Comparison of surface gloss of resin composites according to changes in surface roughness

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Comparison of surface gloss of resin composites according to changes in surface roughness

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논문이 완성되기까지 따뜻한 격려와 아낌없는 지도를 해 주시고 한결같이 이끌어 주신 박성호 교수님께 진심으로 감사드립니다. 교수님의 진료담당 치과위생사부터 시작하여 대학원 지도학생으로 지내는 동안 교수님 곁에서 많이 느끼고 배울 수 있는 값진 시간이었습니다.

귀중한 시간을 내어 부족한 논문을 세심하게 살펴보시고 지도해 주신 박정원 교수님, 신유석 교수님, 김도현 교수님, 김광만 교수님께도 진심으로 감사의 인사를 드립니다.

마지막으로 이 논문을 누구보다 기다렸던 부모님께 깊은 사랑과 감사 인사를 전합니다.

2023년 12월

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(Directed by Professor Sung-Ho Park)

Commonly used composite resin in clinical practice, has developed by improving aesthetics to obtain a smooth surface. However, the smooth surface of the restored composite resin becomes roughly over time. One of the primary methods for evaluating the surface of composite resin is gloss unit (GU). Gloss can be assessed visually and is easily recognized and perceived by both dentists and patients. Therefore, this study

measured the gloss unit to evaluate the surface of several types of composite resins, and to evaluate the gloss retention rate of the composite resins, the roughened surface was observed compared to the control group.

The specimens were produced of 5 composite resins, GRADIA DIRECT ANTERIOR (GA), Tetric N-Ceram (TN), Ceram.x sphereTEC one (CX), Filtek Z350 XT (FT), and ESTELITE ∑QUICK (ES). After creating a smooth surface with a slide glass, five locations were randomly selected to measure the surface gloss unit, and the average was set as the representative value for the specimen. After measuring the GU, roughness was given to the specimen under water pouring at the same speed (150rpm) and pressure (weight 252g) with SiC paper #2400, 1200, and 400. Each time the roughness was given with SiC paper, the GU was measured again. After applying roughness using the same SiC paper, GU between composite resins was compared. In addition, as SiC paper #2400, 1200, and 400 were used step by step, changes in the surface were evaluated, which became increasingly rougher than the surface made of slide glass. The statistical analysis method used was one-way analysis of variance and Tukey multiple comparisons test at the 95% confidence level.

As a result of this study, there was a difference in GU between composite resins. When was the surface of the composite resin is made of slide glass, in the order of TN < GA < FT < ES < CX, when roughness was given to #2400, in the order of CX < TN < GA < ES < FT. When roughness was given to #1200, GU was higher in the order of CX < GA <

TN < FT < ES, and when roughness was given to #400, in the order of FT < CX < GA < TN < ES ($p<0.05$). Each time SiC paper was used in rough stages, it gradually became rougher compared to the surface made of slide glass, and gloss retention rate was lowered. GA is 100% > 64.82% > 34.02% > 19.74%, TN is 100% > 64.53% > 48.56% > 28.74%, CX is 100% > 54.58% > 23.74% > 14.87%, FT is 100% > 94.53% > 55.37% > 14.76%, ES is 100% > 88.09% > 74.10% > 53.23% gloss retention rate has decreased ($p<0.05$).

In conclusion, there was a difference in GU for each composite resin due to the characteristics of the composite resin. When compared to the control group, the gloss retention rate of the composite resins decreased after applying roughness in stages with SiC paper, but differed depending on the composite resins. Among composite resins, ES showed the best gloss retention rate.

Key words: Composite resin, Gloss unit, Gloss retention rate, SiC paper, Abrasive.

Comparison of surface gloss of resin composites according to changes in surface roughness

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(Directed by Professor Sung-Ho Park)

I. Introduction

As economic and social conditions improve, patients are preferring materials with excellent physical properties and aesthetics not only in the anterior teeth but also in the posterior teeth. Because of increasing demand for aesthetic restoration and the development of restorative materials, composite resins are commonly used in dentistry (Zhou et al., 2019).

Over time, with enhancements in the formulation, properties, and aesthetics, composite resins have been frequently used in clinical practice (Samuel, 2009). To increase aesthetics, the size of filler particles has been reduced in composite resins. Macro filled composite resins with a filler particle size of 10–50 ㎛ initially had strong mechanical properties. However, Macro filled composite resins were difficult to polish and maintain color, showing limited aesthetic characteristics. To improve the aesthetics, micro filled composite resins were developed by adding 0.04–0.05 ㎛ amorphous spherical silica. However, micro filled composite resins showed increased fracture rates and wear rates. Hybrids composite resin improves aesthetics after polishing by adding 10–50 ㎛ glass filler particles and 0.01–0.05 ㎛ small colloidal silica particles (Ilie and Hickel, 2011). Additionally, for long-term maintenance of aesthetics, composite resins with reduced glass filler particle size were developed. Hybrid composite can be added to micro filled or nano filled, which becomes micro hybrid or nano hybrid. Recently, spherical nano filled composite resins (0.01–0.1 ㎛) with an increased content of fillers and a reduced resin matrix have been developed using nanotechnology. Additionally, some manufacturers produced resin using nano particles slightly larger than 100 ㎛ and classified it as supra nano. Owing to their improved physical properties and aesthetics, nano filled composite resins are being commonly used in dental treatment (Chen, 2010).

Composite resins must have a smooth surface to achieve successful clinical outcomes as an aesthetic restorative material (Lee and Shin, 2003). Composite resin restorations with a smooth surface improve longevity and aesthetics and help achieve harmony with healthy periodontal conditions in their natural shape (Lu et al., 2003). In contrast, restorations with a rough and irregular surface may pose increased risks of clinical problems such as plaque, bacterial deposition, gingivitis, secondary caries, and discoloration (Van and Davis, 1984).

The primary method to evaluate the smooth surface of composite resins involves measuring the surface roughness (Ra) and gloss unit (GU) (Zhang et al., 2021). When Ra is less than 0.2 ㎛, bacterial adhesion does not increase. However, when Ra is greater than 0.2 ㎛, the surface may affect the initial bacterial adhesion. Therefore, increased roughness of the surface may increase plaque accumulation (Bollenl et al., 1997).

As reported previously in the literature, the smoothest surface was obtained when polyester strips were used on the composite resin surface. Polyester strips helped achieve clinically successful Ra of less than 0.2 ㎛, regardless of the composite resin type (Yap et al., 2004; Say et al., 2014; Camassari et al., 2020). However, on surfaces made under polyester, an oxygen inhibition layer occurs in the surface layer. And due to the resin matrix, composite resins show low microhardness and an increased risk of wear (Stoddard and Johnson, 1991). Therefore, finishing and polishing steps that remove the surface layer of the resin are required to improve its physical properties. The purpose of finishing and polishing is to reach Ra similar to enamel (0.64 ㎛) (Willems et al., 1991).

