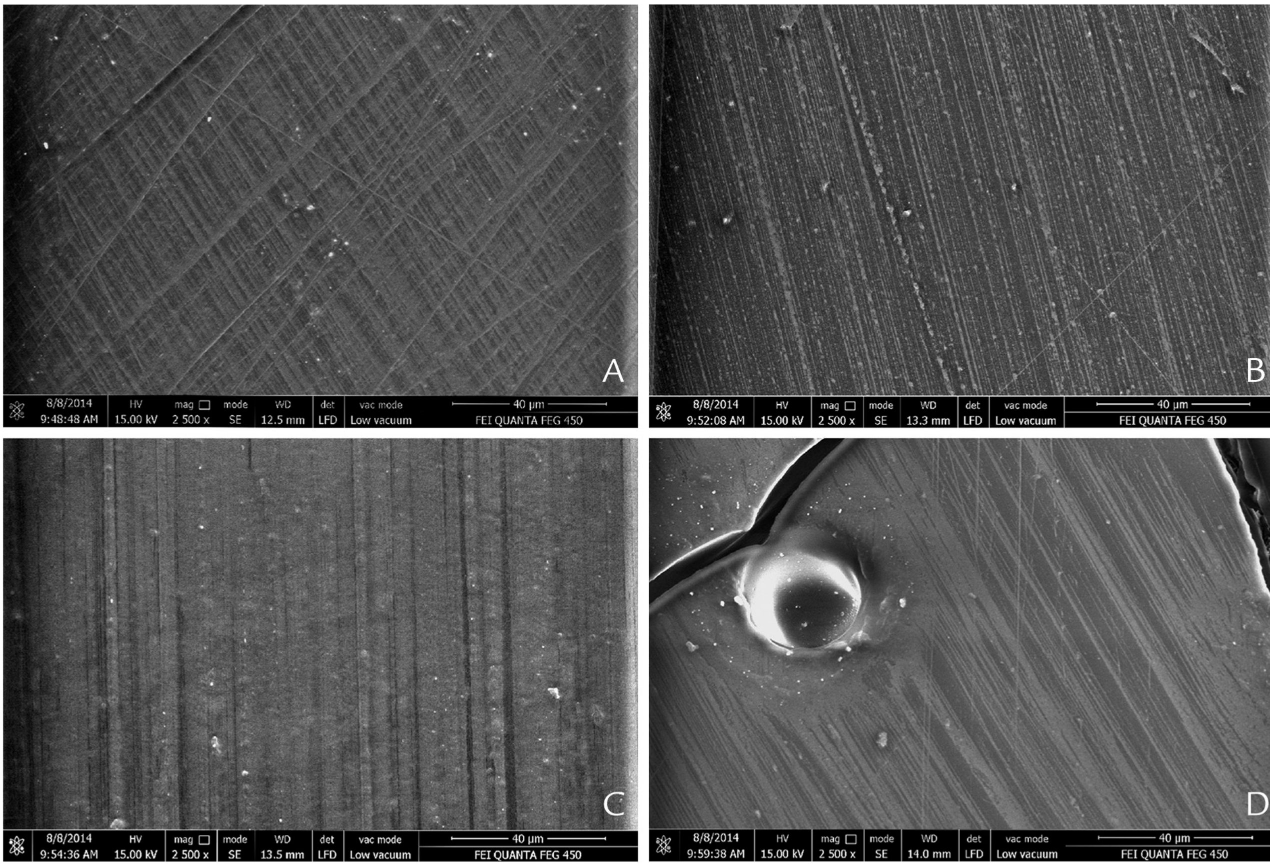

Figure 2. Scanning electron micrograph analysis (×2500) of A, SrVi_C (note rougher surfaces compared with test groups); B, SrVi_Ps; C, SrVi_Og; and D, SrVi_Bc (note oblique microcracks and cavity on surface).

surface particles. A film of incompletely polymerized layer occurs on the surface of composite resin materials when they are contact with oxygen in the air.[19] Because intraoral factors may easily remove this layer, surface defects such as microcracks may occur.[19,21,26] Additionally, the formation of air bubbles in the sealant material during its application by brushing may also cause surface irregularities and increase the R_a values.[19] Microcracks and cavities were observed in the SEM images of SrVi_Bc and SrPh_Bc specimens (Figs. 2D, 4D).

