THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Effect of toothbrushing on surface roughness and gloss of CAD-CAM versus conventional interim materials with different surface treatments

Sarasinee Sattawatthamrong, DDS,[a] Krid Kamonkhantikul, DDS, PhD,[b] Woraporn Homsiang, DDS, PhD,[c] and Mansuang Arksornnukit, DDS, MS, PhD[d]

ABSTRACT

Statement of problem. Characterizing interim restorations promotes esthetics. However, studies on the effects of characterization materials on the surface roughness and gloss of interim materials after toothbrushing are lacking.

Purpose. The purpose of this in vitro study was to evaluate the surface roughness and gloss of 5 different interim materials with different surface treatments after 1 year of simulated toothbrushing.

Material and methods. Cuboid specimens (10×12×2 mm) were fabricated from each interim material: autopolymerized polymethyl methacrylate (UNIFAST Trad), autopolymerized bis-acryl composite resin (Protemp 4), light-activated composite resin (REVOTEK LC), milled polymethyl methacrylate block (DD provi P HI), and 3-dimensionally printed methacrylate oligomer (Nextdent C&B MFH). Each material was divided into 3 groups based on surface treatment (n=10): polishing, application of Lite Art and Resin Glaze, and application of OPTIGLAZE color. The specimens were subjected to 5000 and 10 000 cycles of toothbrushing. The surface roughness and gloss were measured and separately analyzed by using 3-way repeated measures ANOVA (α=.05).

Results. Significant interactions of the surface roughness and gloss among interim materials, surface treatments, and toothbrushing durations were found (*P*<.001). After 5000 and 10 000 cycles, each polished material showed no significant difference in surface roughness compared with baseline: Protemp 4 (*P*>.999), REVOTEK LC (*P*>.999, *P*=.922), and Nextdent C&B MFH (*P*>.999), except for UNIFAST Trad and DD provi P HI (*P*<.001). Coating with Lite Art and Resin Glaze, as well as OPTIGLAZE color, significantly reduced surface roughness after both 5000 and 10 000 cycles for all materials (application of Lite Art and Resin Glaze with UNIFAST TRAD (*P*<.001), Protemp 4 (*P*<.001), REVOTEK LC (*P*<.001), DD provi P HI (*P*<.001), and Nextdent C&B MFH (*P*<.001, *P*=.002), and application of OPTIGLAZE color with UNIFAST TRAD (*P*<.001), Protemp 4 (*P*<.001), REVOTEK LC (*P*<.001, *P*=.002), DD provi P HI (*P*<.001), and Nextdent C&B MFH (*P*<.001, *P*=.008)). Specimens with these treatments also exhibited significantly better gloss compared with the polished specimens (*P*<.001).

Conclusions. After 5000 to 10 000 cycles of toothbrushing, Protemp 4, REVOTEK LC, and Nextdent C&B MFH, interim materials containing fillers, exhibited smoother surfaces compared with UNIFAST Trad and DD provi P HI, interim materials without fillers. Coating of all materials reduced surface roughness and increased gloss. After 5000 to 10 000 cycles of toothbrushing, the surface roughness of each material remained stable; while the gloss decreased slightly, it remained within clinically acceptable levels. (J Prosthet Dent 2025;133:282.e1-e12)

Interim prostheses play an essential role in treatment with fixed dental prostheses by protecting prepared tooth structures and periodontal health while maintaining occlusal relationships and preserving oral function and esthetics throughout treatment. The durability and performance of interim materials depend on

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The author is not an Editorial Board Member/Editor-in-Chief/Associate Editor/Guest Editor for any journal and was not involved in the editorial review or the decision to publish this article.

[a]Graduate student, Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, 34 Henri Dunant Road, Pathumwan, Bangkok, Thailand.
[b]Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, 34 Henri Dunant Road, Pathumwan, Bangkok, Thailand.
[c]Lecturer, Department of Family and Community Dentistry, Faculty of Dentistry, Chiang Mai University, Suthep Road, Suthep, Chiang Mai, Thailand.
[d]Professor, Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, 34 Henri Dunant Road, Pathumwan, Bangkok, Thailand.

Clinical Implications

Finishing interim materials with LiteArt and Resin Glaze is a recommended clinical approach to maintaining low surface roughness and high gloss levels, even after 1 year of toothbrushing.

factors that include mechanical strength, wear resistance, biocompatibility, and color stability.[1,2]

Interim materials have been classified based on their primary resins, including polymethyl methacrylate (PMMA), ethoxylated bisphenol A dimethacrylate, and urethane dimethacrylate.[2,3] The fabrication of interim restorations through conventional polymerization methods presents several drawbacks, including polymerization shrinkage, residual monomers, and voids during mixing, which can impact the mechanical strength of the restoration, surface texture, and fit.[2,4] To address these challenges, computer-aided design and computer-aided manufacturing (CAD-CAM) systems using either subtractive or additive methods have been developed.[5–9]

Characterizing the surface of interim crowns can improve esthetic outcomes and patient satisfaction.[10] However, routine toothbrushing may damage these restorations.[11–15] Glazing has been reported to achieve a smoother surface than polishing.[16–21] However, the ineffectiveness of glazing in improving the roughness of composite resin and resin-ceramic CAD-CAM materials both before and after toothbrushing has been reported, as the glaze layer can degrade over time with continued toothbrushing.[22–25]

The authors are unaware of studies evaluating the effect of toothbrushing on the surface roughness and gloss of characterized interim materials. Therefore, the aim of this in vitro study was to evaluate the surface roughness and gloss of interim materials with different surface treatments after 1 year of simulated toothbrushing. The null hypotheses were that the interim material, surface treatment, and toothbrushing duration would have no significant effect on surface roughness and gloss.

MATERIAL AND METHODS

Thirty-three cuboid specimens ($10\times12\times2$ mm) were fabricated from each interim material: autopolymerized PMMA (UNIFAST Trad (UNF)), autopolymerized bis-acryl composite resin (Protemp 4 (PRT)), light-activated composite resin (REVOTEK LC (RVT)), milled PMMA block (DD provi P HI (DPP)), and 3-dimensionally (3D) printed methacrylate oligomer (Nextdent C&B MFH (NDT)). The details of each material are shown in Table 1.

The sample size was calculated by using a sample size and power calculator software program (G*power v. 3.1.9.4 software; Heinrich-Heine-Universität Düsseldorf). The effect size, determined from a previous study,[15] was 1.66. A minimum of 7 specimens per group was required at α=.05 and power=80%. The sample size was adjusted to 10 specimens per group.