Numerous previous studies have shown that various finishing and polishing systems can be used clinically since Ra is 0.08–0.6 ㎛ (Cazzaniga et al., 2017; Kemaloglu et al., 2017; Dhananjaya et al., 2019; Paolone et al., 2020; Batista et al., 2021). However, composite resins restored within the oral cavity gradually show increased Ra over time, even after finishing and polishing steps. When Ra was greater than 0.3 ㎛, patient felt foreign body sensation with their tongues (Jones et al., 2004). In previous studies that observed surface roughness after brushing, surface roughness of 0.029–0.208 ㎛ was measured (Malavasi et al., 2015; O'Neill et al., 2018; Cavalcante et al., 2021). Ra increased after brushing but was within the clinically acceptable range. Most studies have shown that finishing and polishing, brushing increased Ra within a clinically acceptable range. These findings suggest that measuring GU may be a better method of surface smoothness than Ra (Ferracane, 2010). Moreover, measuring Ra in the oral cavity and perceiving it by the patient is not possible. In contrast, GU can be assessed visually and easily perceived by both patients and dentists (Kamonkhantikul et al., 2014). However, most studies between 2001 and 2021 evaluated Ra, with only a limited number of studies assessing GU (Amaya-Pajares et al., 2022).

Therefore, this study aimed to measure GU and evaluate the smoothness of composite resin surfaces in several types of composite resin. Additionally, Interest in maintaining gloss over time has increased with the recent development of composite resins with the advantage of self–shining/polishing. Maintenance of gloss can be evaluated gloss retention rate. Gloss retention rate is based on the smoothest surface and shows how much gloss the surface maintains when stimulated. So, this study investigated gloss retention rate after grinding with SiC papers.

Ⅱ. MATERIAL AND METHODS

1. Materials

The composition of materials used in this study are mentioned in Table 1. Micro hybrid composite resin GRADIA DIRECT ANTERIOR (GA), nano hybrid composite resin Tetric N-Ceram (TN), Ceram.x sphereTEC one (CX), nano filled composite resin Filtek Z350 XT (FT), supra nano composite resin ESTELITE ∑ QUICK (ES) was used. The five types of composite resins have several types, sizes, and distributions of filler, but all shades used were A2.

To grind the surface of the composite resin, SiC paper (FEPA P grade) #2400 (6.5 ㎛), #1200 (15.3 ㎛), and #400 (35 ㎛) were used (Table 2).

Table 1. Composite resins used in this study

Material	Type	Composition				Manu-facture
		Resin matrix	**Filler**	**Mean filler particle size (㎛)**	**Filler ratio (Vol%)**	
GRADIA DIRECT ANTERIOR (GA)	Micro hybrid	UDMA	Silica, Organic filler	0.85	64	GC, Tokyo, Japan
Tetric N-Ceram (TN)	Nano hybrid	Dimethacrylates	Barium glass, Prepolymer, Ytterbium trifluoride, Mixed oxide	0.04-3	57	Ivoclar Vivadent, Schaan, Liechtenstein
Ceram.x sphereTEC one (CX)	Nano hybrid	PUMA, Bis-GMA, TEGDMA.	Pre polymerized filler, Barium glass, Ytterbium fluoride	0.6	61	Dentsply Sirona, Konstanz, Germany

Filtek Z350 XT (FT)	Nano	Bis-GMA Bis-EMA UDMA TEGDMA PEGDMA	Silica, Zirconia	Silica 0.02, Zirconia 0.004-0.011	63.3	3M ESPE, St Paul, MN, USA
ESTELITE ∑QUICK (ES)	Supra Nano	Bis-GMA TEGDMA	Silica-Zirconia filler, Composite filler	0.2	71	Tokuyama Dental Co, Tokyo, Japan

Table 2. SiC paper used in this study

SiC paper	Average grit size(㎛)
#2400	6.5
#1200	15.3
#400	35.0

2. Methods

2.1 Specimen production

To produce composite resin specimens, a teflon mold with a diameter of 14 mm and a thickness of 4 mm has been produced. A metal body connected to the polishing machine was placed in the center of the manufactured teflon mold. Composite resin was filled into the mold (Figure 1). Excess composite resin was removed, a slide glass was placed above the composite resin, and light cured for 20 seconds using an LED light curing machine VALO (Ultradent, South Jordan, UT, USA). A total of 50 specimens, 10 for each composite resin, were produced.

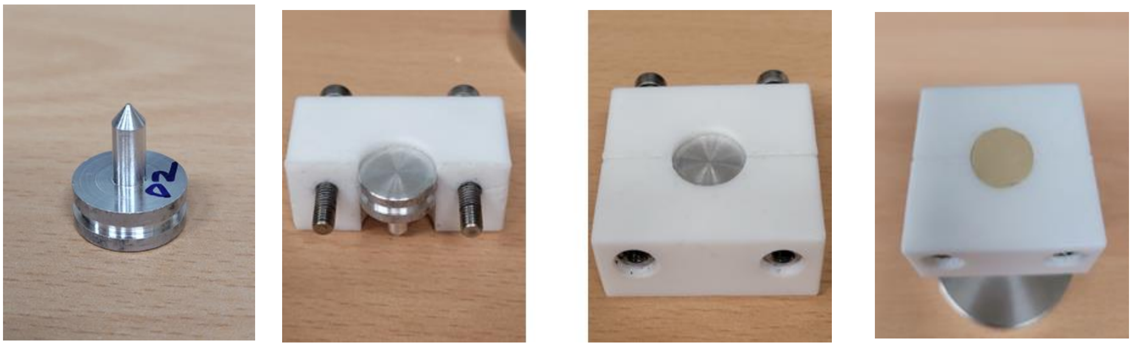

Figure 1. Mold and metal body used in specimen preparation. Place the metal body in the center and connect the molds on both sides.

2.2 Measurement of gloss unit before grinding

The composite resin before grinding was used as a control group, and the surface gloss unit was measured. To measure the surface gloss unit of the composite resin, a small area glossmeter (Novocurve, Rhopoint instrumentation, East Sussex, UK) using a 60° LED light source was used (Figure 2). Before measurement, calibration was performed with a standard gloss plate, and the specimen was covered with an opaque black plastic cylinder (d: 3.2cm, h: 5.4cm) to limit surroundings light and the gloss unit was measured. Five locations were randomly selected and measured middle area of the specimen, and the average value of five measurements was taken as the representative value of each specimen. The GU value of the smoothest surface before grinding was classified into the control group of each composite resin.

Figure 2. Small area glossmeter (Novocurve) used in this study

2.3 Grinding specimens using SiC paper

Specimens that gloss unit was measured before grinding were grinding with a polishing machine (RB 209 MINIPOL-E, R&B, Daejeon, Korea). SiC paper ranging from fine to coarse was used in stages (#2400, #1200, #400). To reduce differences between each experiment, the specimen was fixed to a polishing machine. A weight of 252 g was placed on the fixture to apply a constant pressure to the specimen (Figure 3). The grinding was done under water to prevent heat generate on during grinding (Setcos et al., 1999). Grinded for 1 minute at the same speed for 150 rpm.

Figure 3. Polishing machine (R&B) used in study. Put SiC papers in the polishing machine and place the specimen on it. Fix the specimen to the polishing machine and raise the weight.

