연마시기에 따른 복합레진의 표면 특성에 관한 연구

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국문초록

적절한 마무리와 연마는 치아 수복물의 심미성과 내구성을 향상하기 위하여 필수적인 과정이다. 본 연구에서는 복합레진의 마무리/연마 과정 시행에 있어서 시기적 차이를 두어 마무리/연마 시기가 복합레진의 표면 거칠기와 경도에 미치는 영향을 비교하고자 하였다.

네 종류의 복합레진(Filtek A110, Silux Plus, Revolution formular2, Palifique Estelite)을 이용하여 실현을 제작하고 마무리/연마 과정을 거쳐지 않은 대조군과 종합 직후 마무리/연마를 시행한 경우와 1주 후 마무리/연마를 시행한 두 가지 실험군으로 구분하였다. 이 시험들의 표면 거칠기(R. value, μm)와 경도(VHN)를 측정하고, 주사전자현미경으로 관찰하여 다음과 같은 결과를 얻었다.
1. 네 가지 재료 모두 대조군에서 가장 높은 표면을 얻었고 마무리/연마 과정을 거친 후 표면 거칠기가 증가하였으나, 마무리/연마 시기에 따른 유의한 차이는 보이지 않았다.
2. 표면 거칠기는 종합 직후 마무리/연마를 시행한 경우 Silux Plus와 Revolution formular 2가 차이를 보였고, 1주 후 시행한 경우 Silux Plus와 Palifique Estelite가 차이를 나타내었다(p<0.05).
4. 마무리 연마시기가 표면 거칠기와 경도에 미치는 영향은 재료에 따라 차이를 보였다.

주요 : 복합레진, 마무리/연마 시기, 표면거칠기와 경도

I. Introduction

Proper finishing/polishing of dental restorations are critical clinical procedures that enhance both esthetics and longevity of restored teeth. Residual surface roughness related to composite resin restorations can result in a number of clinical problems for the dentist and the patient such as plaque accumulation, gingival irritation, surface staining, and secondary caries. Finishing is to contour and reduce grossly the restoration to obtain the desired anatomy and polishing is to reduce the roughness and scratches created by the finishing instruments.

The surface created against the restoration matrix often has been shown to be smooth. However, the surface is rich in resin binder, less abrasion-resistant and can contain voids. In clinical practice, it is more common to slightly overfill the cavity and contour back the excess and so produce a harder, more wear-resistant surface.

There is always a problem during finishing/polish-
ing of composite material because the resin matrix and the inorganic filler differ in hardness and so do not abrade uniformly\(^6\).

Composites differ mainly in their inorganic component. The type of inorganic filler, the size of the particles, and the extent of the filler loading vary widely among composites. Such factors influence the polishability of the composite\(^6\). Another approach to the improvement of surface quality of composite resins is the elapsed time between removal of the matrix and finishing\(^7\).

The purpose of this study is to compare the effects of immediate and delayed finishing/polishing procedures on the surface roughness and hardness of those composite resins.

II. Materials and methods

The materials used in the study were as follows: (1) Filtek A110 (3M, USA) (2) Silux Plus (3M, USA) (3) Revolution formular 2 (Kerr, USA) (4) Palfique Estelite (Tokuyama Dental Corp., Japan) (Table 1). All materials were manipulated according to the manufacturers’ instruction. Teflon molds, specimens of 10 mm in diameter and 3 mm in thickness, were first slightly over-filled with the material under evaluation.

The samples were then covered with a Mylar sheet and a glass slide on each side prior to curing with a visible light curing unit (Coltostar, Coltene, USA). Materials were cured on each side of the mold for 30 seconds through the Mylar sheet and glass slide, receiving an additional 60 seconds without those sheets in place.

A total of 48 specimens were made for each material. 16 of them served as the control group and the remaining 32 specimens were randomly divided into two equal groups. The first group was finished/polished immediately after light polymerization and stored for 1 week in distilled water at 37°C, whereas the second group was finished/polished 1 week after light polymerization and stored in distilled water at 37°C. The control group was stored in distilled water at 37°C for 1 week after light polymerization against the Mylar sheet.