Thirty specimens of each material were divided into 3 groups based on surface treatment: polishing (POL), application of Lite Art and Resin Glaze (SHO), and application of OPTIGLAZE color (OPT) (n=10) (Table 1). Another 3 specimens of each material were

Table 1. Materials used

Code	Product (Manufacturer)	Type	Shade	Composition	Batch No.
Interim material					
UNF	UNIFAST Trad (GC Corp)	Autopolymerized polymethyl methacrylate	Ivory	Liquid: methyl methacrylate, accelerant, UV-light absorber, dimethacrylate Powder: polymethyl methacrylate, dibenzoyl peroxide, iron (IIII) oxide	2209141, 2209291
PRT	Protemp 4 (3M ESPE)	Autopolymerized bis-acryl composite resin	A1	Ethoxylated bis-phenol A dimethacrylate, amorphous silica, surface modified with 2-propenoic acid, methyl-, 3- (trimethoxysilyl) propyl ester and phenyltrimethoxy silane	9428757
RVT	REVOTEK LC (GC Corp)	Light-activated composite resin	B2	Urethane dimethacrylate, trimethacrylate, silica crystalline - quartz	2208181
DPP	DD provi P HI (Dental Direkt GmbH)	Milled polymethyl methacrylate block	A1	Polymethylmethacrylate, coloring pigment	903901262201
NDT	Nextdent C&B MFH (Nextdent B.V.)	3D printed methacrylate oligomer	N1	Methacrylic oligomer, glycol methacrylate, phosphine oxide	WU124N02
Staining and glazing material					
SHO	Lite Art (SHOFU Dental GmbH)	-	A	Multifunctional monomer, methacrylate monomer, silica powder, pigment	062226
	Resin Glaze primer (SHOFU Dental GmbH)	-	-	Methyl methacrylate	012217
	Resin Glaze liquid (SHOFU Dental GmbH)	-	-	Methyl methacrylate	102247
OPT	OPTIGLAZE color (GC Corp)	-	A-plus, clear	Methyl methacrylate, silicon dioxide	2208291, 2208241

examined with a scanning electron microscope (SEM). In the POL group, serving as a control, the specimens were ground by using 1000-grit silicon carbide abrasive paper (TOA; TOA Paint Co) in a polishing machine (Minitech 233; Presi) under constant water at 200 rpm for 45 seconds. Subsequently, the specimens were ultrasonically cleaned with distilled water for 5 minutes and dried with absorbent paper. In the SHO and OPT groups, the specimens underwent the same grinding process as the control group and were further ground to 10×12×1.9 mm, verified with a micrometer (Micrometer series 406; Mitutoyo), allowing for the addition of a 100-µm layer of staining material.[26] The specimens were then ultrasonically cleaned and dried as specified earlier. In the SHO group, a Resin Glaze primer, followed by an A-shade Lite Art, was applied in a single direction and light activated with a light-emitting diode polymerization unit (Bluephase N; Ivoclar AG) with a wavelength of 385 to 515 nm and light intensity of 1200 mW/cm^2 for 1 minute. A Resin Glaze liquid was applied over the previously coated surface and light activated for an additional 3 minutes. In the OPT group, an A plus-shade OPTIGLAZE color was applied in a single direction and light activated for 40 seconds. A clear-shade OPTIGLAZE color was applied over the previously coated surface and light activated for 40 seconds. All specimens were stored in 37 °C deionized water for 7 days.

Each specimen in each group was affixed with cyanoacrylate resin (Super Power Glue; Kenji) to a custom 3D printed (Anycubic Photon Mono X 6 K; Anycubic Technology Co) 18.5×12×8.5-mm toothbrushing block (Fig. 1). The specimen blocks and soft-bristled toothbrushes (GUM Classic #311; Sunstar Americas) were mounted onto the brushing machine (V-8 Cross Brushing Machine; SABRI Dental Enterprises). Each plastic container was filled with a toothpaste slurry made with 25 g of toothpaste (Colgate Cavity Protection; Colgate Palmolive) and 50 mL of deionized water.[27] The brushing machine operated in a back-and-forth motion with a vertical load of 2.5 N. Toothbrushing was carried out for 5000 and 10 000 cycles, corresponding to approximately 6 and 12 months of clinical use.[28] After every 5000 cycles, the specimens were rinsed with tap water, ultrasonically cleaned for 1 minute, and dried with absorbent paper, and the surface roughness and gloss were measured. A new toothbrush and a new toothpaste slurry were used for every 10 000 cycles.

The surface roughness (Ra) of each specimen was assessed before (Ra_0), after 5000 cycles (Ra_1), and after 10 000 cycles (Ra_2) of toothbrushing by using a contact stylus profilometer (Talyscan 150; Taylor Hobson). The profilometer was calibrated by using traceable reference standards. Five measurements, each 1.25 mm apart, were made perpendicular to the direction of the toothbrushing movement within an area of 4×5 mm. The cutoff length was 0.8 mm, and the stylus speed was 1000 µm/second. The Ra values were expressed in µm and averaged.

The gloss of each specimen was measured before (G_0), after 5000 cycles (G_1), and after 10 000 cycles (G_2) of toothbrushing by using a glossmeter (IG-331; Horiba). Before testing, the glossmeter was calibrated by using a standard surface provided by the manufacturer. The specimens were then rotated 180 degrees and remeasured. The 60-degree reading mode was chosen. The gloss values were expressed in gloss units (GU) and averaged.

Two representative specimens of each group, one before toothbrushing and the other after 10 000 cycles of toothbrushing, were selected and gold sputter coated. An SEM (Quanta 250; FEI company) was used to observe the surface at an acceleration voltage of 20 kV and ×200 magnification. After SEM imaging, the specimens were not brushed further.

The data were analyzed by using a statistical software program (IBM SPSS Statistics, v28.0; IBM Corp) (α=.05). A Shapiro-Wilk test confirmed the normal distribution. The effects of interim materials, surface treatments, and toothbrushing durations on the Ra and gloss were analyzed by using a 3-way repeated measures ANOVA. The

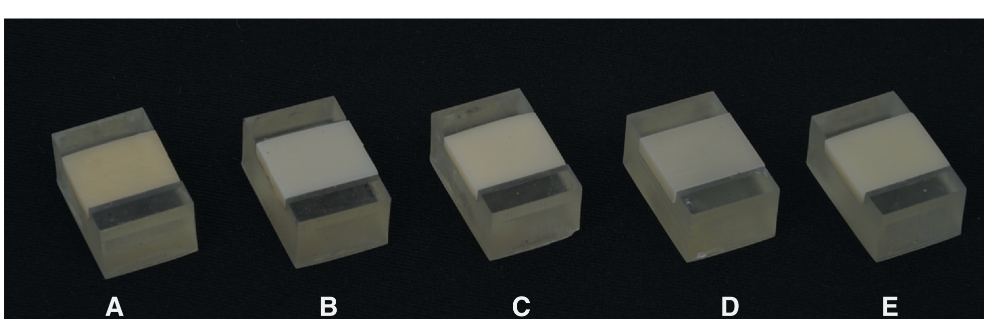

Figure 1. Polished specimens attached to custom toothbrushing block. A, UNIFAST Trad. B, Protemp 4. C, REVOTEK LC. D, DD provi P HI. E, Nextdent C&B MFH.

assumption of sphericity was tested with the Mauchly test, which indicated a lack of sphericity in the data. As the estimated epsilon for the Ra data was below .75, a Greenhouse-Geisser correction was used. Conversely, for the gloss data, where the estimated epsilon exceeded .75, a Huynh-Feldt correction was used. Additionally, a Bonferroni multiple comparison test was conducted to identify differences among groups (α=.05).

RESULTS

The means ± standard deviations of the Ra and gloss values of each group are shown in Tables 2 and 3. The 3-way repeated measures ANOVA result of the Ra value indicated a significant interaction among interim materials, surface treatments, and toothbrushing durations ($P<.001$) (Table 4). Comparing materials within the same surface treatment and toothbrushing duration when treated with POL, the NDT group demonstrated the significantly lowest Ra_0 value ($P<.001$), while the UNF and DPP groups exhibited the highest Ra_0 values. For Ra_1 and Ra_2 values, the UNF and DPP groups showed significantly higher values than the PRT, RVT, and NDT groups ($P<.001$), which exhibited comparability in Ra_1 and Ra_2 values with one another ($P>.999$). In contrast, when treated with SHO and OPT, each material exhibited comparable Ra values with one another ($P>.05$). Comparing surface treatments within the same material and toothbrushing duration, treating with SHO and OPT resulted in significantly lower Ra values compared with treating with POL ($P<.01$). Comparing toothbrushing durations within the same material and surface treatment, there were no significant differences among Ra_0, Ra_1, and Ra_2 values in each group ($P>.05$), except for the polished UNF and DPP groups, which showed a significant increase in Ra values ($Ra_0<Ra_1<Ra_2$) as toothbrushing duration increased ($P<.001$).