2.4 Measurement of gloss unit after grinding

Gloss unit was measured each time it was grinded with SiC paper #2400, 1200, and 400. After grinding, the specimens were washed and dried with an air syringe. As before, a small-area glossmeter (Novocurve) using a 60° LED light source was used. Before measurement, calibration was performed with a standard gloss plate, and the specimen was covered with an opaque black plastic cylinder (d: 3.2cm, h: 5.4cm) to limit surroundings light and the gloss unit was measured. Five locations were randomly selected and measured middle area of the specimen, and the average value of five measurements was taken as the representative value.

2.5 Calculation of gloss retention rate

The gloss retention rate was determined using the measured GU. The surface gloss of the control group produced under slide glass was taken as the standard (100%). Whenever the surface became rough using SiC paper, the reduced gloss was compared with the control group and the ratio was calculated.

$$\text{Gloss retention rate (\%)} = \frac{\text{GU on the surface grinded using SiC paper}}{\text{GU of control group}} \times 100$$

2.6 Statistical analysis

Prior to statistical analysis, skewness and kurtosis were checked to verify normality (West et al., 1995). All statistical analyzes were performed using SPSS statistical program ver. 22.0 (SPSS Inc, Chicago, IL, USA) was used.

The values of all groups were measured using ten specimens. GU was calculated as the average of ten specimens. The statistical analysis of GU used the glossiness of ten specimens to compare between control and sic paper, and between composite resins. Gloss retention rate was calculated as the ratio of the GU after grinding with sic paper to the GU of the control group. The ratio of each of the ten specimens was calculated, and the average was determined as the gloss retention rate of the corresponding group. Statistical analysis of gloss retention rate was performed using the gloss retention rate of ten specimens to compare between sic papers and between composite resins.

All statistical analysis methods were performed using one-way analysis and Tukey multiple comparisons test at the 95% confidence level.

III. RESULTS

The average and standard deviation of GU according to the type of composite resin and SiC paper are shown in Table 3. The difference in surface gloss of composite resin according to SiC paper is shown in Figure 4. In the control group before grinding, the GA and TN groups showed the lowest GU, followed by the FT and ES groups, and the CX group showed the highest GU at 97.12, which was a statistically significant difference (p<0.05). When grinding with SiC paper #2400, the GA group, TN group, and CX group showed statistically the lowest GU, followed by the ES group, and the FT group showed the highest GU at 87.97 (p<0.05). When grinding with SiC paper #1200, the CX group statistically showed the lowest GU, followed by the GA group, TN group, FT group, and ES group, with high GU in that order, and there was a significant difference between all groups (p<0.05). When grinding with SiC paper #400, the CX and FT groups showed the lowest GU, followed by the GA group. However, there was no statistical difference between the GA group and the CX group (p>0.05). The next higher GU was in the TN group, followed by the ES group, showing a significant difference (p<0.05).

Table 3. Mean and standard deviation of gloss unit of composite resins after grinding with different SiC papers

SiC paper	**GA**	**TN**	**CX**	**FT**	**ES**
Control	86.92 ^{Aa} (0.93)	86.17 ^{Aa} (2.36)	97.12 ^{Ac} (1.55)	93.06 ^{Ab} (0.98)	94.10 ^{Ab} (1.30)
#2400	56.32 ^{Ba} (2.60)	55.63 ^{Ba} (4.23)	53.00 ^{Ba} (4.07)	87.97 ^{Bc} (2.74)	82.89 ^{Bb} (2.87)
#1200	29.56 ^{Cb} (1.01)	41.83 ^{Cc} (2.08)	23.06 ^{Ca} (0.78)	51.53 ^{Cd} (2.24)	69.71 ^{Ce} (2.84)
#400	17.16 ^{Db} (1.44)	24.79 ^{Dc} (2.68)	14.43 ^{Dab} (1.52)	13.73 ^{Da} (3.23)	50.07 ^{Dd} (3.33)

Different uppercase letters indicate statistical differences among SiC papers used for polishing (column), and different lowercase letters indicate statistical differences among composite resins (row) by one-way analysis of variance and Tukey multiple comparisons test (p<0.05). GA (GRADIA DIREECT ANTERRIOR), TN (Tetric N-Ceram), CX (Ceram.x sphereTEC one), FT (Filtek Z350 XT), ES (ESTELITE ∑QUICK).

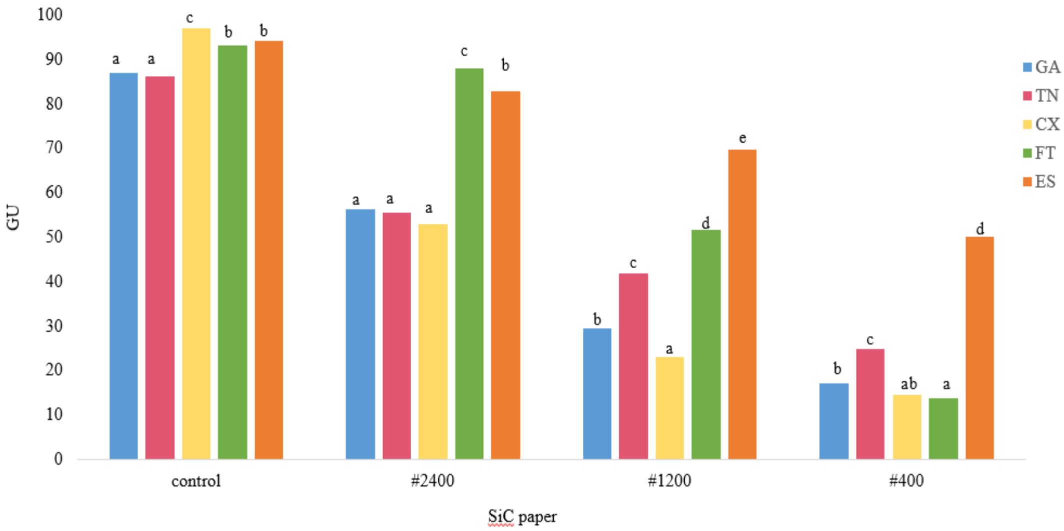

Figure 4. Gloss unit of composite resins after grinding

Different lowercase letters indicate statistical differences among composite resins in each surface treatment by one-way analysis of variance and Tukey multiple comparisons test within each grinding group (p<0.05). GA (GRADIA DIREECT ANTERRIOR), TN (Tetric N-Ceram), CX (Ceram.x sphereTEC one), FT (Filtek Z350 XT), ES (ESTELITE ∑QUICK).

Table 4 and Figure 5 show the gloss retention rate of the composite resin the roughness was applied with SiC paper, based on the control group. After roughening the surface with SiC paper #2400, gloss retention rate was shown in the following order: FT (94.53%), ES (88.09%), GA (64.82%), TN (64.53%), and CX (54.58%) (p<0.05 After roughening the surface with SiC paper #1200, gloss retention rate was shown in the following order: ES (74.10%), FT (55.37%), TN (48.56%), GA (34.02%), CX (23.74%) (p<0.05). After roughening the surface with SiC paper #400, gloss retention rate was shown in the following order: ES (53.23%), TN (28.74%), GA (19.74%), FT (18.87%), CX (14.76%) (p<0.05). For all composite resins, gloss retention rate decreased as the grit size of SiC paper increased. In the case of CX, gloss retention rate was the lowest regardless of the grit size of the SiC paper (p<0.05).

