Surface roughness and color stability of various composite resins

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ABSTRACT

The purpose of this study was to evaluate the difference in the surface roughness after polishing and to evaluate the difference in color stability after immersion in a dye solution among four types of composite resin materials. Four light-polymerized composite resins (Shade A2) with different sized filler content (a nanofilled, a hybrid, a microfilled, a flowble) were used. Average surface roughness (Ra) was measured with a surface roughness tester (Surftest Formtracer) before and after polishing with aluminum oxide abrasive discs (Super-Snap). Color of specimens before and after staining with 2% methylene blue solution were measured using spectrophotometer (CM-3700d) with SCI geometries. The results of Ra and $\triangle$E were analyzed by one-way analysis of variance (ANOVA), a Scheffe multiple comparison test and Student t-test (p = 0.05). After polishing, Ra values were decreased regardless of type of composite resins. In surface roughness after polishing and color stability after staining, nanofilled composite resin was not different with other composite resins except flowable resins. 〔J Kor Acad Cons Dent 32(6):542-549, 2007〕

Key words : Nanofilled, Surface roughness, Color stability, Filler size, Filler contents, Polishing

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Ⅰ. INTRODUCTION

The smooth surface of a restoration provides both optimum esthetics and longevity[1]. Surface irregularities may create clinical problems such as staining, plaque accumulation, recurrent caries and periodontal disease[2,3]. Also rough surface of composite resin restorations results in staining and discoloration due to infiltration of colorants[4].

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It decreases color stability, replacement of restoration should be required. In addition, rough surfaces would influence a dispersion of the light and reflection degree and affect the hue or the translucency of the surface. Though the color change of rough surface is not visible, it has an influence on optical properties. Replacement of restoration or additional polishing would be needed from unesthetic appearance[5]. Therefore, making smooth surface of composite resin restorations is essential step in restorative dentistry[6].

Surface roughness of composite resins is basically influenced by (1) the size, hardness, and amount of filler, (2) resin matrix composition, (3) hardness and grit size of the abrasives during polishing[7-9]. Among these various factors, character-

istics of filler particle such as size and volume should be regarded as one of the important factors. The increase of the filler contents and the reduction of the filler size contributed to reduce the wear rates[10-12] and to improve the surface smoothness of composite resin restorations[10,13,14].

It was reported that larger filler-particle size resulted in rougher surfaces[1,16]. There are many composite resins have various filler size and volume. In the last decades, the size of the filler particles in dental resin composite materials has decreased considerably, from 8-30 ㎛ in traditional composites to 0.7 - 3.6 ㎛ for modern small-particle composites[15]. The use of composite resins with a higher small-sized filler-particle content is increasing[17]. Increased amount of filler contents, decreased filler size and better distribution within the resin matrix result in smoother surfaces[9].

Recently, nanotechnology is of great interest in resin composite research. Nanofilled materials are contain nanometric particles and nanoclusters in a conventional resin matrix[18]. Nanofilled materials are believed to offer excellent wear resistance, strength and ultimate esthetics due to their exceptional polishability, polish retention and lustrous appearance[19]. And, the small size of the filler particles improves the optical properties of resin composites. The human's eye cannot detect the filler particles, because their diameter is lower than the wavelength of visible light (0.4 - 0.8 ㎛). As improving physical and optical properties, manufacturers now recommend the use of nanocomposites for both anterior and posterior restorations.

The aesthetics of restoration is influenced by the color stability of composite resin restorations as well as smooth surfaces. Discoloration of tooth-colored, resin-based materials may be caused by intrinsic and extrinsic factors[20]. The intrinsic factors involve the discoloration of the resin material itself, such as the alteration of the resin matrix and of the interface of matrix and fillers[20]. Extrinsic factors for discoloration include staining by adsorption or absorption of colorants as a result of contamination from exogenous sources such as coffee, tea, and beverages[21-23]. Extrinsic

factors include mechanical wear, microleakage, incomplete adhesion of composite resins and teeth, and rough surface[24-27]. Barkmeier and Cooley[28] were reported that the rougher of composite resin surface, the higher chance of staining and discoloration. Therefore, color stability of esthetic dental materials should also be important for a successful restoration with composite resins.