The 3-way repeated measures ANOVA result of the gloss value indicated a significant interaction among interim materials, surface treatments, and toothbrushing durations ($P<.001$) (Table 5). Comparing materials within the same surface treatment and toothbrushing duration, each material exhibited comparable G_0, G_1, and G_2 values when treated with POL and SHO ($P>.05$). However, when treated with OPT, each material exhibited comparability only in G_0 value ($P>.05$). Comparing surface treatments within the same material and toothbrushing duration, treating with SHO and OPT exhibited significantly higher G_0, G_1, and G_2 values compared with POL ($P<.001$). Treating with SHO exhibited significantly higher G_1, and G_2 values compared with OPT ($P<.05$). Comparing toothbrushing durations within the same material and surface treatment, each material treated with SHO and OPT showed decreased gloss value as toothbrushing duration increased. Conversely, when treated with POL, the UNF and DPP groups exhibited $G_1>G_2>G_0$ values, while the PRT, RVT, and NDT groups showed increased gloss value as toothbrushing duration increased.

Representative SEM images of each group tested before and after 10 000 cycles of toothbrushing are shown in Figures 2 to 6. Before toothbrushing, the POL

Table 2. Mean ±standard deviation of surface roughness value (Ra) of each interim material with each surface treatment at each toothbrushing duration

Interim Material	Surface Treatment	Baseline	5000-cycle Toothbrushing	10 000-cycle Toothbrushing
		Ra_0 (μm)	Ra_1 (μm)	Ra_2 (μm)
UNF	POL	0.447 ±0.026^{CDb1}	2.092 ±0.448^{Bb2}	4.139 ±0.825^{Bb3}
	SHO	0.050 ±0.012^{Aa1}	0.063 ±0.015^{Aa1}	0.065 ±0.015^{Aa1}
	OPT	0.035 ±0.005^{Aa1}	0.066 ±0.008^{Aa1}	0.107 ±0.019^{Aa1}
PRT	POL	0.425 ±0.027^{BCb1}	0.456 ±0.023^{Ab1}	0.482 ±0.023^{Ab1}
	SHO	0.051 ±0.013^{Aa1}	0.054 ±0.014^{Aa1}	0.063 ±0.014^{Aa1}
	OPT	0.039 ±0.009^{Aa1}	0.071 ±0.020^{Aa1}	0.106 ±0.011^{Aa1}
RVT	POL	0.418 ±0.040^{Bb1}	0.453 ±0.044^{Ab1}	0.491 ±0.058^{Ab1}
	SHO	0.050 ±0.009^{Aa1}	0.053 ±0.011^{Aa1}	0.057 ±0.009^{Aa1}
	OPT	0.048 ±0.011^{Aa1}	0.101 ±0.018^{Aa1}	0.139 ±0.023^{Aa1}
DPP	POL	0.466 ±0.018^{Db1}	2.178 ±0.215^{Bb2}	4.683 ±0.257^{Cb3}
	SHO	0.041 ±0.006^{Aa1}	0.048 ±0.009^{Aa1}	0.055 ±0.012^{Aa1}
	OPT	0.043 ±0.013^{Aa1}	0.055 ±0.007^{Aa1}	0.077 ±0.011^{Aa1}
NDT	POL	0.367 ±0.012^{Ab1}	0.379 ±0.024^{Ab1}	0.409 ±0.021^{Ab1}
	SHO	0.053 ±0.007^{Aa1}	0.052 ±0.006^{Aa1}	0.060 ±0.011^{Aa1}
	OPT	0.038 ±0.012^{Aa1}	0.071 ±0.016^{Aa1}	0.104 ±0.023^{Aa1}

DPP, DD provi P HI; NDT, Nextdent C&B MFH; OPT, application of OPTIGLAZE color; POL, polishing; PRT, Protemp 4; RVT, REVOTEK LC; SHO, application of Lite Art and Resin Glaze; UNF, UNIFAST Trad. Ra_0, Ra_1, and Ra_2 indicate surface roughness values before, after 5000 cycles, and after 10 000 cycles of toothbrushing. Different uppercase letters indicate significant differences among interim materials with same surface treatment and toothbrushing duration ($P<.05$). Different lowercase letters indicate significant differences among surface treatments with same interim material and toothbrushing duration ($P<.05$). Different numbers indicate significant differences between toothbrushing durations with same material and surface treatment. ($P<.05$; Bonferroni test).

Table 3. Mean ±standard deviation of gloss value of each interim material with each surface treatment at each toothbrushing duration

Interim Material	Surface Treatment	Baseline	5000-cycle Toothbrushing	10 000-cycle Toothbrushing
		G_0 (GU)	G_1 (GU)	G_2 (GU)
UNF	POL	0.0 ± 0.0^{Aa1}	4.8 ± 2.8^{Aa2}	2.4 ± 2.1^{Aa12}
	SHO	73.8 ± 8.6^{Ab3}	68.6 ± 9.5^{Ac2}	64.6 ± 10.8^{Ac1}
	OPT	82.3 ± 4.7^{Ab3}	57.4 ± 9.5^{Bb2}	44.4 ± 9.8^{ABb1}
PRT	POL	0.0 ± 0.0^{Aa1}	2.8 ± 1.9^{Aa1}	3.2 ± 2.0^{Aa1}
	SHO	74.2 ± 11.6^{Ab3}	69.7 ± 9.9^{Ac2}	64.0 ± 9.2^{Ac1}
	OPT	81.0 ± 9.1^{Ab3}	60.3 ± 10.5^{Bb2}	51.8 ± 9.4^{Bb1}
RVT	POL	0.0 ± 0.0^{Aa1}	4.7 ± 2.4^{Aa2}	9.2 ± 2.0^{Aa3}
	SHO	80.2 ± 5.9^{Ab3}	74.0 ± 5.4^{Ac2}	69.0 ± 6.9^{Ac1}
	OPT	74.8 ± 11.9^{Ab3}	44.8 ± 10.9^{Ab2}	40.0 ± 10.5^{Ab1}
DPP	POL	0.0 ± 0.0^{Aa1}	4.2 ± 3.9^{Aa2}	1.6 ± 1.7^{Aa12}
	SHO	79.1 ± 13.1^{Ab2}	74.6 ± 13.3^{Ac1}	72.1 ± 15.3^{Ac1}
	OPT	78.0 ± 7.1^{Ab3}	61.6 ± 7.1^{Bb2}	48.4 ± 8.7^{ABb1}
NDT	POL	0.0 ± 0.0^{Aa1}	3.4 ± 1.7^{Aa2}	7.1 ± 2.5^{Aa3}
	SHO	76.6 ± 9.3^{Ab3}	68.8 ± 9.4^{Ac2}	64.4 ± 10.0^{Ac1}
	OPT	74.6 ± 11.7^{Ab3}	54.1 ± 10.1^{ABb2}	40.0 ± 12.1^{Ab1}

DPP, DD provi P HI; NDT, Nextdent C&B MFH; OPT, application of OPTIGLAZE color; POL, polishing; PRT, Protemp 4; RVT, REVOTEK LC; SHO, application of Lite Art and Resin Glaze; UNF, UNIFAST Trad. G_0, G_1, and G_2 indicate gloss values before, after 5000 cycles, and after 10 000 cycles of toothbrushing. Different uppercase letters indicate significant differences among interim materials with same surface treatment and toothbrushing duration (P<.05). Different lowercase letters indicate significant differences among surface treatments with same interim material and toothbrushing duration (P<.05). Different numbers indicate significant differences between toothbrushing durations with same material and surface treatment. (P<.05; Bonferroni test).