Table 4. Gloss retention rate (%) of composite resins after grinding with different SiC papers compare to control group

SiC paper	GA	TN	CX	FT	ES
Control	100^{A}	100^{A}	100^{A}	100^{A}	100^{A}
#2400	64.82^{Bb} (3.53)	64.53^{Bb} (4.20)	54.58^{Ba} (4.22)	94.53^{Bd} (2.87)	88.09^{Bc} (3.28)
#1200	34.02^{Cb} (1.30)	48.56^{Cc} (2.40)	23.74^{Ca} (0.75)	55.37^{Cd} (2.15)	74.10^{Ce} (3.45)
#400	19.74^{Db} (1.60)	28.74^{Dc} (2.71)	14.87^{Da} (1.68)	14.76^{Da} (3.49)	53.23^{Dd} (3.97)

Different uppercase letters indicate statistical differences among SiC papers used for grinding (column), and different lowercase letters indicate statistical differences among composite resins (row) by one-way analysis of variance and Tukey multiple comparisons test (p<0.05). GA (GRADIA DIRECT ANTERIOR), TN (Tetric N-Ceram), CX (Ceram.x sphereTEC one), FT (Filtek Z350 XT), ES (ESTELITE ∑QUICK).

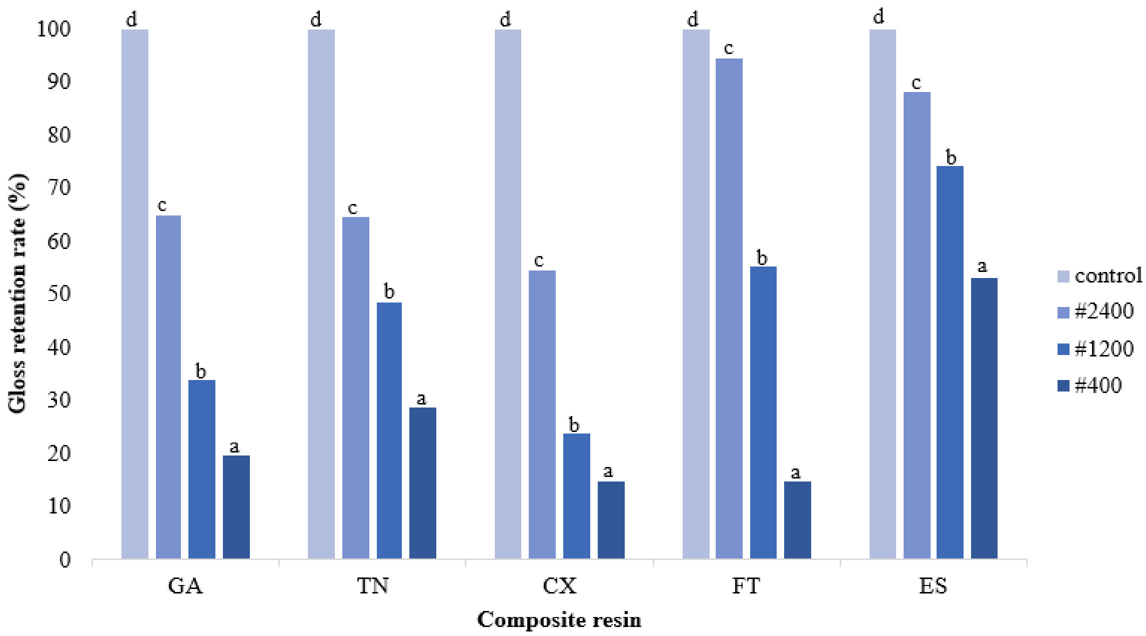

Figure 5. Gloss retention rate (%) of composite resins after grinding. Different lowercase letters indicate statistical differences among SiC paper #2400, #1200 and #400 relative to the control group by one-way analysis of variance and Tukey multiple comparisons test (p<0.05). GA (GRADIA DIRECT ANTERIOR), TN (Tetric N-Ceram), CX (Ceram.x sphereTEC one), FT (Filtek Z350 XT), ES (ESTELITE ∑QUICK).

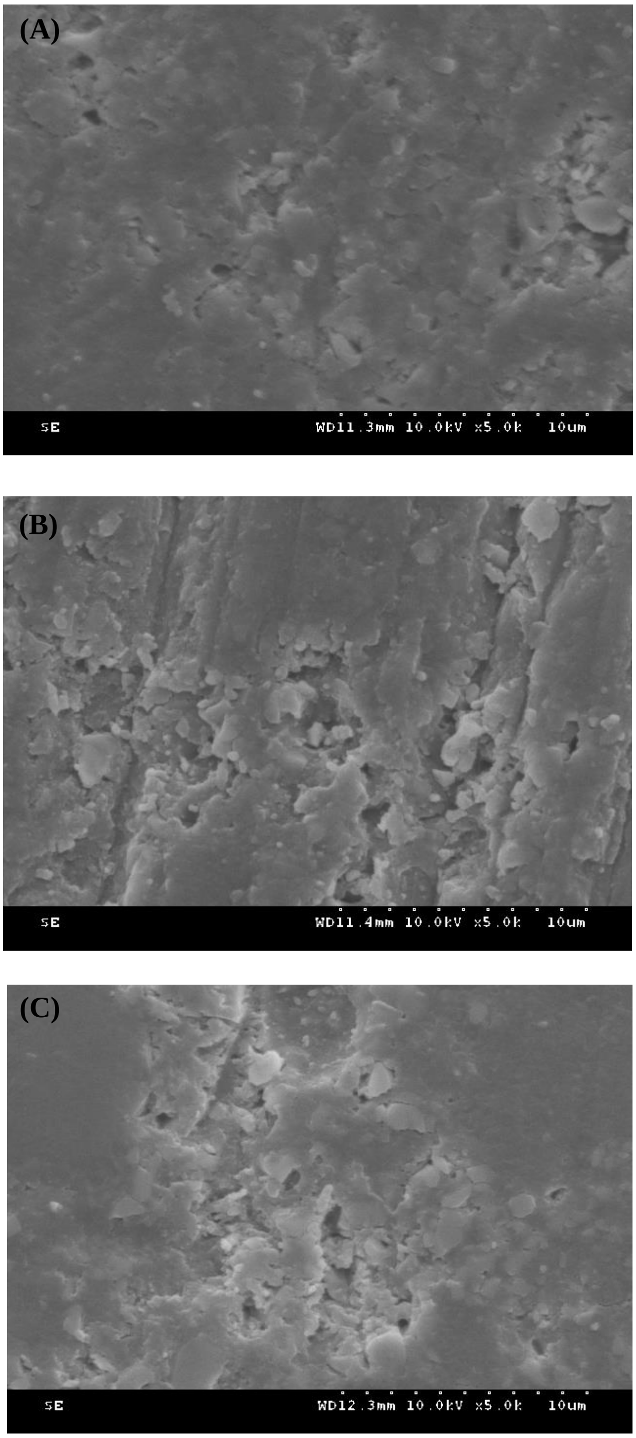

Figure 6. SEM image of the grinded GA (GRADIA DIRECT ANTERIOR) (x 5000).

