Polishing and toothbrushing alters the surface roughness and gloss of composite resins

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This study aimed to investigate the surface roughness and gloss of composite resins after using two polishing systems and toothbrushing. Six composite resins (Durafill V8, Filtek Z250, Filtek Z350 XT, Kalore, Venus Diamond, and Venus Pearl) were evaluated after polishing with two polishing systems (Sof-Lex, Venus Supra) and after toothbrushing up to 40,000 cycles. Surface roughness (Ra) and gloss were determined for each composite resin group (n=6) after silicon carbide paper grinding, polishing, and toothbrushing. Two-way ANOVA indicated significant differences in both Ra and gloss between measuring stages for the composite resins tested, except Venus Pearl, which showed significant differences only in gloss. After polishing, the Filtek Z350 XT, Kalore, and Venus Diamond showed significant increases in Ra, while all composite resin groups except the Filtek Z350 XT and Durafill V8 with Sof-Lex showed increases in gloss. After toothbrushing, all composite resin demonstrated increases in Ra and decreases in gloss.

Keywords: Composite resin, Gloss, Polishing, Surface roughness, Toothbrushing

INTRODUCTION

In dentistry, many commercial composite resins have been introduced into the market. Nano-technologies have been incorporated into dental materials. Nanocomposites are innovative filling materials in restorative dentistry11, and are divided into nanofilled and nanohybrid composites. Nanofilled composite resins contain discrete nanoparticles and clusters of nanofillers, whereas nanohybrid composite resins contain nanoparticles together with conventional fillers. Polishing composite resin restorations is advocated to obtain a smooth and glossy restoration appearance2-4. Rough restoration surfaces can easily accumulate dental plaque and staining substances. Several polishing systems for composite resin restorations are commercially available5-6. Many manufacturers have introduced their own proprietary polishing systems, claiming that these generate a smooth surface with high gloss on composite resins. Polishing systems are described as one-step systems that save time or up to four-step systems that result in high gloss7-8. Polishing systems differ in their types of particle sizes and shapes, and polishing media9,10. It has been demonstrated that increased time spent on finishing and polishing a composite resin creates a restoration with a higher and more durable glosses11,12. The Sof-Lex polishing system, which uses aluminum oxide particles of various grits on polyester discs, is an effective polishing system because of its ability to abrade the composite filler particles and refine the resin surface9. A new polishing system, Venus Supra, which employs diamond particles dispersed in silicone rubber, was developed to polish nanohybrid composite resin13.

The effectiveness of a polishing system is commonly evaluated based on surface roughness, gloss, and scanning electron microscope (SEM) images7. The arithmetic average of the surface roughness (Ra), determined using a profilometer, is commonly used to quantitatively describe surface roughness, but it does not describe the appearance of the composite resin surface14-16. Surface roughness exceeding a threshold Ra value of 0.2 µm is claimed to affect plaque accumulation and staining in vitro7. Restorations visually appear to be smooth when the surface has a roughness of less than 1 µm Ra18. Determination of Ra values in vivo is not possible because the profilometer cannot be used intraorally. However gloss is a feature that can be easily recognized and perceived by both dentists and patients. Gloss characterizes the evenness of the restoration surface15. According to the American Dental Association (ADA) professional product review, 40–60 gloss units are identified as a typically desired gloss15. SEM observation is frequently used to visualize the morphology of the polished surface3,4,10,12. Regression analysis has been used to determine the relationship between Ra and gloss3,15. However, the results varied and were inconclusive.

Restoration surfaces may deteriorate intraorally due to several factors18. Toothbrushing is considered a crucial factor affecting the surface roughness and gloss of composite resins1,17-20. Many investigations have shown the effects of toothbrushing on the surface roughness and gloss of composite resins, in terms of brushing time12,20,22-25, brushing force16,24, and abrasivity of the particles contained in toothpaste23. If the polished...
surface of a composite resin is easily deteriorated by toothbrushing, the restoration will lose its initial high gloss from polishing in a very short time. Therefore, attempting to achieve a very high restoration gloss after contouring and finishing may not be important. The relationships between polishing systems and the characteristics of surface roughness and gloss of composite resins after toothbrushing have not been clearly identified.