Table 4. Results of 3-way repeated measures ANOVA analyzing surface roughness value (Ra) among interim materials with different surface treatments and toothbrushing durations

Source	df	SS	MS	F	P
Material	4	42.92	10.73	277.31	<.001
Treatment	2	127.38	63.69	1645.87	<.001
Material × treatment	8	88.28	11.04	285.16	<.001
Between subjects	135	5.22	0.04		
Time	1.25	24.06	19.28	841.94	<.001
Time × material	4.99	30.61	6.13	267.82	<.001
Time × treatment	2.50	41.85	16.77	732.24	<.001
Time × material × treatment	9.98	62.05	6.22	271.43	<.001
Within subject	168.45	3.86	0.02		

specimens exhibited parallel grooves from grinding with silicon carbide abrasive paper (Figs. 2A1-6A1), while the SHO and OPT specimens appeared smooth (Figs. 2B1-6B1, 2C1-6C1). After toothbrushing, polished UNF and DPP specimens showed noticeable abrasion with large and deep parallel grooves along the toothbrushing direction (Figs. 2A2, 5A2). Polished PRT, RVT, and NDT specimens showed shallow grooves along the toothbrushing direction (Figs. 3A2, 4A2, 6A2). However, the surfaces of SHO and OPT specimens showed no noticeable change (Figs. 2B2-6B2, 2C2-6C2).

DISCUSSION

The study revealed that staining and glazing significantly reduced Ra and increased gloss, irrespective of the interim materials. When staining and glazing were applied, Ra did not increase throughout the toothbrushing duration. Instead, the gloss value decreased over time, regardless of the interim materials. The surface roughness and gloss were affected by the interim materials, surface treatments, and toothbrushing durations. Therefore, the null hypothesis that the interim material, surface treatment, and toothbrushing duration

Table 5. Results of 3-way repeated measures ANOVA analyzing gloss value among interim materials with different surface treatments and toothbrushing durations

Source	df	SS	MS	F	P
Material	4	601.82	150.46	0.82	.516
Treatment	2	403821.57	201910.79	1096.88	<.001
Material × treatment	8	3262.26	407.78	2.22	.030
Between subjects	135	24850.37	184.08		
Time	2	12608.67	6304.34	663.85	<.001
Time × material	8	326.54	40.82	4.30	<.001
Time × treatment	4	19290.86	4822.72	507.84	<.001
Time × material × treatment	16	813.90	50.87	5.36	<.001
Within subject	270	2564.08	9.50		

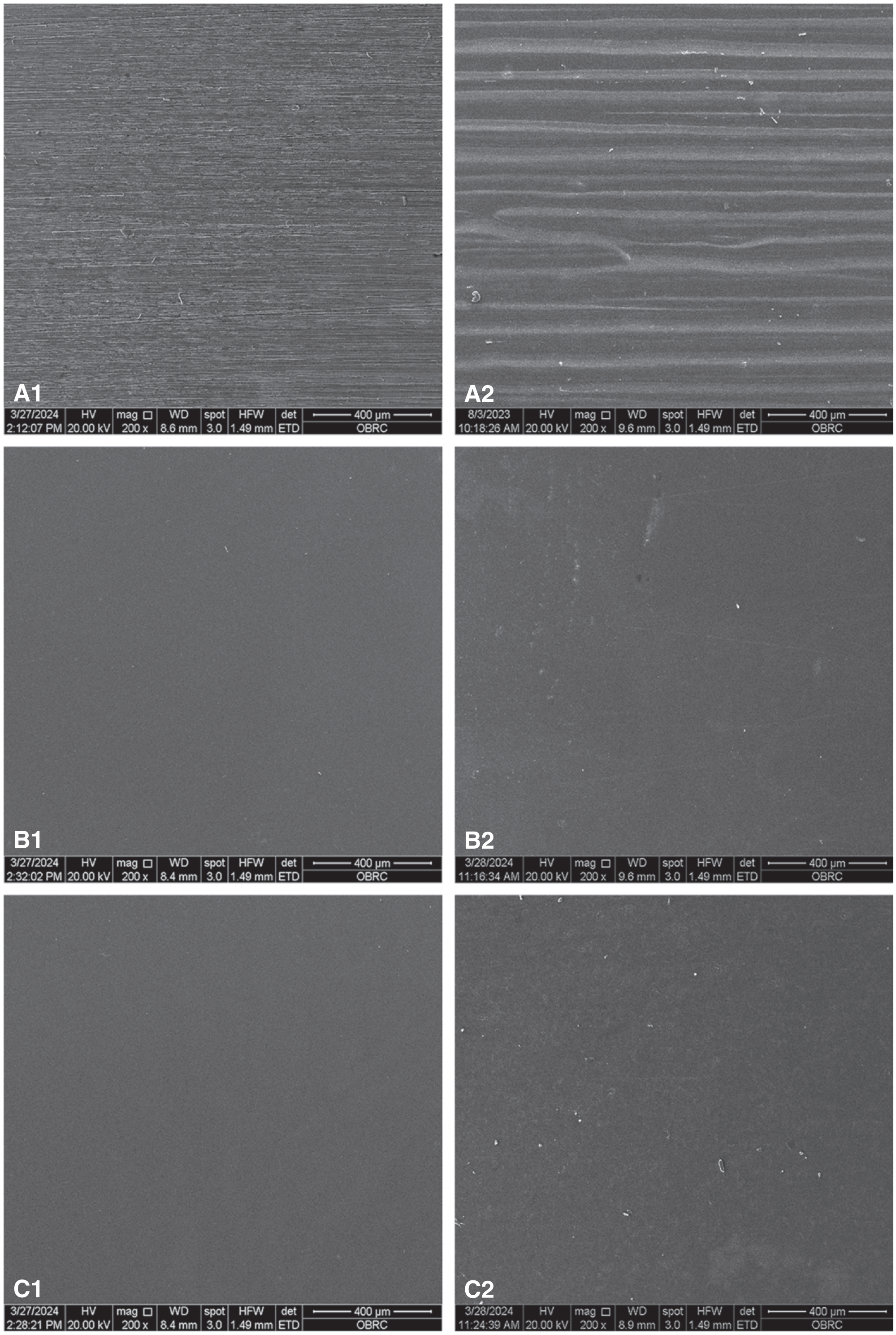

Figure 2. Scanning electron microscope images of UNIFAST Trad groups. (Original magnification ×200). A, POL. B, SHO. C, OPT. 1, Before toothbrushing. 2, After 10 000 cycles of toothbrushing. OPT, application of OPTIGLAZE color; POL, polishing; SHO, application of Lite Art and Resin Glaze.

would have no significant effect on surface roughness and gloss was rejected.