(A) represents the surface grinded with SiC paper #2400, (B) represents the surface grinded with SiC paper #1200, (C) represents the surface grinded with SiC paper #400.

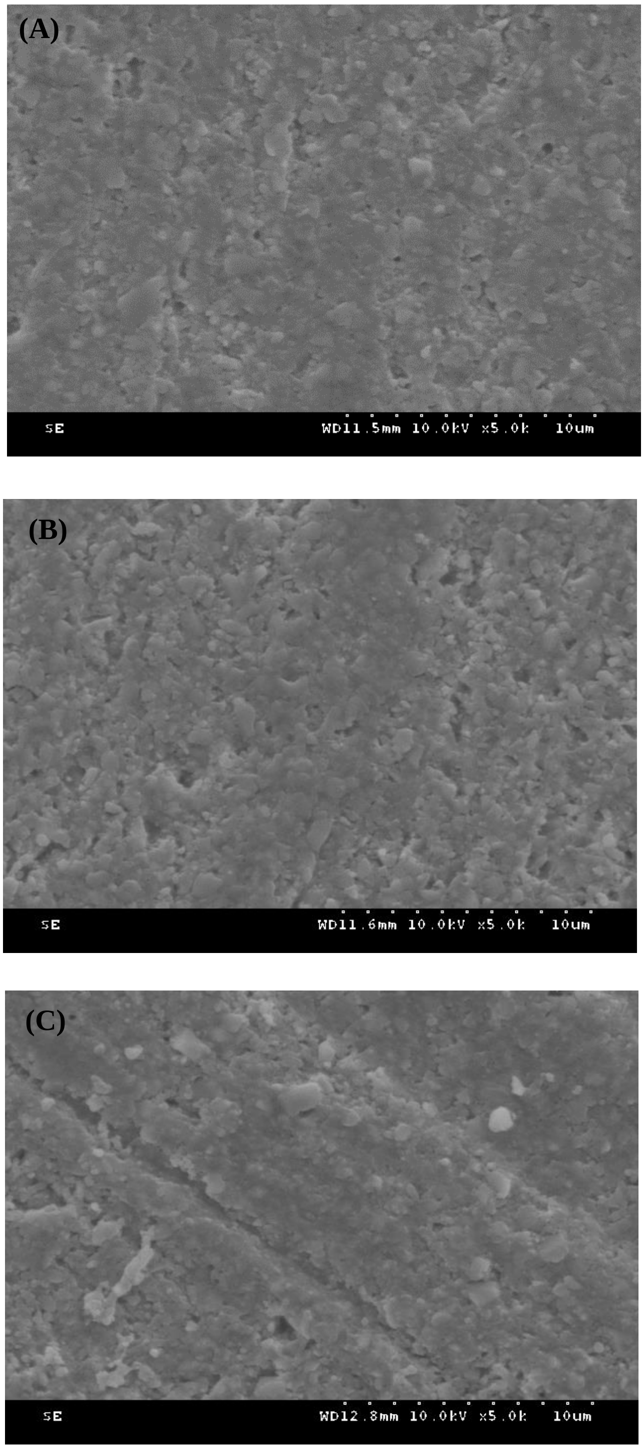

Figure 7. SEM image of the grinded TN (Tetric N-Ceram) (x 5000).

(A) represents the surface grinded with SiC paper #2400, (B) represents the surface grinded with SiC paper #1200, (C) represents the surface grinded with SiC paper #400.

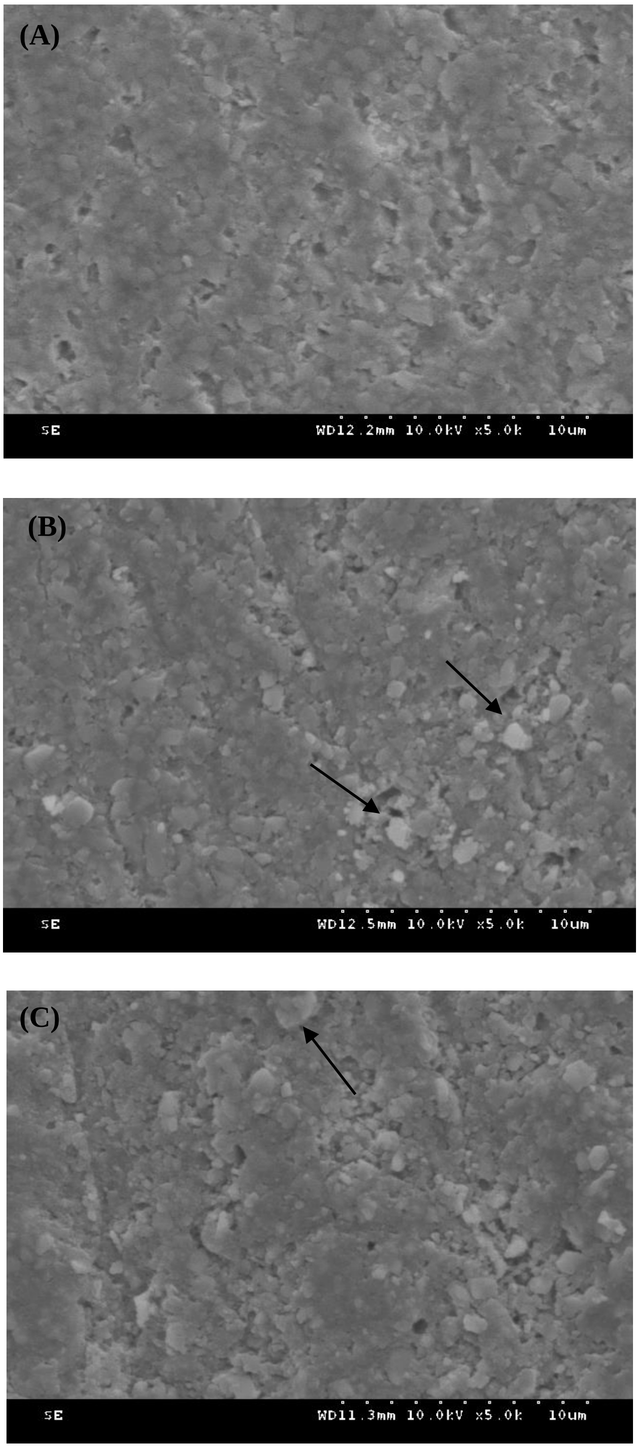

Figure 8. SEM image of the grinded CX (Ceram.x sphereTEC one) (x 5000).

(A) represents the surface grinded with SiC paper #2400, (B) represents the surface grinded with SiC paper #1200, (C) represents the surface grinded with SiC paper #400. Arrows show to a relatively large pre-polymerized filler particle.