Therefore, the objective of the present study was to investigate the surface roughness and gloss of composite resins after polishing using two polishing systems and after toothbrushing. The null hypothesis was that there would be no significant differences in surface roughness and gloss of each composite resin after polishing using the two polishing systems and toothbrushing.

**MATERIALS AND METHODS**

*Specimen preparation*

The six composite resins were selected for the present study according to the types of filler particles and size. Their compositions and manufacturers are listed in Table 1.

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Code</th>
<th>Manufacturer</th>
<th>Batch #</th>
<th>Monomer</th>
<th>Filler</th>
<th>Volume%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durafill® VS</td>
<td>Microfilled</td>
<td>DUR</td>
<td>Heraeus Kulzer, Hanau, Germany</td>
<td>010210</td>
<td>Bis-GMA, UDMA, TEGDMA</td>
<td>SiO₂ (20–70 nm), Prepolymer &lt;20 µm, SiO₂ in prepolymer: 32 wt%</td>
<td>66</td>
</tr>
<tr>
<td>Filtek™ Z250</td>
<td>Microhybrid</td>
<td>Z250</td>
<td>3M ESPE, St. Paul, MN, USA</td>
<td>N402566</td>
<td>Bis-GMA, Bi-EMA, UDMA</td>
<td>SiO₂/ZrO₂ clusters (0.01–3.5 µm), average 0.6 µm</td>
<td>60</td>
</tr>
<tr>
<td>Filtek™ Z350 XT</td>
<td>Nanofilled</td>
<td>Z350</td>
<td>3M ESPE</td>
<td>N383364</td>
<td>Bis-GMA, UDMA, TEGDMA, PEGDMA</td>
<td>Non-aggregated SiO₂ (20 nm), Non-aggregated ZrO₂ (4–11 nm), SiO₂/ZrO₂ clusters (0.6–10 µm)</td>
<td>63.3</td>
</tr>
<tr>
<td>Kalore</td>
<td>Nanohybrid</td>
<td>KAL</td>
<td>GC Corp., Tokyo, Japan</td>
<td>1208071</td>
<td>UDMA (DuPont), DMA, UDMA</td>
<td>Prepolymer 17 µm (SrO₃, 400 nm, lanthanoid fluoride 100 nm), F-A-silicate (700 nm), Sr-Ba-glass (700 nm), SiO₂ (16 nm)</td>
<td>69</td>
</tr>
<tr>
<td>Venus® Diamond</td>
<td>Nanohybrid</td>
<td>VED</td>
<td>Heraeus Kulzer</td>
<td>10048</td>
<td>TCD-DI-HEA, PE-crosslinker</td>
<td>Ba- Al-F- glass &lt;20 µm SiO₂ (5 nm)</td>
<td>64</td>
</tr>
<tr>
<td>Venus® Pearl</td>
<td>Nanohybrid</td>
<td>VEP</td>
<td>Heraeus Kulzer</td>
<td>10023</td>
<td>TCD-DI-HEA, UDMA</td>
<td>Ba- Al-F-glass, pre-polymerized filler (&lt;5 µm), SiO₂ (5 nm)</td>
<td>59</td>
</tr>
</tbody>
</table>

Bis-GMA: bisphenol A diglycidylether methacrylate; UDMA: urethane dimethacrylate; TEGDMA: triethyleneglycol dimethacrylate; Bi-EMA: ethoxylated bisphenol-A dimethacrylate; DMA: dimethacrylate; PEGDMA: poly(ethylene glycol)-dimethacrylate; TCD-DI-HEA: (Bis-(acryloxyloxy)methyl) tricyclo[5.2.1.0₂,₆]decane