All materials treated with either SHO or OPT sustained a mean Ra below the critical 0.2 µm threshold,[29] even after 1 year of clinical toothbrushing. In contrast, those treated with POL showed a mean Ra above this threshold. Exceeding the 0.2-µm threshold has been reported to promote bacterial attachment, elevating the risk

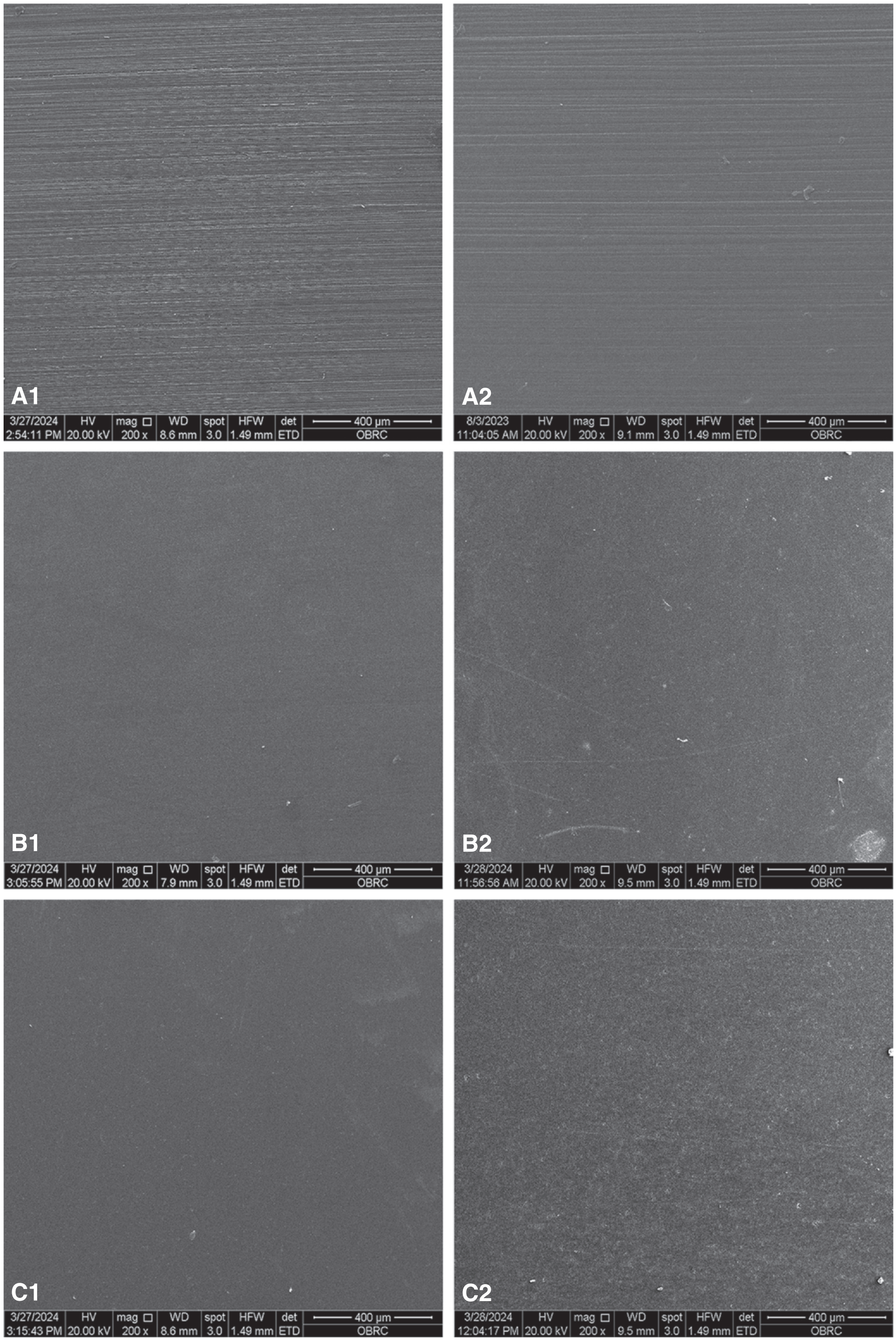

Figure 3. Scanning electron microscope images of Protemp 4 groups. (Original magnification ×200). A, POL. B, SHO. C, OPT. 1, Before toothbrushing. 2, After 10 000 cycles of toothbrushing. OPT, application of OPTIGLAZE color; POL, polishing; SHO, application of Lite Art and Resin Glaze.

of gingivitis, secondary caries, and discoloration.[29] After toothbrushing, the polished PRT, RVT, and NDT maintained a mean Ra below 0.5 μm, which is the maximum roughness threshold for a finished restoration surface to remain undetectable by the patient's tongue.[30] In contrast, the polished UNF and DPP experienced an increase in Ra ranging between 2.0 and 4.6 μm, exceeding the visual smoothness threshold of 1 μm.[31] Therefore, treating the surface of the interim material with either SHO or OPT is effective in achieving a smoother surface.