Among the numerous parameters, surface roughness and color change measurement are generally performed procedure and they are convenient for comparison of surface condition of composite resin restorations. Color change mathematically expresses the amount of difference between the $L^*a^*b^*$ coordinates of different specimens or the same specimen at different instances[29]. The Commission Internationale de l' Eclairage (CIE) $L^*a^*b^*$ color system, which is related to the color perception of the human eye for 3 coordinates, is an approximately uniform color space with coordinates for lightness, namely white-black (L^*), red-green (a^*), and yellow-blue (b^*)[30]. A spectrophotometer with an integrating sphere can operate at two different measuring geometries the specular component included (SCI) geometry, and the specular component excluded (SCE) geometry[31].

The objectives of this study were to evaluate the difference in the surface roughness among 4 types of composite resin materials before and after polishing and to evaluate the difference in color stability on color measuring geometries of SCE after immersion in a dye solution among four types of composite resin materials.

Ⅱ. MATERIALS AND METHODS

In this study, four light-polymerized composite resins (Shade A2) with different sized filler contents were used (Table 1). All the resin composites were packed into a teflon mold (8 ㎜ in diameter and 2 ㎜ in thickness) on a cover glass. After packing the composites, light cured for 30 seconds with a light-curing unit (Bluephase, Ivoclar vivadent, Shann, Liechte-nstein) with an output of 610 mW/cm² for cm². Ten specimens were prepared for

Table 1. Composite resins used in this study

Filler type	Brand name	Filler Composition	Manufacturer
Nanofilled	Filtek Z350	5 - 20 ㎜ size, 78.5 volume %	3M ESPE Dental Products, St Paul, MN, USA
Hybrid	Filtek Z100	0.01 - 3.5 ㎛ size, 66 volume %	3M ESPE Dental Products, St Paul, MN, USA
Micofilled	Metafil CX	1 - 100 ㎛ size, 54 volume %	Sun Medical, Shiga, Japan
Flowable	Metafil flo	0.015 - 20 ㎛ size, 44 volume %	Sun Medical, Shiga, Japan

each composite. All specimens were finished with green stone and white stone.

1. Surface roughness (Ra) measurement

The Ra of ten specimens of each composite measured with a cutoff value of 0.8 ㎜, a measuring speed of 0.5 ㎜/s with a surface roughness tester (Surftest Formtracer, Mitutoyo, Kanagawa, Japan). After then, the specimens were polished sequentially with medium, fine and superfine aluminum oxide abrasive discs (Super-Snap, Shofu, Kyoto, Japan) for 30 seconds. After polishing, the Ra of ten specimens of each composite measured.

2. Color difference (ΔE) measurement

In sequence, staining procedure was performed. Each specimen was immersed separately into 2% methylene blue solution for 24h. After immersion, specimens were rinsed with distilled water for 30 seconds.

Measurement was made between before and after polishing and after staining, according to CIE L*a*b* color scale relative to the CIE standard illuminant D65 over a white background on reflection spectrophotometer (CM-3600d, Minolta, Tokyo, Japan) with the specular component excluded (SCE) geometries. The illuminating and viewing configuration was CIE diffuse/8° geometry. The total color difference (ΔE^*ab) represents the sum of all color coordinate differences: L (lightness), a (-a green, +a red) and b (-b blue, +b yellow), and it was calculated as follows: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

3. Statistic analysis

Differences of the Ra values and ?E values among various composite resins were analyzed statistically by one-way analysis of variance (ANOVA) and a Scheffe multiple comparison test ($p = 0.05$). Also, (1) difference of the Ra values between before and after polishing, (2) the ΔE values for differences between after polishing and after staining were analyzed statistically by Student t-test ($p = 0.05$).

Ⅲ. RESULTS

1. Surface roughness

The results of the Ra values according to the type of composite resin and polishing are shown in Table 2.

The Ra values after polishing were decreased significantly in all type of resins ($p < 0.05$).

The Ra values of nanofilled and hybrid composite resin were lower than microfilled and flowable resin before polishing ($p < 0.05$). No significant difference was found between nanofilled and hybrid composite resin, between microfilled and flowable composite resin before polishing ($p > 0.05$).