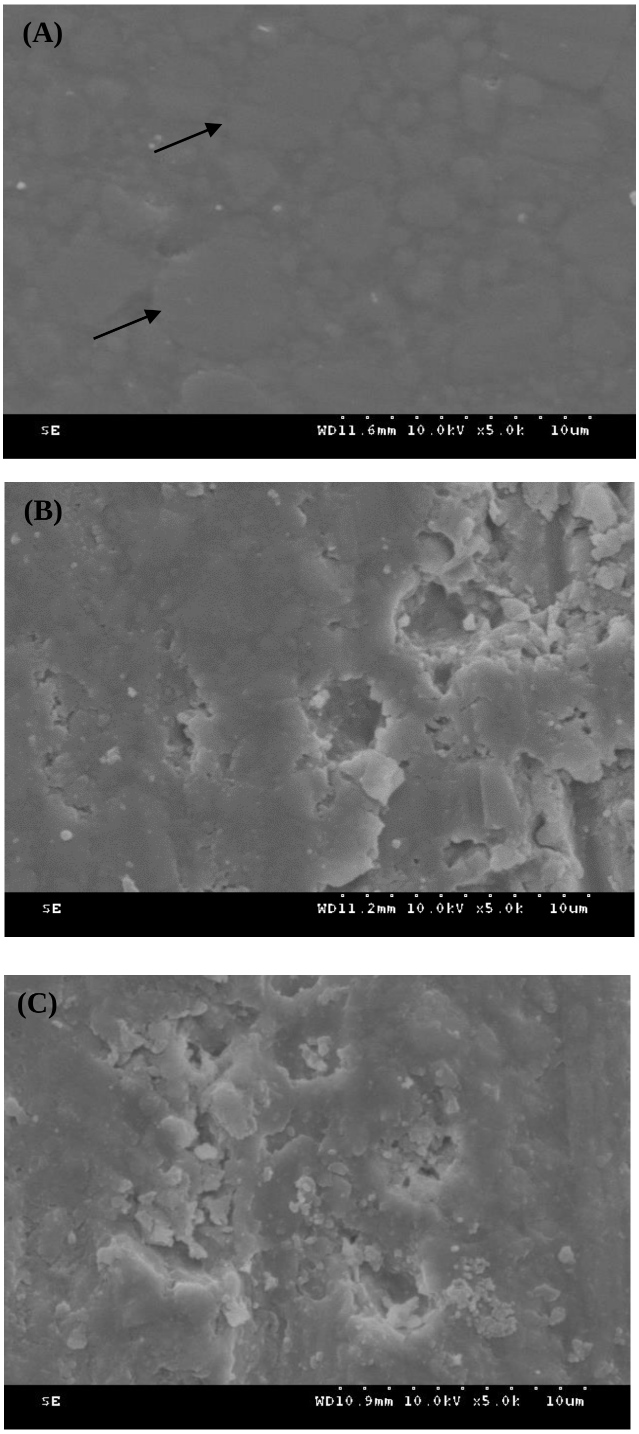

Figure 9. SEM image of the grinded FT (Filtek Z350 XT) (x 5000).

(A) represents the surface grinded with SiC paper #2400, (B) represents the surface grinded with SiC paper #1200, (C) represents the surface grinded with SiC paper #400. Arrows show nanoclusters.

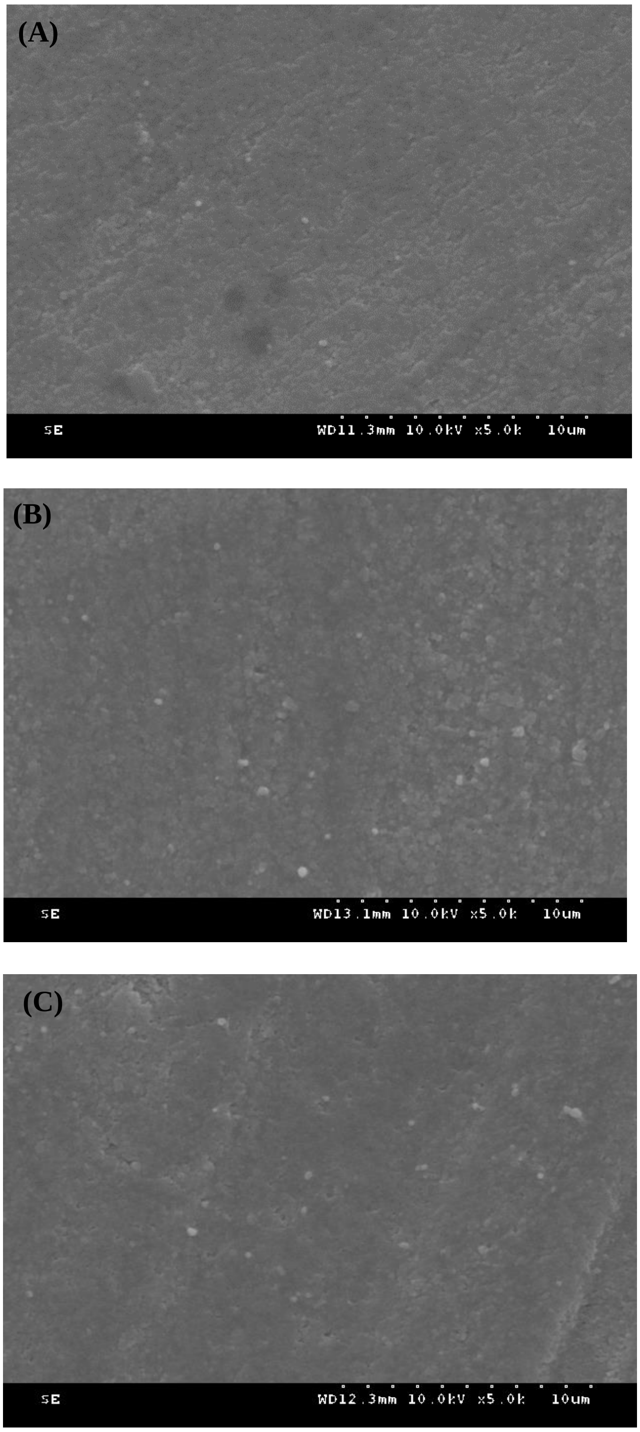

Figure 10. SEM image of the grinded ES (ESTELITE ∑ QUICK) (x 5000).

(A) represents the surface grinded with SiC paper #2400, (B) represents the surface grinded with SiC paper #1200, (C) represents the surface grinded with SiC paper #400.

IV. DISCUSSION

In clinical practice, a smooth surface of composite resin restorations is aesthetically and functionally important. A smooth surface with a high GU can produce excellent results visually at the immediately after restoration. However, over time, the surface will become rough due to the intraoral environment, which affects aesthetics and function. Ra and GU have strong correlation (r=0.73) (Cazzaniga et al., 2017), but Ra is not recognized by the patient. In contrast, GU can be assessed visually and easily perceived by both patients and dentists (Kamonkhantikul et al., 2014). Additionally, since gloss measured at a 60° angle is like what humans perceive as tooth gloss, it is the most clinically significant method to evaluate surface smoothness (Reis et al., 2003). Chiang et al. (2016) said that GU is a standardized method and allows quick comparison between materials. Therefore, this study aimed to measure GU and evaluate the smoothness of composite resin surfaces in several types of composite resin. It also assessed changes in the gloss of roughened surfaces with SiC papers to investigate the gloss retention rate of composite resins.