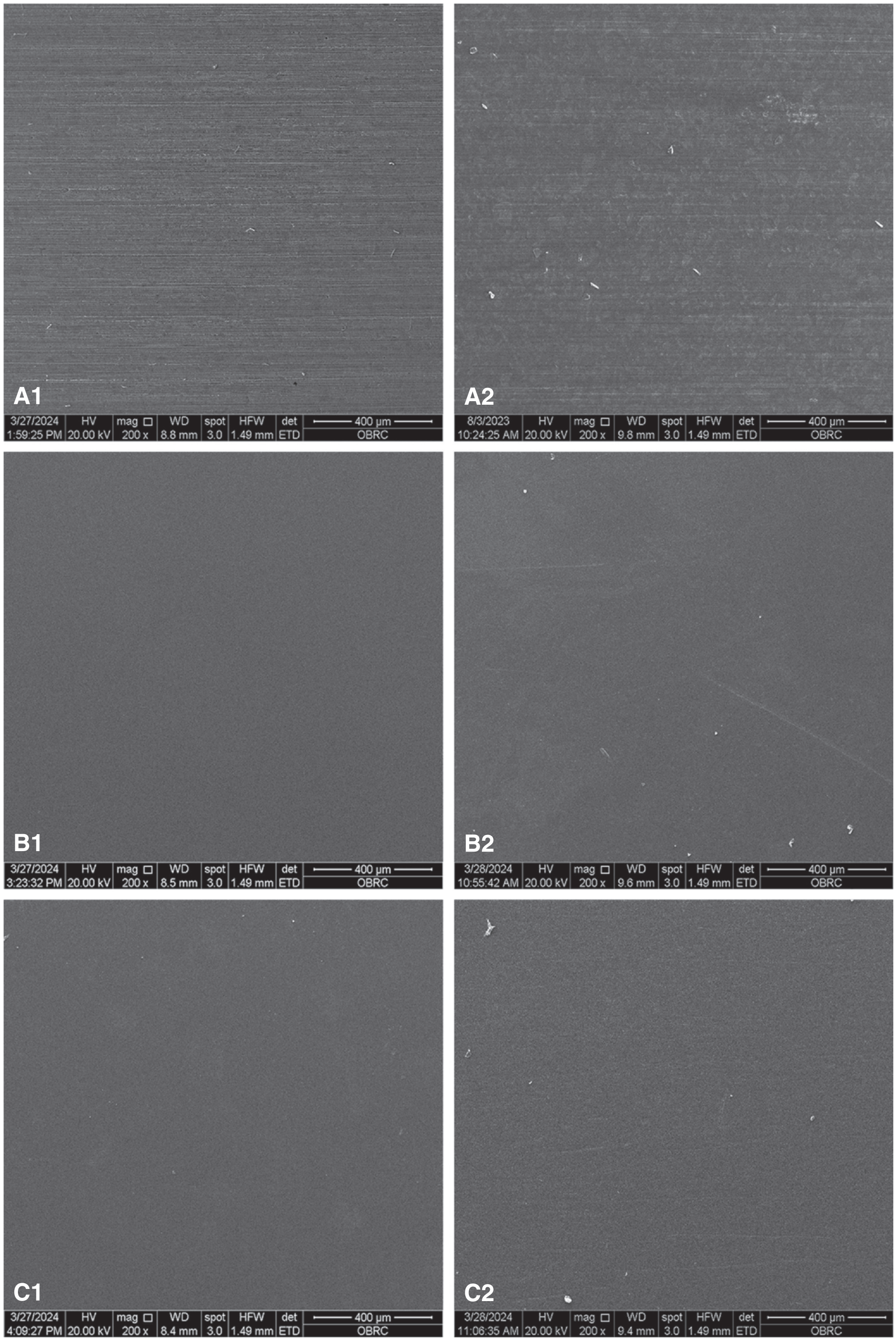

Figure 4. Scanning electron microscope images of REVOTEK LC groups conducted at ×200 magnification. A, POL. B, SHO. C, OPT. 1, Before toothbrushing. 2, After 10 000 cycles of toothbrushing. OPT, application of OPTIGLAZE color; POL, polishing; SHO, application of Lite Art and Resin Glaze.

For the gloss value, treating with either SHO or OPT enhanced the gloss value to above 70 GU. After toothbrushing, the gloss value decreased but remained above the recommended threshold, 40 to 50 GU.[32] In contrast, the gloss value of the polished materials remained below 10 GU both before and after toothbrushing, indicating an unacceptable gloss value.

The significant difference in mean Ra between the interim materials after toothbrushing implies variations in surface properties based on the material's

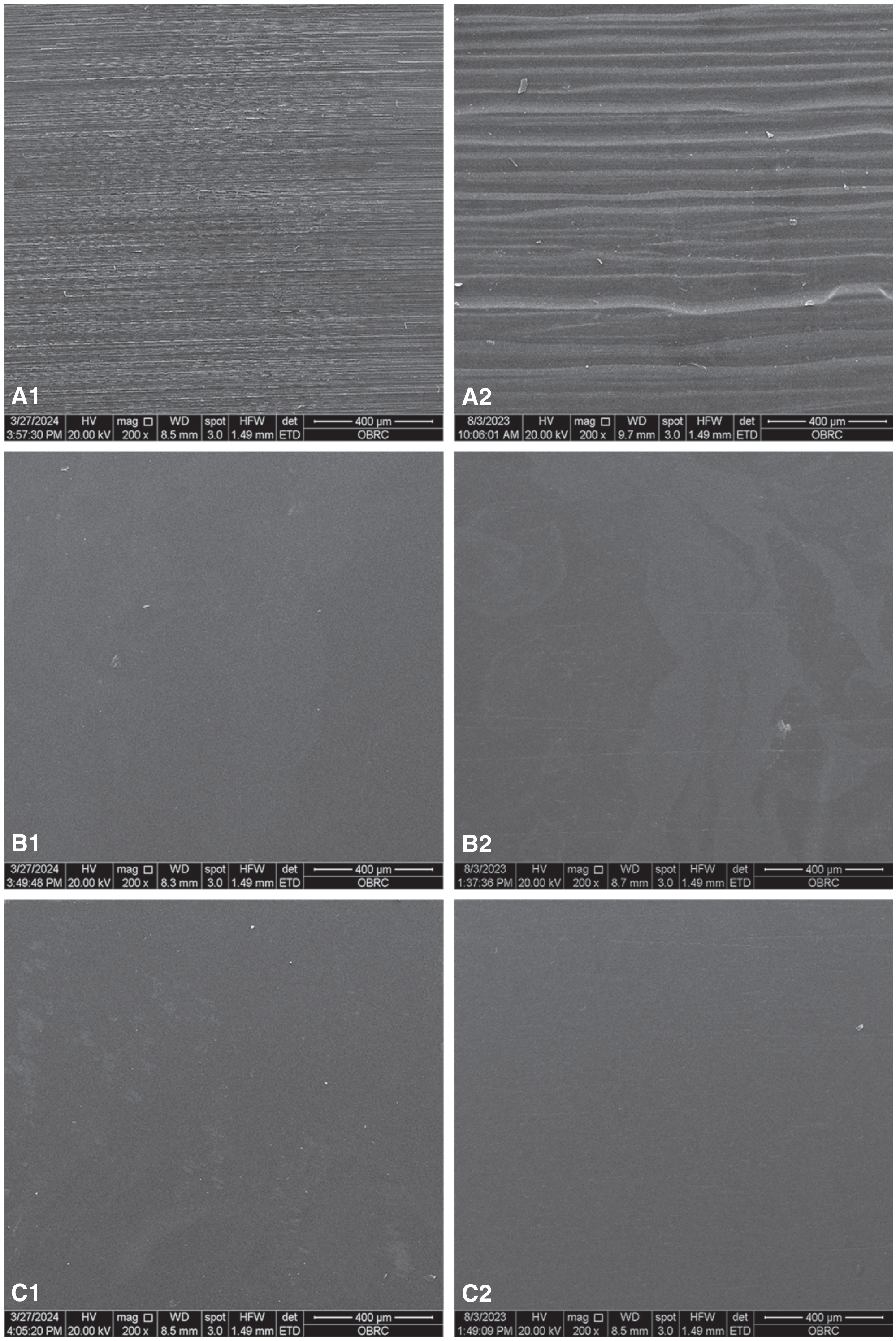

Figure 5. Scanning electron microscope images of DD provi P HI groups. (Original magnification ×200). A, POL. B, SHO. C, OPT. 1, Before toothbrushing. 2, After 10 000 cycles of toothbrushing. OPT, application of OPTIGLAZE color; POL, polishing; SHO, application of Lite Art and Resin Glaze.

composition. Both UNF and DPP are unfilled PMMA materials, resulting in inferior abrasive wear resistance (Figs. 2A2, 5A2). In contrast, PRT, an ethoxylated bisphenol A dimethacrylate-based composite resin, is a multifunctional monomer with a large aromatic ring and the ability to undergo cross-linking. This material also incorporates 20% to 30% amorphous silica (particle size 20 to 50 nm). Similarly, RVT, a urethane dimethacrylate-based composite resin containing 15% silica crystalline-quartz as a filler, and NDT, a 3D printed microfilled