Finishing/polishing using the Sof-Lex (3M, USA) was accomplished according to the manufacturer’s directions (Table 2). The Sof-Lex system is a series of four coated abrasive disks that decrease in aggressiveness and particle size as one progresses from coarse through medium, fine, and super-fine disks. The disks were applied with light pressure in a circular pattern and were discarded after use.

All specimens were then examined in the surface roughness and hardness evaluation below described.

1. Surface roughness evaluation

Profilometric analysis were carried out with the Surfcomer SE1700 (Karaka Laboratory Ltd., Japan). The typical profile tracings for the various materials and polishing techniques were compared and the Ra values recorded. The Ra values is the arithmetic mean of the departures of the roughness profile from the mean line calculated by the computer. Five traces were recorded on each specimen at five different locations and along the direction of rotation of

<p>| Table 1. Materials tested in this study |</p>
<table>
<thead>
<tr>
<th>Material</th>
<th>Brand Name</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>Microfilled composite</td>
<td>Filtek A110</td>
<td>3M</td>
</tr>
<tr>
<td></td>
<td>Silux Plus</td>
<td>3M</td>
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<tr>
<td>Hybrid composite</td>
<td>Revolution formular 2</td>
<td>Kerr</td>
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<tr>
<td></td>
<td>Palfique Estelite</td>
<td>Tokuyama Dental Corp.</td>
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<p>| Table 2. Finishing/polishing system and sequences tested in this study |</p>
<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sof-Lex</td>
<td>3M</td>
<td>coarse(30s) - medium(30s) - fine(30s) - superfine(30s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dry - wash - dry - wash - dry - wash</td>
</tr>
</tbody>
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99
the polishing instrument.

2. Microhardness test

The Vickers hardness number (VHN) was determined for each specimen with the Microhardness tester FM (Future Tech Corp., Japan). Indentations were made with a 300 g load applied for 10 seconds.

3. SEM analysis

A scanning electron microscope (JSM5400, JEOL, Japan) photomicrographed each sample at magnifications ×500. Polished surfaces with the Sof-Lex were compared with the unpolished surfaces for each material.

4. Statistical analysis

Data were analysed using Kruskal walis test, Tukey HSD multiple comparison test to test for differences among means (p<0.05), and correlation test.

II. Results

1. Surface roughness evaluation

The smoothest surfaces were produced by the Mylar sheet and finishing/polishing procedure increased surface roughness. However, finishing/polishing timing had no influence on surface roughness. There were significant differences of surface roughness between Revolution formular 2 and Silux Plus regarding immediate finishing/polishing, and between Palique Estelite and Silux Plus regarding delayed finishing/polishing (p<0.05) (Table 3).

2. Microhardness test

The sequence of the hardness was ascending order by Revolution formular 2, Silux Plus, Filtek A110, Palique Estelite. However, there was no significant difference in hardness among the control group and

<table>
<thead>
<tr>
<th>Table 3. Surface roughness values (mean±SD, µm)</th>
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<tr>
<td>Control</td>
</tr>
<tr>
<td>Filtek A110</td>
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<tr>
<td>Silux Plus</td>
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<tr>
<td>Revolution formular 2</td>
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<td>Palique Estelite</td>
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Values connected by brackets are not significantly different at p<0.05.

<table>
<thead>
<tr>
<th>Table 4. Vickers hardness number (mean VHN±SD)</th>
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<tbody>
<tr>
<td>Control</td>
</tr>
<tr>
<td>Filtek A110</td>
</tr>
<tr>
<td>Silux Plus</td>
</tr>
<tr>
<td>Revolution formular 2</td>
</tr>
<tr>
<td>Palique Estelite</td>
</tr>
</tbody>
</table>

Values connected by brackets are not significantly different at p<0.05.
two finishing/polishing timing groups. For all materials, delayed finishing/polishing with the Sof-Lex generally resulted in similar surface hardness with immediate finishing/polishing and the control group (Table 4).