Seventy-two acrylic resin blocks (12×20×10 mm) were prepared using an autocuring resin (Meliodent rapid repair, Heraus Kulzer, Hanau, Germany) in Teflon molds and randomly divided into six groups (n=12). In each group, a cylindrical cavity, 8-mm-diameter and 3-mm-depth, was drilled in the center of each of the acrylic blocks’ surface. The cavity was filled with its respective test composite resin and covered with a Mylar strip, which was pressed flush under a glass slide. The composite resin was then light activated with a light curing unit (GC Prima II, GC Corporation, Tokyo, Japan), (light intensity 600 mW/cm²) in contact with the Mylar strip for 40 s. The 12 composite resin specimens of each material, embedded in the acrylic blocks, were wet-ground for 1 min each using P2,400, and P4,000 grit silicon carbide (SiC) paper at 150 rpm on a polishing machine (Nano 2000, Pace Technologies, Tucson, AZ, USA). The specimens were then thoroughly rinsed with tap water, ultrasonically cleaned for 5 min to remove any debris, and dried with compressed air for 20 s. The surface roughness and gloss of the specimens were measured using a profilometer and a gloss meter, respectively. After measuring the SiC ground surfaces, the specimens were randomly divided into two equal
groups (n=6) for polishing with either aluminum oxide abrasive discs (Sof-Lex Extra Thin Contouring and Polishing discs, Superfine, 3M ESPE, St. Paul, MN, USA) or diamond impregnated silicone polishers (Venus Supra, High-gloss polishers, Heraeus Kulzer, Hanau, Germany). The manufacturers and compositions of the polishing systems are listed in Table 2. Polishing with Sof-Lex discs was performed dry using a handpiece at 8,000 rpm under light pressure and rotational action over the entire composite surface for 20 s. The Venus Supra polishers were used with copious water spray under the same conditions as the Sof-Lex discs. Finally, the polished specimens were rinsed, ultrasonically cleaned, and dried prior to measuring surface roughness and gloss.

Toothbrush testing
After the polished specimens were stored for 7 days in deionized water at 37°C, the specimen blocks were mounted in a toothbrushing machine (V-8 Cross Brushing Machine, SABRI Dental Enterprises, Inc., Villa Park, IL, USA) operating at forth and back brushing strokes of 55 mm and at a frequency of 2 Hz. The specimens were brushed with a vertical force of 2.5 N on the toothbrushes (GUM Classic #411, Sunstar Americas, Inc., Chicago, IL, USA). The specimens and toothbrushes were immersed in containers of toothpaste slurry, prepared using a homogenizer from 50 mL of deionized water and 25 g of toothpaste (Colgate cavity protection, Colgate-Palmolive, Chonburi, Thailand). Following 10,000 (10k) brushing cycles in the toothpaste slurry, the specimens were prepared for surface roughness and gloss determination as previously described. The same specimens were subjected to an additional 10,000 (20k total) and 20,000 (40k total) toothbrushing cycles, with their surface roughness and gloss determined after each additional cycling.

Surface roughness measurement
The Ra value of each specimen was determined using a profilometer (Talyscan 150, Taylor Hobson Ltd, Leicester, England) equipped with an inductive gauge stylus with a 2 µm tip radius. The tracing length was 2 mm, the tracing speed was 500 µm/s, and the cut-off length was 0.25. Five parallel measurements, each 400 µm apart, were performed in two perpendicular directions. The Ra value was calculated as the mean of the 10 measurements of each specimen.

Gloss measurement
Gloss was determined by a gloss meter (IG-331, Horiba, Ltd., Kyoto, Japan) calibrated on a black glass standard provided by the manufacturer. The 60 degree measurement mode was selected. Each specimen was centrally placed over the reading aperture. The light beam was transmitted to the surface of composite resin and reflected to the sensor. The measured area was oval shaped (3x6 mm²). The specimen was measured, rotated 180 degrees, measured again, and the results were averaged.

Scanning electron microscope (SEM) observation
Two representative specimens of each material after SiC grinding, polishing with the two different systems, and after the 10k, 20k, and 40k toothbrushing cycles were selected and sputter-coated with platinum. A SEM (VE-8800, Keyence Inc., Osaka, Japan) was used to observe and take photographs of the samples at an acceleration voltage of 10 kV and a magnification of 1000×.

Statistical analysis
The Ra values and the gloss units of each composite resin were separately analyzed using two-way ANOVA with the measuring stages (SiC grinding, polishing, 10k, 20k and 40k toothbrushing cycles) and polishing systems (Sof-Lex and Venus Supra) as main factors, followed by Tukey’s post-hoc comparisons (p<0.05). Additionally, the relationship between log [Ra value] and log [gloss units] was analyzed using linear regression.