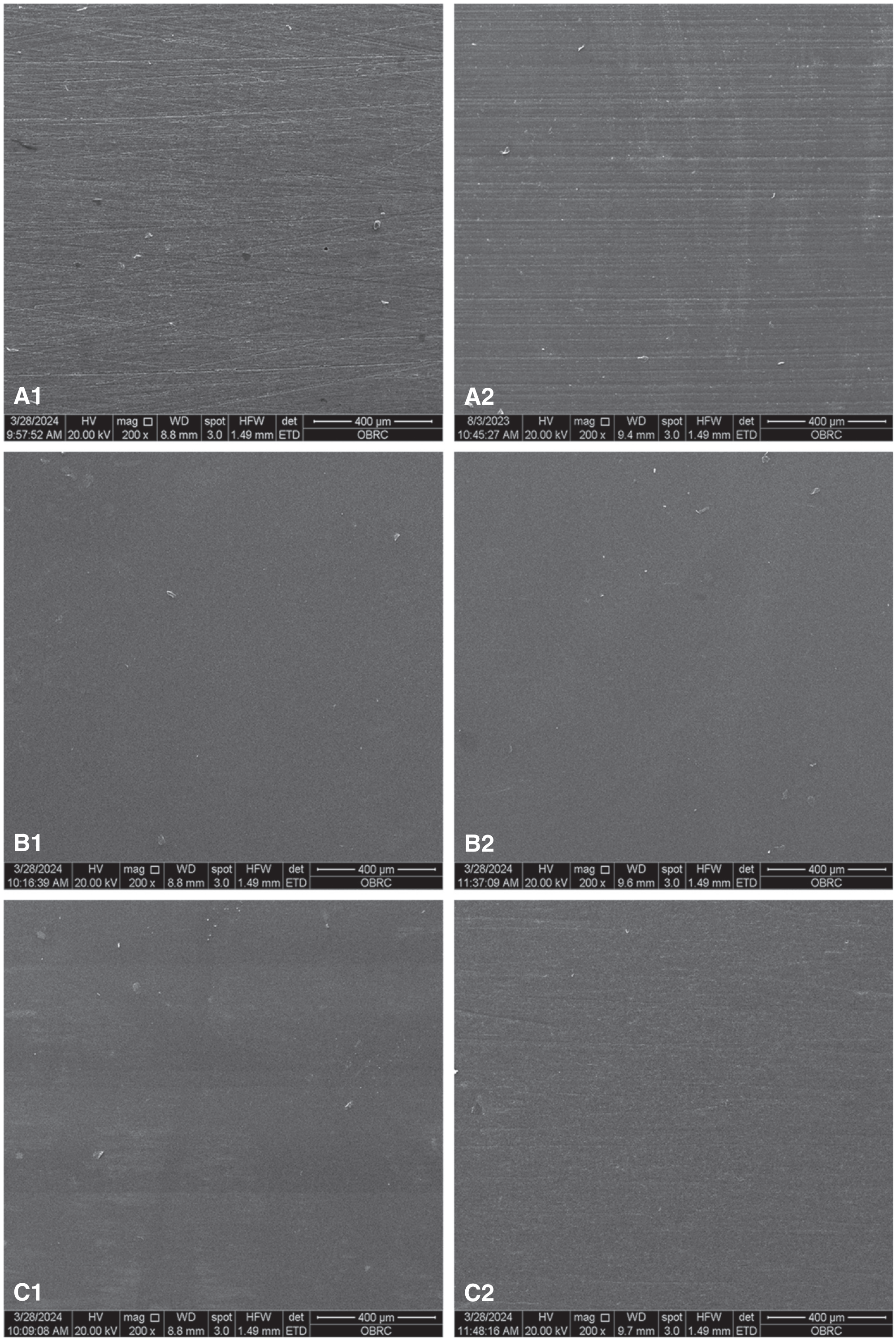

Figure 6. Scanning electron microscope images of Nextdent C&B MFH groups. (Original magnification ×200). A, POL. B, SHO. C, OPT. 1, Before toothbrushing. 2, After 10 000 cycles of toothbrushing. OPT, application of OPTIGLAZE color; POL, polishing; SHO, application of Lite Art and Resin Glaze.

hybrid composite resin composed of methacrylic oligomers and <2.5% phosphine oxide as a filler, demonstrated a significant enhancement in wear resistance with the Ra remaining unchanged. SEM images of these materials containing fillers also showed less abrasion from toothbrushing, with shallower parallel grooves formed by the bristles (Figs. 3A2, 4A2, 6A2).

Stained and glazed interim materials exhibited significantly smoother surfaces compared with polished interim materials throughout the toothbrushing duration (Figs. 2B1-6B1, 2B2-6B2, 2C1-6C1, 2C2-6C2). This improvement was attributed to the low viscosity of the methyl methacrylate monomer contained in the glazing material, allowing it to cover the surface and penetrate into the microfissures and microdefects developed after the polishing procedure. Additionally, the glazing material may contain inorganic fillers that further enhance surface properties, resulting in increased wear resistance. These findings are partially consistent with those of previous studies,[16,17] demonstrating that the use of a surface sealant significantly reduced Ra in CAD-CAM milled and conventional interim materials, except for the 3D printed ones. However, the Ra values in the previous studies still exceeded the threshold of 0.2 μm.[16,17] Conversely, staining and glazing has been reported to increase the Ra of composite materials.[22,23] These discrepancies among the studies may be attributed to differences in the material brands, the surface coating agents, and the tested parameter settings.

The long-term esthetic success of interim materials is also determined by the maintenance of a high and stable gloss value. In the current study, treating with SHO produced better gloss retention compared with treating with OPT. This could be attributed to the 3-step application process of SHO, which includes a primer to enhance bonding, followed by color staining and glazing. In contrast, OPT has a 2-step application process without a primer, involving color staining followed by glazing with a clear color that acts as the glazing material. Therefore, staining and glazing interim materials with SHO can be recommended for clinical use to achieve lower surface roughness and higher gloss levels.

The impact of toothbrushing on the surface properties of restorative materials depends on factors that include the relative dentin abrasion value of the toothpaste,[33] toothbrush stiffness,[33] toothbrushing force,[34] and toothbrushing cycle.[14] In the present study, the toothbrush type, brushing force, cycle rate, and toothpaste were standardized for each test group. Colgate Cavity Protection toothpaste with a relative dentin abrasion value of 80 and containing dicalcium phosphate as an abrasive system was used.[35] The abrasive particles in this toothpaste may be smaller than those in 1000-grit silicon carbide abrasive paper, contributing to the increased gloss of polished materials after toothbrushing. In the current study, toothbrushing resulted in an increase in the Ra of conventional PMMA and CAD-CAM PMMA. Conversely, a previous study reported that toothbrushing increased the Ra of bis-acryl composite resin and conventional PMMA, whereas that of CAD-CAM PMMA was not affected.[15] Certain glazing materials have been reported to be ineffective in maintaining the surface smoothness of restorative materials.[22,23] However, a study[23] reported that using OPTIGLAZE was effective in stabilizing the surface smoothness after toothbrushing, consistent with the finding of the current study that, despite an increase in toothbrushing duration, the surface roughness of stained and glazed interim material remained the same as baseline.

Limitations of the present study included that the toothbrushing simulation did not replicate all oral environments, such as temperature variations and saliva. The use of a harder brush, toothpaste with a higher degree of relative dentin abrasion value, and non-unidirectional movement could also have influenced the results. Additionally, the lack of detailed glazing composition limits the ability to analyze the specific impact of glaze composition on surface properties and wear resistance. Future studies should explore the use of other roughness depth parameters such as 10-point mean roughness and volume loss to accurately quantify abrasive wear rates.

CONCLUSIONS

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

1. After 5000 to 10 000 cycles of toothbrushing, Protemp 4, REVOTEK LC, and Nextdent C&B MFH, which are interim materials containing fillers, exhibited smoother surfaces compared with UNIFAST Trad and DD provi P HI, which are unfilled interim materials.
2. Staining and glazing with Lite Art and Resin Glaze, as well as with OPTIGLAZE color, resulted in a decrease in surface roughness and an increase in gloss across all materials. After 5000 to 10 000 cycles of toothbrushing, the surface roughness of each material remained stable, while the gloss slightly decreased but remained within clinically acceptable levels.