3. SEM analysis

SEM of the surface of the composite resin specimens finished with Sof-Lex and Mylar strip exhibited surface features which were essentially independent of finishing/polishing timing and Sof-Lex disks produced some scratches (Fig. 1~12).

IV. Discussion

According to Johnson et al. \(^9\), Chandler et al. \(^9\), Glantz and Larson\(^10\), McLundie and Murray\(^11\), and Heath and Wilson\(^13\), a smooth surface is an essential requisite for a successful restoration. Previous studies have shown that the smoothest surface obtainable on composite resin restorations was achieved by curing the material in direct contact with a smooth matrix surface\(^9,12\). Criteria such as surface roughness, particle-size distribution, and surface hardness characterize the outer surfaces of materials and are important parameters in determining their polishability and abrasive-wear rate\(^15,16\).

The surface directly influences the longevity of the restoration and its environment, but researching the clinical behavior of materials is arduous\(^17\). Lui and Low\(^18\), Wet and Hardwick\(^19\), Wet and Ferreira\(^20\), Kelsey et al.\(^21\), and Christensen and Christensen\(^22\) believed that microfilled composite resins were more efficiently polished with aluminium-oxide disks. If we use the same instruments for the hybrid composite resins, better results would be seen than for the microfilled composites with the exception of the use of aluminium-oxide disks. Tjan and Chan\(^6\), Wet and Ferreira\(^20\) indicated that the difference in surface roughness between both types of composite resins might be attributed to the difference in composition of the particles of inorganic filling. This created unequal wear and roughness in the composite resins with less inorganic filling and, consequently, less hardness.

In this study, the smoothest surface was produced by Mylar sheet. Surface smoothness has not been improved regardless of timing of finishing/polishing procedure that were employed. Microfilled composites, such as Silux Plus showed the rougher surface than Revolution formula2 regarding immediate finishing/polishing, than Palfique Estelite regarding delayed finishing/polishing.

From simple observation, it can be deduced that posterior composite resins with smaller filler particles produced a smoother surface\(^6\). The American Dental Association Council on Dental Materials considered composites containing filler particles size up to 5 um as "polishable" composites\(^23\). Analysis of the data revealed that increased hardness resulted in increased surface roughness. In addition, the data tend to indicate that the hardness of the composite increased with an increase in the filler content, which agreed to the findings of Li et al.\(^24\).

Another approach to the improvement of surface quality of composite resins is the elapsed time between removal of the matrix and finishing\(^7\). Will there be a difference in surface smoothness if the composite resin is finished at the same appointment or later?

Reports vary on the best time to finish a composite resin. Two of them recommended finishing as soon as the matrix is removed or immediately following polymerization with an ultraviolet light\(^25,26\). Another author recommended waiting for 10 to 20 minutes before finishing\(^27\).

On the other hand, one authority suggested waiting for at least 24 hours before finishing\(^28\). Another recommended delaying finishing until the next appointment\(^29\). Studies showed that composite resins continue to polymerize after the initial set and they harden over a period of time\(^27,28,29\). These studies would suggest that delaying finishing would allow the resin to become harder and then smoother surface may be made.

In this study, for all materials, finishing/polishing timing had no influence on the surface roughness. Hardness may be as the resistance to permanent indentation or penetration. It is, however, difficult to formulate a definition that is completely acceptable, since any test method will involve complex stresses in the material being tested from force applications, with the result that a variety of qualities are in-
olved in any single hardness test\(^3\). Change in hardness may reflect the state of cure of a material and the presence of an on-going setting reaction or maturity of the restorative material\(^2\). In the experiment, hardness testing was conducted after 1 week storage in distilled water at 37°C for all specimens. Maturity of cement at the time of evaluation was thus common and any differences in hardness may be attributed to the effects of the finishing/polishing procedures at the two time intervals\(^2\).