The mechanical properties and surface roughness of resin materials depend on the filler particle size, hardness, and percentage content.[2,15,19] Silicon dioxide, glass, and ceramic are the preferred inorganic filler materials. The polishing of filled resins causes a higher fraction of these inorganic components in the surface layer and thus increases the surface roughness and free energy.[5] A similar study found that unfilled resins tended to decrease surface roughness with the increasing molecular weight of methacrylate components.[2] In another study, although low bacterial adhesion and fluorescence values were found for PMMA resin teeth, the highest R_a values and the highest adhesion of bacteria were observed for filler-supplemented resin teeth.[5] In agreement with these previously reported results, the R_a values of SrVi_C (unfilled PMMA) teeth were lower than those of Vita_C (micro-filler reinforced polyacrylic resin) and SrPh_C (nano-filled composite resin) tooth groups. The SEM images also showed an irregular surface texture of Vita_C specimens, perhaps because of the fraction of the inorganic filler components (Fig. 3A).

The discoloration of resin-based materials is a complex phenomenon and is associated with several mechanisms, including surface roughness and chemical and physical interactions.[16,17,21] Although obtaining a precise relationship between surface roughness and staining is not usually possible, surface roughness has been shown to be the main reason for the adsorption of stains. The adsorption and absorption of a colorant onto/into the organic phase of resin materials and the high surface reactivity of poorly polymerized surfaces have also been blamed for staining.[15,16,21] In this study, the color changes for specimens treated with conventional polishing technique were not only higher than the sealant coupling techniques but also above the acceptable threshold, regardless of denture tooth type or thermal cycling (ΔE_{00}=2.54-3.46). Although each sealant agent coupling technique reduced the staining potential of denture teeth, the color change values of SrVi_Bc and SrPh_Bc were above the acceptable threshold (ΔE_{00}=2.31-2.81). Reducing surface irregularities and