RESULTS
The results of two-way ANOVA of the Ra value and gloss units of each composite resin are shown in Table 3. For Ra, the main factor of the measuring stages of all groups except for the VEP group was significant (p<0.01), but that of polishing system and their interaction were not. Therefore, the data of both polishing systems were pooled. The Ra values of each composite resin at each measuring stage were analyzed using the Tukey’s post-hoc test comparison test and are shown in Table 4. After polishing, the Ra values of the Z350, KAL, and VED groups significantly increased (p<0.05), while those of the remaining composite resins did not significantly increase. The Ra values of the DUR, KAL, and VED groups showed an increase after each toothbrushing cycle, while those of the Z250, Z350 and VEP groups showed little to no change.

Table 2 Polishing systems tested in the present study

<table>
<thead>
<tr>
<th>Polishing System</th>
<th>Polishing tool</th>
<th>Abrasive grain size</th>
<th>Manufacturer</th>
<th>Batch#</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sof-Lex™</td>
<td>Superfine</td>
<td>3 µm</td>
<td>3M ESPE</td>
<td>N160585</td>
<td>Aluminum oxide (40–70%) on polyester film</td>
</tr>
<tr>
<td>Venus Supra</td>
<td>High gloss polisher</td>
<td>4–8 µm</td>
<td>Heraeus Kulzer</td>
<td>231757</td>
<td>Diamond particles (65%) in Silicone polymer</td>
</tr>
</tbody>
</table>
Table 3  Two-way ANOVA of Ra value and gloss unit of each composite resin for the two main factors and interaction

<table>
<thead>
<tr>
<th>Composite resin</th>
<th>Ra value (P value)</th>
<th>Gloss unit (P value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measuring stage</td>
<td>Polishing Interaction</td>
</tr>
<tr>
<td>DUR</td>
<td>&lt;0.01*</td>
<td>0.32 0.44</td>
</tr>
<tr>
<td>Z250</td>
<td>&lt;0.01*</td>
<td>0.32 0.84</td>
</tr>
<tr>
<td>Z350</td>
<td>&lt;0.01*</td>
<td>0.70 0.54</td>
</tr>
<tr>
<td>KAL</td>
<td>&lt;0.01*</td>
<td>0.42 0.81</td>
</tr>
<tr>
<td>VED</td>
<td>&lt;0.01*</td>
<td>0.17 0.74</td>
</tr>
<tr>
<td>VEP</td>
<td>0.21</td>
<td>0.82 0.31</td>
</tr>
</tbody>
</table>

* indicates statistically significant differences (p<0.05).

Table 4  Mean and Standard deviation of Ra values in µm of each composite resin at each measuring stage

<table>
<thead>
<tr>
<th>Composite resin</th>
<th>SiC grinding</th>
<th>Polishing</th>
<th>10k</th>
<th>20k</th>
<th>40k</th>
</tr>
</thead>
<tbody>
<tr>
<td>DUR</td>
<td>0.045(0.003)a</td>
<td>0.043(0.005)a</td>
<td>0.040(0.006)a</td>
<td>0.050(0.016)a</td>
<td>0.075(0.012)b</td>
</tr>
<tr>
<td>Z250</td>
<td>0.043(0.004)a</td>
<td>0.049(0.006)b</td>
<td>0.054(0.005)b</td>
<td>0.056(0.003)b</td>
<td>0.057(0.015)b</td>
</tr>
<tr>
<td>Z350</td>
<td>0.037(0.004)a</td>
<td>0.043(0.004)b</td>
<td>0.048(0.006)b</td>
<td>0.041(0.008)b</td>
<td>0.048(0.006)b</td>
</tr>
<tr>
<td>KAL</td>
<td>0.040(0.002)a</td>
<td>0.046(0.005)b</td>
<td>0.073(0.011)c</td>
<td>0.090(0.014)d</td>
<td>0.102(0.012)d</td>
</tr>
<tr>
<td>VED</td>
<td>0.044(0.004)a</td>
<td>0.055(0.007)b</td>
<td>0.075(0.021)b</td>
<td>0.101(0.029)b</td>
<td>0.138(0.038)b</td>
</tr>
<tr>
<td>VEP</td>
<td>0.046(0.006)a</td>
<td>0.050(0.007)b</td>
<td>0.052(0.007)a</td>
<td>0.051(0.011)a</td>
<td>0.055(0.010)b</td>
</tr>
</tbody>
</table>