Helvatjoglou Antoniadis et al.\(^30\) found that surface hardness was improved by finishing/polishing procedures. The delayed finishing/polishing of microfilled composite resin resulted in a significantly harder surface for all of the finishing/polishing techniques employed. Approximately 75% of the polymerization of photopolymerized composite resins take place during the first 10 min but this curing reaction may continue for a period of 24 hours\(^31\). As finishing/polishing procedures were conducted immediately after photopolymerization, this pre-maturity could make the composite more susceptible to effects of heat generation. Heat generation frequently leads to swarm reattachment to the surface as the resin matrix is softened, resulting in lower hardness values\(^32\). The heat generated also causes smearing of the resin and the creation of local hot spots\(^33\). Delaying finishing time may make the composite less susceptible to the negative effects of heat generation\(^34\). In this study, delayed finishing/polishing of composite resin with the Sof-Lex system increased hardness as compared to the control. The reason for this observation is not known and warrants further investigation. The results obtained in heavily filled composite resin were, however, different. No significant difference in hardness between the two finishing/polishing times were noted.

Every effort was made to standardize the various aspects of the methodology in the study. The variations in each group may be accounted for by the differences, in pressure exerted on the glass plates during fabrication and finishing/polishing of the specimens. The aforementioned parts of the experiment were conducted by only one operator to keep variations to a minimum. The instruments were used at slow speed with a constantly moving, polishing action. A special effort was made to avoid holding the instrument in one location with heavy pressure. Movement of the instrument prevents heat generation and creation of grooving.

Therefore, the roughness might also be due to the hardness of the instruments, which are rarely perfectly rounded or absolutely concentric. This lack of smoothness could also create scratches\(^17\).

The Sof-Lex disk system is a classic, coated-abrasive system, utilizing abrasive particles of decreasing size and abrasiveness over the three of four disks used clinically to finish and polish composite resins\(^35\). Data from this indicate that the Sof-Lex disk system is highly effective for composites. The average surface roughness after Sof-Lex finishing, appeared no significant difference as compared with the control group.

Finishing/polishing is also a function of time, meaning that the results depend on the amount of time spent in the finishing procedure\(^36\). The results presented in this study may not be optimal and may be at variance with other studies, but the time increments used in each successive step of finishing are considered clinically realistic.

Average surface roughness measurement provide little information about the true nature of a surface finish. Indeed, it can be misleading in that the surface of 2 dissimilar materials may have similar Ra values but may have a very different appearance\(^36\).

Results from the visual comparison of SEM micrographs were corroborated by quantitative evidence from the profilometry studies. A variety of abrasive instruments are available for use in the air turbine, which could be used for gross trimming, but the high speed at which they run creates considerable surface damage and this would be difficult to remove by final polishing. Degradation of the sub-surface resin matrix by excessive heat production during contouring could lead to considerable early surface wear of the restoration. Contouring and shaping are satisfactorily achieved with instruments that run at low speeds. Careful contouring of the unpolymerized composite resin with hand instruments reduces the need for rapid removal of large amounts of hardened resin and consequently reduces the risk of surface damage\(^36\).

In conclusion, this in vitro study showed no differences in surface roughness of composite resins fin-
ished at different time intervals. This results did confirm that the smoothest surface occurs after removal of the matrix, and wherever possible, composite resins should be left completely untouched when the contour and margins are correct.

As was discussed by St Germain and Meiers, correlation to clinical practice may be limited to situations where accessible, relatively flat surfaces are finished. Further study is needed to determine which finishing techniques are best suited to surfaces.

V. Conclusions

Four brands of composite resins were evaluated for the effects of immediate and delayed finishing/polishing procedures on the surface characteristics (surface roughness and hardness).