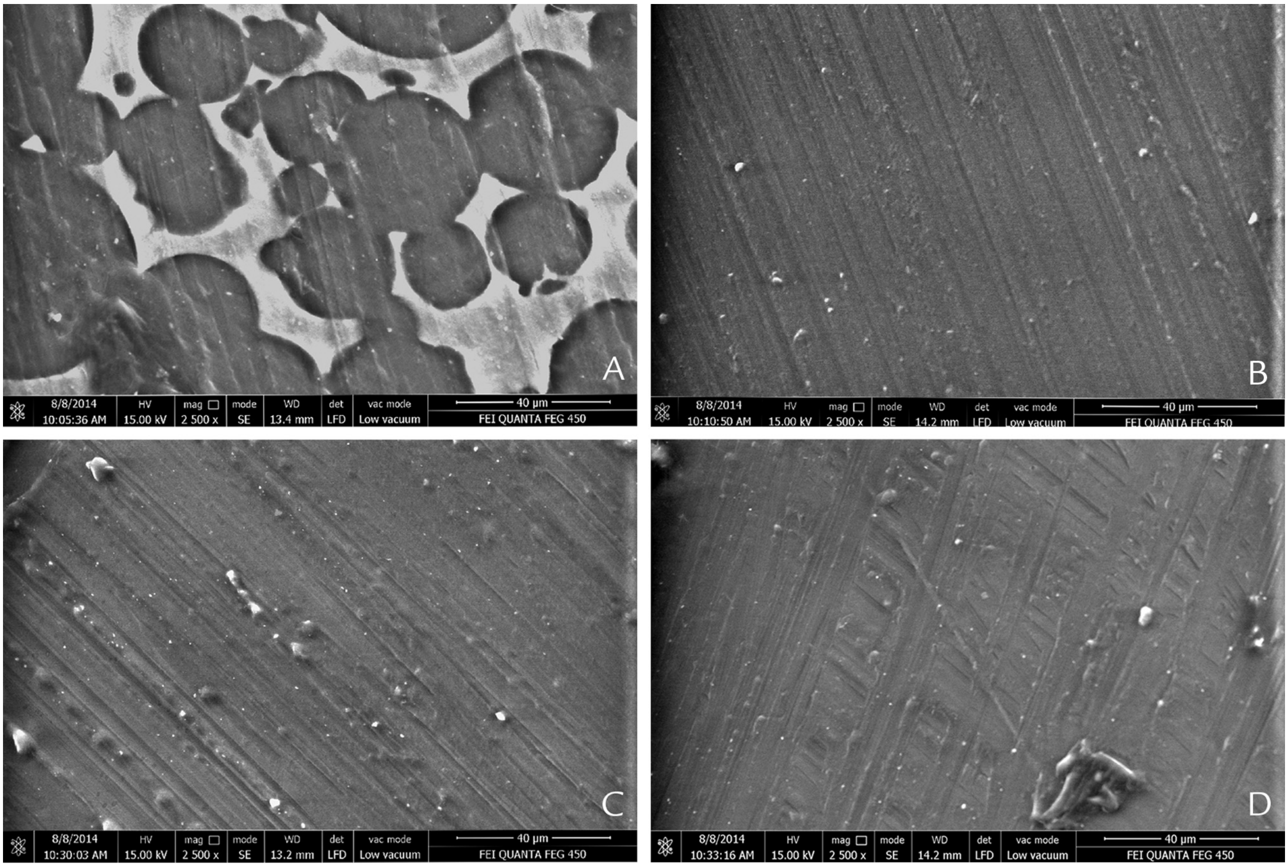

Figure 3. Scanning electron micrograph analysis (×2500) of A, Vita_C (note irregular surface texture); B, Vita_Ps; C, Vita_Og; and D, Vita_Bc.

defects and enhancing surface smoothness may account for the sealant agent's superiority in providing improved resistance to stain. The higher ΔE_{00} values for SrVi_Bc and SrPh_Bc teeth were also correlated with higher R_a values. Conversely, a previous study indicated that the discoloration of coating resins depended on the resin composition and that leaving incomplete polymer networks and matrix film on the finished surface of sealant-coated specimens may make them more open and accessible to colorants. As a result, the absorption of colorants and penetration into the matrix of coating material caused internal staining.[18] The different results obtained for the sealant agents evaluated in this study could also be attributed to the intrinsic factors of these materials. In another study, the effect of resin surface sealers on the staining resistance of an interim material was evaluated. The authors concluded that the polymerization duration and content of the sealant material affected the staining resistance and that using methacrylate- or dimethacrylate-containing glaze materials improved resistance more than those containing ethoxylatedbisphenol-A dimethacrylate.[21] The results of the present study were similar to this finding. The dipentaerythritolpentaacrylate-containing Bc sealant agent was less stain resistant than the methacrylate- or PMMA-containing Ps and Og agents. In the present study, while the Ps and Og sealant agents were light-polymerized for 90 seconds, the Bc agent was light-polymerized for only 30 seconds. The shorter polymerization time might have affected the stain resistance of Bc, which was also mentioned in a previous study.[21]

Although the color change of sealant agent/denture tooth specimens was substantially associated with the sealant agent's intrinsic and/or extrinsic staining factors, conventionally polished specimens were affected by the chemical and physical factors of the teeth themselves. In the present study, the color change values of conventionally polished teeth were close to each other. However, significant increases were observed for TC SrVi and SrPh teeth compared with NT groups. This result was consistent with the results reported in a previous study, in which the color of denture teeth was affected by thermal cycling. In addition, the SrVi teeth exhibited the greatest change in color when compared with different brands of denture teeth.[10] Another study showed that the color change value of SrVi teeth in coffee solution was significantly greater than that of the Vita teeth and that discoloration ratios increased with the immersion period.[12] The color change of resin materials after thermal cycling may be associated with the absorption and adsorption of the discolorant. Increasing the hydrophobic content of denture teeth may