The data of both polishing groups, Sof-Lex and Venus Supra, were pooled due to the existence of significant differences only in measuring stage. Values with the same superscript letters in each row were not statistically significant differences at \( p \geq 0.05 \). mean (S.D.), \( n=6 \)

Table 5  Mean and Standard deviation of gloss units of each composite resin at each measuring stage

<table>
<thead>
<tr>
<th>Composite resin</th>
<th>Measuring stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SiC grinding Polishing</td>
</tr>
<tr>
<td>DUR</td>
<td>64(5)b,c 72(5)d</td>
</tr>
<tr>
<td>Z250</td>
<td>48(4)b,c 77(8)c</td>
</tr>
<tr>
<td>Z350</td>
<td>81(10)a,b</td>
</tr>
<tr>
<td>KAL</td>
<td>58(9)d</td>
</tr>
<tr>
<td>VED</td>
<td>46(7)d</td>
</tr>
<tr>
<td>VEP</td>
<td>44(11)b,c</td>
</tr>
</tbody>
</table>

* represent the data of both polishing groups, Sof-Lex and Venus Supra, were pooled due to the existence of significant differences only in measuring stage. Values with the same superscript letters in each row were not statistically significant differences at \( p \geq 0.05 \). mean (S.D.), \( n=6 \)
The results of two-way ANOVA of gloss units indicated that the main factor of the measuring stages of all composite resins was significant ($p<0.01$), while polishing systems showed a significant difference ($p<0.01$) only for Z250. DUR and Z250 also were significantly different ($p<0.05$) in the interaction (Table 3). Therefore, the gloss unit results, except those of DUR and Z250, were pooled and analyzed with the Tukey’s post-hoc comparison test at each measuring stage, with the results shown in Table 5. Polishing significantly increased ($p<0.05$) the gloss units of all composite resins except for the Z350 and the DUR with Sof-Lex polishing group. Toothbrushing decreased the gloss unit of all composite resins. The gloss units gradually decreased with increased toothbrushing cycles.

SEM images of each composite resin after polishing with Sof-Lex or Venus Supra, and after 40k brushing cycles are shown in Fig. 1. The DUR samples (Fig. 1 A1, 3) demonstrated shallow scratches produced on the surface by polishing with either system, while scattered
Deep scratches were observed on the surface of the KAL and VED samples polished with Sof-Lex (Fig. 1 D1 and E1). Large sized prepolymerized particles of the DUR sample (Fig. 1 A2, 4), KAL samples (Fig. 1 D2, 4), and VED sample (Fig. 1 E2, 4) glass filler particles were seen on their respective specimen surfaces after 40k brushing cycles. Minor scratches produced by polishing were detected on the Z250 samples (Fig. 1 B2, 4) and small filler particles were seen on the surface after toothbrushing. The surface of the Z250 samples polished by Venus Supra (Fig. 1 B3) appeared to be smoother than those polished by Sof-Lex (Fig. 1 B1). The surfaces of the Z350 and VEP samples (Fig. 1 C1, 3 and F1, 3) polished with either system were relatively smooth. After toothbrushing, the surfaces of the Z350 and VEP samples (Fig. 1 C2, 4 and F2, 4) were slightly rough and small filler particles could be seen.

The relationship between Ra value and gloss units was analyzed. A significant negative correlation between log [Ra value] and log [gloss units] was detected with an R² value of 0.63 (p<0.01). The regression equation was as follows: log[gloss units] = −1.15×log[Ra value]+0.23.

**DISCUSSION**

The present study investigated the surface roughness and gloss of composite resins after polishing with two polishing systems and being subjected to toothbrushing. Statistical analysis indicated significant differences in Ra values and gloss units of each composite over the measuring stages, except for the Ra value of VEP. Therefore, the null hypothesis was rejected for gloss units and partially rejected for Ra values.