REFERENCES

1. Gratton DG, Aquilino SA. Interim restorations. *Dent Clin North Am.* 2004;48:487–497.
2. Burns DR, Beck DA, Nelson SK. A review of selected dental literature on contemporary provisional fixed prosthodontic treatment: Report of the committee on research in fixed prosthodontics of the academy of fixed prosthodontics. *J Prosthet Dent.* 2003;90:474–497.
3. Prasad DK, Shetty M, Alva H, Prasad DA. Provisional restorations in prosthodontic rehabilitations - Concepts, materials and techniques. *J health Allied Sci NU.* 2012;02:72–77.
4. Peñate L, Basilio J, Roig M, Mercadé M. Comparative study of interim materials for direct fixed dental prostheses and their fabrication with CAD/CAM technique. *J Prosthet Dent.* 2015;114:248–253.
5. Rayyan MM, Aboushelib M, Sayed NM, Lbrahim A, Jimbo R. Comparison of interim restorations fabricated by CAD/CAM with those fabricated manually. *J Prosthet Dent.* 2015;114:414–419.
6. Reeponmaha T, Angwaravong O, Angwarawong T. Comparison of fracture strength after thermo-mechanical aging between provisional crowns made with CAD/CAM and conventional method. *J Adv Prosthodont.* 2020;12:218–224.
7. Batisse C, Nicolas E. Comparison of CAD/CAM and conventional denture base resins: A systematic review. *Appl Sci.* 2021;11:5990.

8. Taşın S, Ismatullaev A. Comparative evaluation of the effect of thermocycling on the mechanical properties of conventionally polymerized, CAD-CAM milled, and 3D-printed interim materials. *J Prosthet Dent*. 2022;127:173.e1–173.e8.
9. Pantea M, Ciocoiu RC, Greabu M, et al. Compressive and flexural strength of 3D-printed and conventional resins designated for interim fixed dental prostheses: An in vitro comparison. *Materials (Basel)*. 2022;15:3075.
10. Barwacz CA, Hernández M. Direct extrinsic characterization maximizing esthetics of fixed interim restorations. *J Cosmet Dent*. 2013;29:122–131.
11. O'Neill C, Kreplak L, Rueggeberg FA, Labrie D, Shimokawa CAK, Price RB. Effect of tooth brushing on gloss retention and surface roughness of five bulk-fill resin composites. *J Esthet Restor Dent*. 2018;30:59–69.
12. AlAli M, Silikas N, Satterthwaite J. The effects of toothbrush wear on the surface roughness and gloss of resin composites with various types of matrices. *Dent J ((Basel))*. 2021;9:8.
13. Kamonkhantikul K, Arksornnukit M, Lauvahutanon S, Takahashi H. Toothbrushing alters the surface roughness and gloss of composite resin CAD/CAM blocks. *Dent Mater J*. 2016;35:225–232.
14. Sehovic E, Ioannidis A, Hämmerle CH, Özcan M, Mühlemann S. Effect of tooth brush abrasion on the color, gloss and surface roughness of internally and externally stained monolithic ceramic materials. *J Prosthodont Res*. 2022;66:303–311.
15. Köroğlu A, Şahin O, Küçükekenci AS, Dede DÖ, Yıldırım H, Yilmaz B. Influences of toothbrushing and different toothpastes on the surface roughness and color stability of interim prosthodontic materials. *Materials ((Basel))*. 2022;15:5831.
16. Taşın S, Ismatullaev A, Usumez A. Comparison of surface roughness and color stainability of 3-dimensionally printed interim prosthodontic material with conventionally fabricated and CAD-CAM milled materials. *J Prosthet Dent*. 2022;128:1094–1101.
17. Köroğlu A, Sahin O, Dede D, Yilmaz B. Effect of different surface treatment methods on the surface roughness and color stability of interim prosthodontic materials. *J Prosthet Dent*. 2016;115:447–455.
18. Halis G, Köroğlu A, Şahin O, Dede DÖ, Yilmaz B. Effect of simulated tootbrushing on surface roughness of sealant agent coupled nanohybrid composite resins. *J Esthet Restor Dent*. 2022;34:907–914.
19. Tekçe N, Fidan S, Tuncer S, Kara D, Demirci M. The effect of glazing and aging on the surface properties of CAD/CAM resin blocks. *J Adv Prosthodont*. 2018;10:50–57.
20. Nahsan F, da Silva L, Baseggio W, Francisconi PAS, Franco EB, Mondelli RF. Effect of sealants in the composite surface roughness after tooth brushing. *Biosci J*. 2014;30:1959–1966.
21. Alhassan M, Maawadh A, Labban N, Alnafaiy SM, Alotaibi HN, Binmahfooz AM. Effect of different surface treatments on the surface roughness and gloss of resin-modified CAD/CAM Ceramics. *Appl Sci*. 2022;12:11972.
22. Lopes MB, Saquy PC, Moura SK, et al. Effect of different surface penetrating sealants on the roughness of a nanofiller composite resin. *Braz Dent J*. 2012;23:692–697.
23. Mühlemann S, Bernini JM, Sener B, Hämmerle CH, Özcan M. Effect of aging on stained monolithic resin-ceramic CAD/CAM materials: Quantitative and qualitative analysis of surface roughness. *J Prosthodont*. 2019;28:e563–e571.
24. Tribst JPM, Maria de Oliveira Dal Piva A, Werner A, et al. Effect of surface treatment and glaze application on shade characterized resin-modified ceramic after toothbrushing. *J Prosthet Dent*. 2021;125:691.e1–691.e7.
25. Dal Piva AMdO, Bottino MA, Anami LC, et al. Toothbrushing wear resistance of stained CAD/CAM ceramics. *Coatings*. 2021;11:224.
26. Garza LA, Thompson G, Cho SH, Berzins DW. Effect of toothbrushing on shade and surface roughness of extrinsically stained pressable ceramics. *J Prosthet Dent*. 2016;115:489–494.
27. International Organization for Standardization. ISO14569-1. Dental materials - Guidance on testing of wear - Part 1: Wear by toothbrushing. Geneva: International Organization for Standardization,; 2007.
28. Sexson JC, Phillips RW. Studies on the effects of abrasives on acrylic resins. *J Prosthet Dent*. 1951;1:454–471.
29. Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: A review of the literature. *Dent Mater*. 1997;13:258–269.
30. Jones CS, Billington RW, Pearson GJ. The in vivo perception of roughness of restorations. *Br Dent J*. 2004;196:42–45.
31. Chung KH. Effect of finishing and polishing procedure on the surface texture of resin composites. *Dent Mater*. 1994;10:325–330.
32. da Costa JB, Ferracane JL, Amaya-Pajares S, Pfefferkorn F. Visually acceptable gloss threshold for resin composite and polishing systems. *J Am Dent Assoc*. 2021;152:385–392.
33. Turssi CP, Binsaleh F, Lippert F, et al. Interplay between toothbrush stiffness and dentifrice abrasivity on the development of non-carious cervical lesions. *Clin Oral Investig*. 2019;23:3551–3556.
34. Hamza B, Tanner M, Körner P, Attin T, Wegehaupt FJ. Effect of toothbrush bristle stiffness and toothbrushing force on the abrasive dentine wear. *Int J Dent Hyg*. 2021;19:355–359.
35. Schemehorn BR, Moore MH, Putt MS. Abrasion, polishing, and stain removal characteristics of various commercial dentifrices in vitro. *J Clin Dent*. 2011;22:11–18.

Corresponding author:
Dr Krid Kamonkhantikul
Department of Prosthodontics, Faculty of Dentistry
Chulalongkorn University
34 Henri-Dunant Road, Pathumwan, Bangkok 10330
THAILAND
Email: Krid.K@chula.ac.th

https://doi.org/10.1016/j.prosdent.2024.10.003