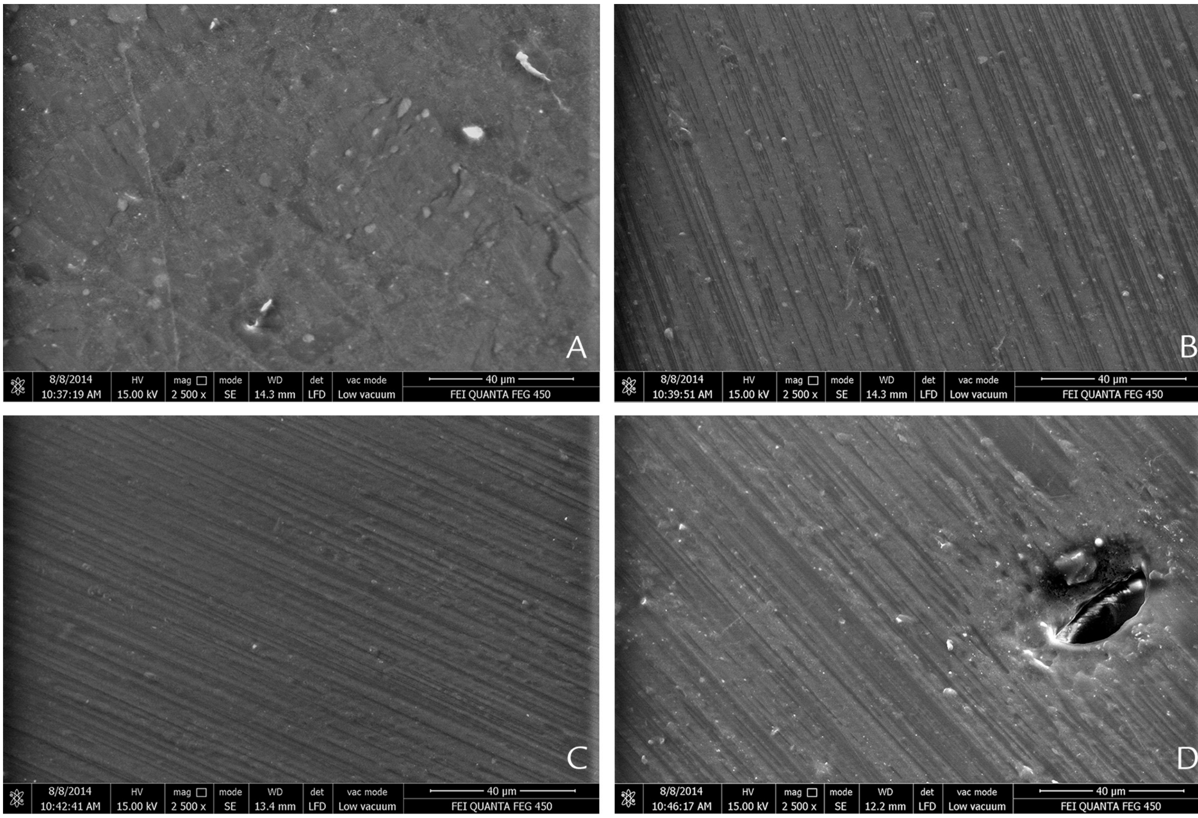

Figure 4. Scanning electron micrograph analysis (×2500) of A, SrPh_C (note rougher surface compared with test groups); B, SrPh_Ps; C, SrPh_Og; and D, SrPh_Bc (note micropore/cavity on surface).

Table 4. Mean, standard deviation (SD), and Tukey multiple-comparison test of denture tooth specimen color differences (ΔE_{00})

Denture Tooth	Surface Treatment	NT		TC	
		Mean	SD	Mean	SD
SR Vivodent	Control	2.69	(0.65)^{Acde}	3.46	(0.30)^{Bd}
	Palaseal	1.91	(0.54)^{Aabcd}	2.65	(0.37)$^{Ab\text{-}d}$
	Optiglaze	2.46	(0.42)^{Aabcde}	2.65	(0.50)^{Abcd}
	Biscover	2.42	(0.31)^{Aabcde}	2.81	(0.39)^{Acd}
Vitapan	Control	2.75	(0.67)^{Abcde}	2.86	(0.97)^{Acd}
	Palaseal	1.79	(0.56)^{Aa}	2.31	(0.84)^{Aabc}
	Optiglaze	1.83	(0.53)^{Aab}	1.59	(0.54)^{Aa}
	Biscover	1.93	(0.93)^{Aabcd}	1.92	(0.31)^{Aab}
SR Phonares	Control	2.54	(0.23)^{Aabcde}	3.37	(0.35)^{Bd}
	Palaseal	1.89	(0.20)^{Aabc}	2.33	(0.24)^{Aabc}
	Optiglaze	2.03	(0.29)^{Aabcde}	2.34	(0.43)^{Aabc}
	Biscover	2.31	(0.18)^{Aabcde}	2.39	(0.50)^{Aabc}

Results of Tukey HSD post hoc comparisons are shown as superscripts, and values having same letters are not significantly different (P>.05).
Uppercase letters indicate differences between NT and TC groups and lowercase letters indicate differences between denture tooth/surface treatment combinations.