The results were as follows:
1. The smoothest surface was produced by Mylar sheet and finishing/polishing procedure increased surface roughness. However, the surface roughness of composite resins were not influenced by the finishing/polishing timing.
2. There were significant differences about surface roughness between Revolution formular 2 and Silux Plus regarding immediate finishing/polishing, and between Palique Estelite and Silux Plus regarding delayed finishing/polishing ($p<0.05$).
3. The sequence of the surface hardness was ascending order by Revolution formular 2, Silux Plus, Filtek A110 and Palique Estelite. However, there was no significant difference in hardness among the control group and two finishing/polishing timing groups.
4. The effects of finishing/polishing time on surface roughness and hardness appears to be material dependent, but there was no correlation between surface roughness and surface hardness.

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Explanation of Figures

**Fig. 1.** SEM micrograph of Filtek A110 with Mylar-produced surface ($\times 500$).

**Fig. 2.** SEM micrograph of Filtek A110 finished/polished immediately with the Sof-Lex system ($\times 500$).

**Fig. 3.** SEM micrograph of Filtek A110 finished/polished after 1 week with the Sof-Lex system ($\times 500$).

**Fig. 4.** SEM micrograph of Silux Plus with Mylar-produced surface ($\times 500$).

**Fig. 5.** SEM micrograph of Silux Plus polished finished/polished immediately with the Sof-Lex system ($\times 500$).

**Fig. 6.** SEM micrograph of Silux Plus finished/polished after 1 week with the Sof-Lex system ($\times 500$).
Explanation of Figures

Fig. 7. SEM micrograph of Revolution formular 2 with Mylar-produced surface (×500).

Fig. 8. SEM micrograph of Revolution formular 2 finished/polished immediately with the Sof-Lex system (×500).

Fig. 9. SEM micrograph of Revolution formular 2 finished/polished after 1 week with the Sof-Lex system (×500).

Fig. 10. SEM micrograph of Palfique Estelite with Mylar-produced surface (×500).

Fig. 11. SEM micrograph of Palfique Estelite finished/polished immediately with the Sof-Lex system (×500).

Fig. 12. SEM micrograph of Palfique Estelite finished/polished after 1 week with the Sof-Lex system (×500).
Abstract

A STUDY ON THE EFFECTS OF FINISHING/PolISHING TIMING ON SURFACE FEATURES OF COMPOSITE RESTORATION

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Department of Pediatric Dentistry, and Dental Research Institute, College of Dentistry, Chonnam National University, Gwangju Health College, Department of Dental Hygiene*

Proper finishing/polishing of dental restorations are critical clinical procedures that enhance both esthetics and longevity of restored teeth. This study was to compare the effects of immediate and delayed finishing/polishing procedures on the surface roughness and surface hardness of tooth-colored restorative materials including two microfilled composite resins, such as Filtek A110 and Silux Plus, two hybrid composite resins, such as Revolution formular2 and Palifique Estelite. A total of 48 specimens were made for each material. The first 16 specimens served as the control group and the remaining 32 specimens were randomly divided into two equal groups. The control group was stored in distilled water at 37°C for 1 week after light polymerization against the Mylar sheet. The first experimental group was finished/polished immediately after light polymerization and stored for 1 week in distilled water at 37°C, whereas the while the second group was finished/polished 1 week after light polymerization and stored in distilled water at 37°C.

The results were as follows:

1. The smoothest surface was produced by Mylar sheet and finishing/polishing procedure increased the surface roughness. However, the surface roughness of composite resins were not influenced by the finishing/polishing timing.

2. There were significant differences about surface roughness between Revolution formular 2 and Silux Plus regarding immediate finishing/polishing, and between Palifique Estelite and Silux Plus regarding delayed finishing/polishing (p<0.05).

3. The sequence of the surface hardness was ascending order by Revolution formular 2, Silux Plus, Filtek A110 and Palifique Estelite. However, there were no significant differences about hardness among the control group and two finishing/polishing timing groups.

4. The effects of finishing/polishing time on surface roughness and hardness appeared to be material-dependent.

Key words: Composite resin, Finishing/polishing timing, Surface roughness and hardness