After polishing, the flowable composite resin showed the smoothest surface, followed by the nanofilled, the hybrid, and the microfilled composite resins. But, there was no significant difference between flowable and nanofilled composite resin, between nanofilled and hybrid composite resin, and between hybrid and microfilled composite resin ($p > 0.05$).

Table 2. Ra values before and after polishing (Mean ± SD)

Composite resin	Before-Polishing	After-Polishing	Student *t*-test *p*-value
Filtek Z350	0.34 ± 0.06[a]	0.16 ± 0.02[ac]	*p* < 0.05
Filtek Z100	0.36 ± 0.07[a]	0.17 ± 0.03[ab]	*p* < 0.05
Metafil CX	0.52 ± 0.09[b]	0.19 ± 0.03[b]	*p* < 0.05
Metafil flo	0.46 ± 0.07[b]	0.13 ± 0.01[c]	*p* < 0.05

abc: Different letter indicates significant differences between the groups in vertical row (*p* < 0.05).

Table 3. Measured color (ΔE) after polishing and staining with SCE geometry (Mean ± SD)

Composite resin	After Polishing	After Staining	Student *t*-test *p*-value
Filtek Z350	3.70 ± 0.71[a]	2.60 ± 0.46[a]	*p* < 0.05
Filtek Z100	3.49 ± 0.48[a]	3.24 ± 1.02[a]	*p* > 0.05
Metafil CX	3.25 ± 0.55[a]	3.42 ± 0.59[a]	*p* > 0.05
Metafil flo	3.80 ± 0.59[a]	4.51 ± 0.39[b]	*p* < 0.05

ab: Different letter indicates significant differences between the groups in vertical row (*p* < 0.05).

2. Color stability

ΔE values by the measuring SCE geometry after polishing and after staining are shown in the Table 3.

ΔE values between after polishing and after staining were not different in hybrid and micro-filled composite resin (*p* > 0.05). After staining, ΔE value of nanofilled composite resin decreased significantly, ΔE value of flowable composite resin increased rather (*p* < 0.05).

ΔE values among all type of composite resins after polishing were not significantly different (*p* > 0.05).

After staining, ΔE value of flowable composite resin was the highest and different from others (*p* < 0.05).

IV. DISCUSSION

High quality finishing and polishing can improve the aesthetics and longevity of direct tooth-colored restorations[32]. The presence of surface irregularities arising from poor finishing and polishing may create clinical problems such as staining, plaque retention, gingival irritation, and recurrent caries[2,33,34]. However, it is difficult to finish and polish the composite resin restorations to the completely smooth surface. In the present study, the Ra values after polishing were decreased significantly in all type of resins (*p* < 0.05). Therefore, proper finishing and polishing of composite resin restorations are important steps in restorative dentistry[6].

Surface micromorphology of resin composites after polishing has been shown to be influenced by the size, hardness and amount of filler particles in composite[35]. In several studies[1,16], it was also reported that larger filler-particle size resulted in greater Ra values. And, an increase in the amount of filler content results in smoother surfaces because of decreased particle size and better distribution within the resin matrix[9]. Sarac et al.[17] reported that the lowest value was obtained with nanohybrid composite resin in nanohybrid, microhybrid, and hybrid composite resins. And, the highest Ra was obtained with hybrid resin. But, previous other studies[1,36] have shown that no

significant difference was found among various types of composite resins. In this study, the order of surface roughness from the roughest to the smoothest after polishing was microfilled, followed by the hybrid, then the nanofilled, and finally with the flowable composite resin. The Ra of nanofilled composite resin is similar to the Ra of flowable resin. The reason of this result is assumed that filler size of nanofilled resin is the smallest and filler volume percentage is the highest than others, so it polished more uniformly. But, total filler volume percentage of flowable resin was the lowest than others, and resin matrix contents were higher than others. Extremely increased matrix contents seemed to make smooth surfaces after polishing.

The surface conditions of resin composite restorations change during finishing and polishing procedures. The specular component is the reflected light from the surface such that the angle of reflection equals the angle of incidence. Inclusion or exclusion of a specular component may influence the measured color of composites with different surface conditions. The SCI geometry includes the specular component of the reflected light by placing a white cap at the specular reflection point in the integrating sphere. The SCE geometry excludes the specular component of the reflection by opening the white cap[31].