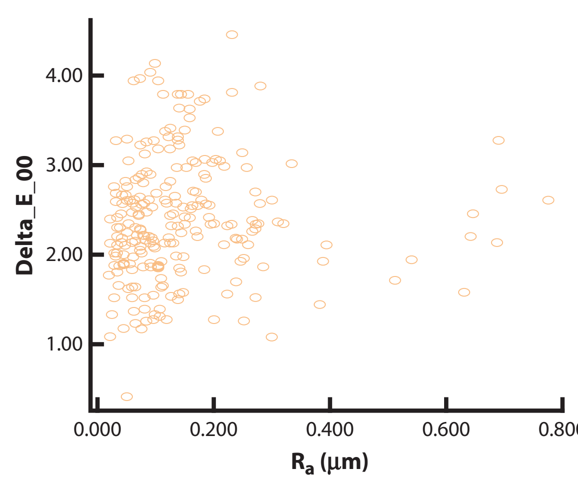

Figure 5. Correlation plot for R_a (µm) and (ΔE_{00}) values.

reduce the susceptibility to water sorption and staining.[10-12] In the present study, the lower color change values for TC_Vita teeth than for SrVi teeth may be explained by the higher degree of hydrophobic cross-linking and filler content, which might have caused less water sorption. The effects of thermal cycling and water immersion on the discoloration of composite resins were not only associated with the oxidation of amine accelerators but also the alteration of the organic matrix and matrix-filler interface.[10,13,16,17] The potential swelling of the composite resin matrix by water uptake should increase the staining tendency and may also explain the high color change values for the TC_SrPh teeth evaluated. A previous study indicated that the frame of the filler content may also affect the discoloration results. Using silanized filler content might reduce the formation of microgaps and microfractures among the resin matrix-filler interfaces and thus decrease water uptake and staining probabilities.[13] Several studies have reported that the resin matrix type played a major role in the color stability of the composite resins and that greater discoloration was recorded for the composite resins with triethylene glycol dimethacrylate (TEGDMA) than for those with diglycidyl ether methacrylate (bis-GMA) or urethane dimethacrylate (UDMA).[16,17] In the present study, although the SrPh composite resin teeth have UDMA resin matrix and silanized SiO_X filler composition, the effect of thermal cycling might have damaged the matrix-filler connection and thus increased the staining potential.

This in vitro study has some limitations. Only 1 brand of denture teeth was evaluated for each PMMA, reinforced-PMMA, and composite resin tooth group. The long-term performance of sealant agents on candida or bacterial adhesion, wear resistance, and optical properties may also be investigated and compared with different laboratory and chairside polishing techniques. In the present study, the time of the thermal cycling procedure was limited and only 1 type of staining solution was used to simulate the intraoral conditions. However, many other factors such as occlusal relations, nutritional habits, toothbrushing, mouth rinsing, and saliva should be taken into consideration. The conclusions of this study should be verified with long-term clinical studies.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. The type of denture tooth material and surface treatment technique were significant for both R_a and ΔE_{00} values, but thermal cycling was only significant for ΔE_{00} values.
2. The use of surface sealant agents decreased the R_a and ΔE_{00} values except for the Biscover sealant agent, which caused a significantly rougher surface for SR Vivodent and Phonares II teeth than for the teeth in the conventionally polished groups.
3. Conventionally polished teeth showed the highest color changes, which were clinically unacceptable ($\Delta E00>2.25$). The color change of the conventionally polished SR Vivodent and Phonares II teeth significantly increased with thermal cycling.
4. Color changes after the use of some sealant agents were visually perceptible but clinically acceptable ($1.30 < \Delta E_{00} \leq 2.25$) for different tooth groups.