The study results showed differences in the GU between composite resins, even if those surfaces were manufactured under the same conditions (Table 3). There were differences in GU between the composite resins in the control, SiC paper #2400, #1200, and #400 groups. Especially after grinding with SiC paper #1200, there were significant differences in GU between all composite resins. In general, the larger the particle size of the composite resin filler, the greater the surface roughness, and the smaller the particle size, the greater the surface smoothness (Reis et al., 2002; Jung et al., 2007; Janus et al., 2010). In this study results, after grinding with SiC paper #2400, nano filled type FT with 0.04-0.011 ㎛ particles showed the highest GU, supporting the findings reported in other studies (Lee et al., 2007). This study results demonstrated that nanotechnology with small particles helps achieve a smooth surface on composite resin restorations. However, after grinding with SiC papers #1200 and #400, nano hybrid type CX (0.6 ㎛) showed a lower GU than micro hybrid type GA (0.85 ㎛), despite the smaller filler particle size. In a previous study by Pala et al. (2016) that compared the GU of micro hybrid and nano hybrid types of composite resins, showed that the micro hybrid type G-aenial posterior had a higher GU than the nano hybrid type CLEARFIL MAJESTY, supporting our findings in the current study. However, Burgess et al. (2010) and Da Costa et al. (2012) reported that the micro hybrid and nano hybrid types had similar GU. Additionally, Batista et al. (2021) stated that the nano hybrid type with smaller filler particles had a higher GU, showing inconsistencies when comparing the GU by filler type. Composite resins consist of a filler, resin matrix, coupling agent, and initiating system. GU was affected not only by the filler size but also by the reflection of light and the refractive index of the resin matrix and filler (Lee et al., 2005). It was confirmed that the GU of composite resin is not determined by the particle size of the filler.

Lassila et al. (2020) reported that the polishing tool had a significant effect on composite resin GU. Consistent with these findings, we observed that FT after grinding with SiC paper #2400 and ES after grinding with SiC paper #1200 and #400 showed the highest GU (Figure 4). The SiC papers used in this study show different grits. SiC paper #2400 has a grit size of 6.5 ㎛, similar polishing system to Sof-Lex super fine (5 ㎛, 3M ESPE, St Paul, MN, USA) and Super-Snap super fine (8 ㎛, Shofu Inc., Kyoto, Japan). SiC paper #1200 has a grit size of 15.3 ㎛, similar polishing system to Sof-Lex fine (14 ㎛, 3M ESPE, St Paul, MN, USA). SiC paper #400 has a grit size of 35.0 ㎛, the same as that of Super-Snap medium (35 ㎛, Shofu Inc., Kyoto, Japan). In previous studies by Ereifej et al. (2012), ES showed the highest GU when using the PoGo one step system (20 ㎛). FT showed the highest GU when using Sof-Lex helices (25–29 μm) in the study by Nithya et al. (2020). These results show differences in the GU of composite resins by polishing tools. Based on this evidence, it may be thought that FT would show a high GU when polished using Sof-Lex super fine or Super-Snap super fine, which are like SiC paper #2400. ES may show a high GU when polished using Sof-Lex fine, like SiC paper #1200, or Super-Snap medium, like SiC paper #400. However, such an expectation is simply a prediction based on the comparison of grit sizes. Additional studies should be conducted to determine whether surfaces polished with Sof-Lex and Super-Snap may show GU equivalent from our findings.

Restored composite resins with smooth surfaces show increased roughness over time. In this study, grinding composite resins with SiC papers led to decreased gloss retention rate compared to the control group (Table 4). CX showed statistically the lowest GU, regardless the grit size of SiC paper. Thus had the lowest gloss retention rate among all composite resins in this study. CX consists of organically modified ceramic (ormocer) nanoparticles (0.023 ㎛), nanofillers (0.01 ㎛), and glass fillers (1.1–1.5 ㎛) and is a nanohybrid-type composite resin with sphere-shaped pre-polymerized fillers (15 ㎛) (Shetty et al., 2021). According to the scientific review by the manufacturer, methacrylic polysiloxane nanoparticles are spread at a high density in the matrix and have commensurate properties to glasses or ceramics. In this study, the surface layer of the control group made of slide glass without grinding is a resin matrix rich layer. Therefore, the control group of CX had a significant amount of methacrylic polysiloxane, like glasses or ceramics, in the surface layer. Such methacrylic polysiloxane, present in the resin matrix rich layer, is thought to have increased the refractive index of light, resulting in a high GU of CX. Gloss retention rate is the ratio of GU reduced compared to the control group. Hence, if the standard control group has a high GU, gloss retention rate may be evaluated lower than the control group has a low GU, even if the amount of GU reduction is similar. Alli et al. (2021) reported that organically modified ceramics (ormocer) based matrices have lower gloss retention rate than methacrylate-based matrices because of the combination of filler and matrix. Similarly, Ergücü and Türkün (2007), and Sang et al. (2021) showed that CX have large pre-polymerized filler (15 ㎛) and glass filler (1.1–1.5 ㎛), which causes the fillers to fall off during grinding (Figure 8). Consequently, CX have holes that increase the roughness of the surface and lower the GU. These findings are consistent with the results of this study.

GU is determined by the size, distribution, and shape of the particles. In general, the smaller the composite resin fillers, the greater the GU (Takanashi et al., 2008). As reported in many studies, nano filled composite resins, which have nanoparticle fillers in the matrix that provide protection during polishing, tend to have the smoothest and glossiest surface (Rodrigues et al., 2015). The FT used in this study is a nano filled composite resin with nanoclusters (0.6–10 ㎛) of nanoparticles. Nanoclusters break into exceedingly small particles instead of falling off the surface during grinding (Figure 9). Therefore, it wears similarly to the resin matrix and shows excellent gloss retention rate (Turssi et al., 2005; Takanashi et al., 2008). In the results of this study, when roughness was applied with SiC paper #2400, FT showed high GU with slight difference from the control group and excellent gloss retention rate. This was consistent with study Turssi et al. (2005), Takanashi et al. (2008). However, when the roughness was applied with SiC paper #1200, the GU was higher compared to other composite resins, but decreased more than the GU of #2400. When the roughness was applied with SiC paper #400, the GU decreased more than the GU of #1200 and was the lowest compared to other composite resins. Hence, gloss retention rate was reduced rapidly (Figure 5). The decrease in the gloss retention rate of FT may be related to the resin matrix. Among FT matrixes, TEGDMA has been replaced by UDMA and Bis-EMA to reduce polymerization shrinkage and maintain long-term aesthetics. Previous study by Rosentritt et al. (2021), indicate that lower contents of UDMA increase GU. Based on this finding, the high content of UDMA in FT may have reduced gloss retention rate. However, in a study that evaluated the gloss retention rate of FT from 2000 to 2021 (Amaya-Pajares et al., 2022), there were no results showing that the gloss retention rate of FT decreased rapidly after a certain polishing stage or after a certain period, so this study differs from previous studies. Furthermore, UDMA is fragile and has low hardness. Therefore, the UDMA matrix with lower hardness compared to other composite resins may have been affected by the large grit of SiC paper.