In the present study, six composite resins were selected based on filler concepts in each composite resin. DUR and Z250 were representatives of conventional microfilled and microhybrid composite resin, respectively. Z350, consisting of nanoparticle and nanocluster, was the nanofilled composite resin. KAL, VED and VEP were nanohybrid composite resins.

Abrasive SiC paper was used to pre-grind the surface of the composite resins as a baseline reference. This was done to mimic the best possible clinical finishing as the starting point. With the very smooth surfaces after finishing, it was anticipated that we could observe the effectiveness of the finest polishing stage in improving Ra and gloss.

The two polishing systems used in our study, Sof-Lex and Venus Supra, were chosen because they both contain approximately the same abrasive particle size. However, they differ in polishing medium (aluminum oxide or diamond), base substrate material (polyester or silicone), and usage conditions (without or with water spray). Therefore, we expected the polished composite resin surfaces to show differences in roughness and gloss after using these systems. The finest polishing steps of the systems were chosen for polishing the surface. The resin surface after SiC grinding was sufficiently smooth, thus it was unnecessary to use any coarser polishing steps of the systems.

In the present study, the design of the toothbrushing wear protocol followed the ISO technical specification on brushing force, using a maximum force of 2.5 N as defined in previous studies. Other studies have used 1 N, 1.7 N, 2 N, or 5 N depending on their purposes. The 1 N force was utilized to simulate the applied force during toothbrushing. In contrast, the 5 N force was utilized to accelerate wear in the brushing simulator.

Soft bristle type toothbrushes were selected for use in our study per a previous study. Differences in toothbrush bristle stiffness have demonstrated minimal effect on composite resin wear. However, the medium used with brushing can have an effect on wear. A study demonstrated that six-hour brushing with water caused less abrasion on composite resin than one hour brushing with toothpaste. Furthermore, the type of toothpaste is a crucial factor in the rate of composite resin surface deterioration. Toothpastes containing less abrasive particles may slow the rate of gloss reduction with less increase in the surface roughness of composite resin. Colgate toothpaste was used in the present study because it is common and popular in Thailand.

A high number of toothbrushing cycles are necessary to produce an unequivocal effect on the roughness and gloss of composite resin. However, it is unclear how the number of toothbrushing cycles used in in vitro testing relates to quantifying toothbrushing wear in vivo. A study suggested that 36,000 strokes (18,000 cycles) equated to three years in vivo and another suggested 5,760 strokes (2,880 cycles) was the same as one year in vivo. Studies have also suggested 10,000 cycles could be interpreted as one year in vivo. Therefore, the 40k brushing cycles used in the present study can be assumed to simulate 4 to 13.8 years in vivo.

Many parameters have been used to evaluate surface morphology. Some investigators measured the volume loss from surface wear. In the present study, three parameters were chosen for evaluating the alteration in surface morphology after polishing and toothbrushing. Surface roughness (Ra) is an important laboratory parameter based on the depth of the scratches present on a material’s surface. However, differences in Ra can only be discriminated by patients when the difference is over 0.5 µm. The surface roughness of enamel to enamel contact areas, which is considered as an appropriate standard for comparing a restoration to enamel, is 0.64±0.25 µm. Surface gloss is a parameter that is more clinically perceptible to clinicians and patients. However, high initial gloss does not ensure long term gloss retention. SEM also provides an overall understanding of the surface morphology. Therefore, it is suitable to evaluate surface characteristics both quantitatively and qualitatively.