REFERENCES

1. Quirynen M, van der Mei HC, Bollen CM, Schotte A, Marechal M, Doornbusch GI, et al. An in vivo study of the influence of the surface roughness of implants on the microbiology of supra- and subgingival plaque. J Dent Res 1993;72:1304-9.
2. Borchers L, Tavassol F, Tschernitschek H. Surface quality achieved by polishing and by varnishing of temporary crown and fixed partial denture resins. J Prosthet Dent 1999;82:550-6.
3. Sen D, Göller G, Işsever H. The effect of two polishing pastes on the surface roughness of bis-acryl composite and methacrylate-based resins. J Prosthet Dent 2002;88:527-32.
4. Kuhar M, Funduk N. Effects of polishing techniques on the surface roughness of acrylic denture base resins. J Prosthet Dent 2005;93:76-85.
5. Hahnel S, Rosentritt M, Bürgers R, Handel G. Adhesion of Streptococcus mutans NCTC 10449 to artificial teeth: an in vitro study. J Prosthet Dent 2008;100:309-15.
6. Ferracane JL, Condon JR, Mitchem JC. Evaluation of subsurface defects created during the finishing of composites. J Dent Res 1992;71:1628-32.
7. Ghazal M, Kern M. The influence of antagonistic surface roughness on the wear of human enamel and nanofilled composite resin artificial teeth. J Prosthet Dent 2009;101:342-9.
8. Bollen CM, Papaioanno W, Van Eldere J, Schepers E, Quirynen M, van Steenberghe D. The influence of abutment surface roughness on plaque accumulation and peri-implant mucositis. Clin Oral Implants Res 1996;7:201-11.
9. Tanaka R, Kurogi T, Murata H. Effect of melamine foam cleaning on the surface condition of composite resin artificial teeth. J Prosthodont 2013;22:626-32.
10. Assunção WG, Barão VA, Pita MS, Goiato MC. Effect of polymerization methods and thermal cycling on color stability of acrylic resin denture teeth. J Prosthet Dent 2009;102:385-92.
11. Mutlu-Sagesen L, Ergün G, Ozkan Y, Bek B. Color stability of different denture teeth materials: an in vitro study. J Oral Sci 2001;43:193-205.
12. Koksal T, Dikbas I. Color stability of different denture teeth materials against various staining agents. Dent Mater J 2008;27:139-44.
13. Imamura S, Takahashi H, Hayakawa I, Loyaga-Rendon PG, Minakuchi S. Effect of filler type and polishing on the discoloration of composite resin artificial teeth. Dent Mater J 2008;27:802-8.
14. O'Donnell EF, Radford DR, Sinclair GF, Clark RK. Chairside polishing of heat-cured acrylic resin: an SEM and EDA study. Int J Prosthodont 2003;16:233-8.
15. Sarac D, Sarac YS, Kulunk S, Ural C, Kulunk T. The effect of polishing techniques on the surface roughness and color change of composite resins. J Prosthet Dent 2006;96:33-40.
16. Güler AU, Güler E, Yücel AC, Ertaş E. Effects of polishing procedures on color stability of composite resins. J Appl Oral Sci 2009;17:108-12.
17. Gönülol N, Yilmaz F. The effects of finishing and polishing techniques on surface roughness and color stability of nano composites. J Dent 2012;40:64-70.
18. Manabe A, Kato Y, Finger WJ, Kanehira M, Komatsu M. Discoloration of coating resins exposed to staining solutions in vitro. Dent Mater J 2009;28:338-43.
19. Bertrand MF, Leforestier E, Muller M, Lupi-Pégurier L, Bolla M. Effect of surface penetrating sealant on surface texture and microhardness of composite resins. J Biomed Mater Res 2000;53:658-63.
20. Dickinson GL, Leinfelder KF. Assessing the long-term effect of a surface penetrating sealant. J Am Dent Assoc 1993;124:68-72.
21. Doray PG, Eldiwany MS, Powers JM. Effect of resin surface sealers on improvement of stain resistance for a composite provisional material. J Esthet Restor Dent 2003;15:244-50.
22. Paravina RD, Powers JM. Esthetic color training in dentistry. 1st ed. St Louis: Mosby; 2004. p. 3-47.
23. Rosenstiel SF, Land MF, Fujimoto J. Color science, esthetic and shade selection. In: Contemporary fixed prosthodontics. 4th ed. St. Louis: Mosby; 2006. p. 594-6.
24. CIE Technical Report: Colorimetry. CIE pub no. 15.3. Vienna, Austria: CIE Central Bureau; 2004.
25. Ghinea R, Pérez MM, Herrera LJ, Rivas MJ, Yebra A, Paravina RD. Color difference thresholds in dental ceramics. J Dent 2010;38:57-64.
26. Kürklü D, Azer SS, Yilmaz B, Johnston WM. Porcelain thickness and cement shade effects on the colour and translucency of porcelain veneering materials. J Dent 2013;41:1043-50.
27. Lee YK. Comparison of CIELAB DeltaE (*) and CIEDE2000 color-differences after polymerization and thermocycling of resin composites. Dent Mater 2005;21:678-82.

Corresponding author:
Dr Burak Yilmaz
The Ohio State University
College of Dentistry, 305 W 12th Ave
Columbus, Ohio 43210
Email: yilmaz.16@osu.edu