Some manufacturers state that composite resin can self-polishing and shining if brushed daily after restoration. So, gloss retention rate is a fundamental aspect of composite resins as an aesthetic restorative material. Among the composite resins evaluated in this study, ES showed the highest gloss retention rate (Figure 5). Marghalani (2010) has reported that composite resins with spherical filler have the highest GU. In another study, Takanashi et al. (2008) showed that ES with a uniform spherical filler grinding with 3000 grits has a better GU than hybrid resin with an irregularly shaped filler grinded with 15000 grit. The uniform spherical filler of ES with a high refractive index allows for high gloss retention rate. Jassé et al. (2013) showed that composite resins with high filler contents had the highest GU. Small fillers located closely together prevent polishing tools with a grit larger than the inter-filler spaces, which helps prevent the removal of the resin matrix or the loss of fillers (Kusumoto et al., 1989; Dennis et al., 2021). Additionally, greater contents of fillers on a polished surface can reduce biofilms, improving not only the aesthetic and physical properties but also the biological function (Ionescu et al., 2012).

In summary of this study, GU varied depending on the composite resin type. Composite resins polymerized under a slide glass showed the highest GU. After roughening with SiC paper, the gloss retention rate decreased because all composite resin GUs decreased. CX had the lowest gloss retention rate. FT showed high gloss retention rate when grinded with SiC paper #2400. After that, a rapid decrease after polishing with SiC papers #1200 and #400. Among the composite resins, ES showed the highest gloss retention rate.

Previous studies mostly compared GU before and after polishing or using different polishing systems or compared GU before and after brushing (Amaya-Pajares et al., 2022). The comparison of different polishing systems showed that multi-step polishing systems lead to increased smoothness of the surface compared to one-step polishing systems. However, changes in GU at each step could not be evaluated. The number of studies comparing before and after brushing was insufficient to assess the change in GU depending on brushing time or number of times. In this study, after making a control group using a slide glass, the GU was measured and compared each time grinded with SiC paper #2400, #1200, and #400, and the change in gloss retention rate were assessed at each stage of surfaces with increasing roughness. It is significant that it differs from previous studies.

However, certain limitations must be considered when interpretating this study's findings. First, since this study was conducted in a laboratory, clinical polishing instruments were not used. Second, oral cavity factors were not considered. Composite resin restorations in the oral cavity are decomposed by mechanical wear and chemical stimulation from food over time, which decrease the GU and gloss retention rate. Therefore, future studies should evaluate oral cavity factors for evaluation of GU and gloss retention rate of composite resins.

V. CONCLUSION

As a result of this study, there was a statistical difference in GU between composite resins, and even if it was the same composite resin, there was also a difference between GU control group and after grinding with each SiC paper. Gloss retention rate calculated the change in surface roughness based on the GU of the control group. Gloss retention rate showed statistical differences between composite resins, and statistical differences existed at each stage of roughness change.

GU was influenced not only by the size of the filler but also by the composition of the composite resin and varied according to changes in surface roughness. Since gloss retention rate was calculated based on the GU of the control group, the GU of the control group influenced it.

Among the composite resins used in the study, ES has a higher GU value compared to other composite resins and has a high gloss retention rate value due to a small decrease in GU. Considering these results, ES may be an appropriate composite resin of choice as an esthetic restorative material in clinical practice.

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Abstract (IN KOREAN)

표면 거칠기의 변화에 따른 복합레진의 표면 광택 비교

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임상에서 일반적으로 사용되는 복합레진은 매끄러운 표면을 얻기 위하여 심미성을 개선하며 발전해왔다. 하지만 수복된 복합레진의 매끄러운 표면은 시간의 흐름에 따라 구강내에서 마모되면서서 거칠게 변화한다. 복합레진의 표면을 평가하는 방법 중 하나는 표면 광택도이다. 광택도는 시각적으로 평가할 수 있고 치과의사와 환자 모두가 쉽게 인식하고 인지할 수 있다. 이에 본 연구는 수종의 복합레진의 표면을 평가하기 위하여 광택도를 측정하였고, control 그룹에 비하여 거칠게 변화하는 표면을 관찰하여 복합레진의 광택 유지도를 평가하고자 하였다.

복합레진 GRADIA DIRECT ANTERIOR (GA), Tetric N-Ceram (TN), Ceram.x sphereTEC one (CX), Filtek Z350XT (FT), ESTELITE ∑QUICK (ES) 5개를 이용하여 시편을 제작하였다. Slide glass로 매끄러운 표면을 만든 후 무작위로 5곳을 선정하여 표면 광택도를 측정하였고, 그 평균을 시편의 대표값으로 설정하였다. 광택도 측정 후 동일한 속도와 압력으로 주수 하에 SiC paper #2400, 1200, 400으로 거칠기를 주었고, SiC paper로 거칠기를 주었을 때 마다 광택도를 다시 측정하였다. 동일한 SiC paper를 이용하여 거칠기를 준 후 복합레진 간 GU를 비교하였다. 그리고 SiC paper #2400, 1200, 400을 단계별로 사용할수록 slide glass로 만든 표면보다 점점 거칠어지는 표면의 변화를 평가하였다. 통계분석을 위하여 one-way analysis of variance and Tukey multiple comparisons test를 이용하였다.

연구 결과, 복합레진 간 GU는 차이가 있었다. 복합레진의 표면을 slide glass로 만든 경우 TN < GA < FT < ES < CX순으로, #2400으로 거칠기를 준 경우 CX < TN < GA < ES < FT순으로, #1200으로 거칠기를 준 경우 CX < GA < TN < FT < ES순으로, #400으로 거칠기를 준 경우 FT < CX < GA < TN < ES순으로 GU가 높았다. 거친 단계별로 SiC paper를 사용할 때 마다 slide glass로 만든 표면에 비하여 점차 거칠게 변해서 gloss retention rate은 낮아졌다. GA의 gloss retention rate은 100% > 64.82% > 34.02% > 19.74%, TN은 100% > 64.53% > 48.56% > 28.74%, CX는 100% > 54.58% > 23.74% > 14.87%, FT는 100% > 94.53% > 55.37%

> 14.76%, ES는 100% > 88.09% > 74.10% > 53.23%로 감소하였다 ($p<0.05$).

결과적으로 복합레진의 서로 다른 특성으로 인하여 복합레진 마다 GU에 차이가 있었다. 대조군과 비교 시 SiC paper를 이용하여 단계별로 거칠기를 준 후 복합레진의 gloss retention rate은 모두 감소하였으나 그 정도는 복합레진 별로 차이가 있었다. 그 중 가장 우수한 gloss retention rate을 보인 복합레진은 ES였다.

핵심되는 말 : 복합레진, 표면 광택도, 광택 유지도, 연마용 사포