For Ra, the statistical analysis indicated a slight but significant increase in roughness after polishing for several of the composite resins in the present study. This might be attributed to the relatively equal polishing particle size contained in P4000 SiC paper (average particle size 3 µm), and the Sof-Lex (3 µm) and
Venus Supra (4–8 µm) systems. These results are in partial agreement with a previous study that suggested surface roughness was comparable when polishing particles less than 12 µm in size were used\(^{29}\). Following the toothbrushing cycles, the Z250, Z350, and VEP samples maintained their Ra, while the DUR, KAL, and VED samples showed an increase in Ra. This may be due to the smaller filler particles in the Z250, Z350, and VEP samples, which are easily exfoliated during abrasive wear of the resin matrix by the toothpaste slurry compared to the large, irregular shapes of the prepolymerized particles and glass filler particles in the DUR, KAL, and VED samples, which are less able to be abraded and exfoliated\(^{24,27}\). The SEM images confirmed that large filler particles were present on the surfaces of the DUR, KAL, and VED samples after 40k brushing cycles. However, the Ra values of all composite resins at each measuring stage were less than 0.2 µm, similar to that of a previous study\(^{17}\). This suggests that the surface roughness after toothbrushing would not be susceptible to plaque accumulation and staining as proposed by Bollen et al.\(^{2}\).

ADA specifications state that after polishing the gloss units of composite resin range from 40–60\(^{15}\). Our study found that after SiC grinding, the gloss units of several composite resins was below 60. However, the gloss units of all composite resins increased and exceeded 60 after polishing with the two polishing systems. This demonstrated the effectiveness of the polishing systems in obtaining high gloss on the composite resin surfaces. Smaller polishing particle sizes of < 9 µm as found in these systems can generate improved gloss of composite resin\(^{20}\). The small particle size resulted in an increase in gloss units after polishing, while Ra remained stable after polishing. After toothbrushing, all composite resins showed a reduction in gloss units except for the Z350 samples, which retained their gloss units up to 40k brushing cycles. The small filler particles of the Z350 samples likely caused a decrease in diffuse reflection resulting in a glossy appearance\(^{12,30}\). The spherical shaped filler particles of the Z350 samples might also be a factor in high light reflection compared to the irregular filler particles of the DUR, KAL, and VED samples\(^{11}\).

The results of the present study indicate that nanofilled composite resin, such as Z350, is the composite resin of choice for use in the esthetic zone because it can retain both Ra value and gloss after 40k cycles of toothbrushing. However, the use of nanohybrid composite resins, such as KAL and VED, should be carefully considered due to the easy loss of gloss from toothbrushing. Interestingly, neither polishing system caused a marked reduction in Ra but generated in an increase in gloss of the composite resins. This suggests that both polishing systems were only effective in improving gloss. Thus, in non-esthetic zones such as class I and II restorations, extensive polishing of the composite resin surface may not be indicated because the Ra values after SiC grinding were below 0.2 µm, which would not promote plaque accumulation and staining\(^{2}\), and also well below 0.64 µm, which is the average roughness value of enamel\(^{29}\). Despite the increase in Ra values following toothbrushing, the differences in Ra values between the polished resin and after 40k brushing cycles were less than 0.5 µm, which is the threshold for detection by a patient\(^{26}\). However, Ra values from different studies cannot be directly compared because different studies used different profilometer settings and experimental designs.

A negative correlation between Ra value and gloss units has previously been reported\(^{16,21,24}\), and this was confirmed by the present study. Although a previous study reported a strong correlation between Ra values and gloss units\(^{26}\) a subsequent study demonstrated a weak correlation\(^{17}\). Therefore, this remains unresolved and clarification is needed regarding this issue.

The results from the present study only provide information on the surface properties (Ra and gloss) of composite resins after treatment in a simulated brushing machine. Comparing Ra, gloss, and surface wear might be another desirable and valuable approach for better understanding the surface characteristics of composite resins. Finally, long-term clinical observations of restorations in service would provide information on the in vivo outcome.

**CONCLUSION**

Within the limitations of this study, it can be concluded that both polishing systems, Sof-Lex and Venus Supra, were comparably effective in creating a high gloss on the composite resins tested in this study. Polishing with Sof-Lex or Venus Supra after SiC grinding provided significant increases in gloss units, but the difference between the two systems was marginal. Toothbrushing up to 40k cycles caused a significant increase in Ra of all the composite resins tested except VEP and Z250. Toothbrushing up to 40k cycles caused a significant decrease in gloss units of all the composite resins. Z350, nanofilled composite resin, is the composite resin of choice for use in the esthetic zone because it can retain both Ra value and gloss after 40k cycles of toothbrushing.

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