An increasingly roughed surface will reflect the individual segment of specular beam at slightly different angles. Lee et al.[31] stated that the SCE measuring geometry is more appropriate to detect small color differences of dental esthetic restorative materials when the surface conditions are not the same. Therefore, in this study SCE geometry was employed to measure the color of dental restorative materials.

Dietschi and colleagues[37] showed that (1) the staining may be related to a high resin content and water adsorption; (2) the resin matrix, which is a major component of composite resins, has been reported to be critical in color stability; (3) the higher filler content, the higher color stability.

In this study, when compared after polishing with after staining, ∆E value of nanofilled composite resin decreased significantly. ∆E value of flowable composite resin increased in spite of low Ra value. As, filler contents of flowable resin were lower than other resins, resin matrix contents increased. Therefore, it was seemed that absorption of stains increased.

Staining susceptibility of composites is not related to surface roughness alone, it is related to the volume and size of fillers. Increased filler size and filler content resulted in decrease of organic matrix. So, the amounts of color change were lower[1].

In this study, ∆E value of flowable composite resin was the highest after staining and different from others. In spite of the difference of size and volume of fillers among the used resins except flowable resin, color stability was not different statistically. But, in case of flowable resin due to extremely lower filler content, color stability was lower than others. *In vitro* surface roughness and staining test, these results proved that the staining susceptibility of composites is not related to extrinsic factors such as surface roughness alone, but to intrinsic factors such as filler and especially matrix composition as well.

A ∆E value of 3.7 or less is considered to be clinically acceptable according to Johnston and Kao[38]. In this study, after staining ∆E value of nanofilled, hybrid, microfilled composite resin was lower than 3.7, it's result was acceptable clinically. In anterior restoration, the use of nanofilled, hybrid, and microfilled composite resins would be acceptable when considered color stability. But, after staining ∆E value of flowable composite resin was higher than 3.7, color stability was very low. Therefore, though surface smoothness of flowable resin was good, flowable resin was unfavorable in color stability.

Compared with others, nanofilled composite resin wasn't excellent in surface roughness and color stability. And, further research is needed to assess the surface roughness and the color stability of other nanocomposites.

Ⅴ. CONCLUSIONS

1. The Ra after polishing was decreased regardless of type of composite resins ($p < 0.05$).

2. After polishing, the flowable composite resin showed the smoothest surface, followed by the nanofilled, the hybrid, and the microfilled composite resins. But, there were no significant differences between flowable and nanofilled composite resin, between nanofilled and hybrid composite resin, and between hybrid and microfilled composite resin ($p > 0.05$).

3. ΔE values among all type of composite resins after polishing were not significantly different ($p > 0.05$). After staining, ΔE value of flowable composite resin was the highest and different with others ($p < 0.05$).

Within the limitations of this study, nanofilled composite resin, except the flowable resin, was not different with other composite resins in surface roughness after polishing and color stability after staining.

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국문초록

수종의 복합 레진의 표면 거칠기와 색 안정성

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본 연구의 목적은 네 종류의 복합레진의 연마 후의 표면 거칠기에 있어서의 차이와 염색액에 담근 후 색 안정성에 있어서의 차이를 평가하기 위한 것이다. 필러 크기와 함량이 다른 (나노입자형, 혼합형, 미세입자형, 흐름성) 네 종류의 광중합 복합레진 (색상 A2)을 사용하였다. 산화 알루미늄 마모 디스크 (Super-Snap)로 연마하기 전과 후에 평균 표면 거칠기 (Ra)를 표면 조도 측정기 (Surftest Formtracer)로 측정하였다. 2% 메틸렌 블루 용액으로 착색하기 전과 후 표본의 색은 SCI geometry를 이용해 spectrophotometer (CM-3700d)로 측정되었다. 표면 거칠기와 색 변화 값은 one-way ANOVA, Scheffe multiple comparison test와 Student t-test로 분석되었다. 연마 후, 표면 거칠기 값은 복합레진의 종류에 관계없이 감소하였다. 연마 후 표면 거칠기와 착색 후 색 안정성에 있어서, 나노입자형 복합레진이 흐름성 레진을 제외한 다른 복합레진들과 유사하였다.

주요어: 나노입자형, 표면 조도, 색 안정성, 필러 크기, 필러 함량, 연마