Microleakage of class Ⅱ posterior composite resin filling using various light curing methods

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ABSTRACT

구치부 광중합 복합레진 수복시 여러 광조사 방법에 따른 미세변연누출에 관한 연구

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목 적

최근 복합레진의 미세변연누출을 줄이기 위한 새로운 광중합 조사방법이 연구되고 있다. 또한 구치용 복합레진이 개발되면서 그 제조회사에서는 5mm 깊이까지 광중합이 가능하다고 소개하고 있다. 본 연구에서는 논리적 가설에 근거한 몇가지 광중합 조사방법이 구치부 class Ⅱ 와동의 복합레진 충전시 미세변연누출에 어떠한 영향을 미치는지를 관찰하였다.

재료 및 방법

100개의 우식증이 없는 사람의 상하악 대구치를 사용했다. 각 치아에 교합-치은방향으로 4mm, 협설 4mm, 깊이 2mm의 class Ⅱ 와동을 형성하여 인접치와 함께 베이스플레이트 왁스에 매몰하고 구치용 복합레진인 Surefil을 제조회사의 지시대로 충전하였다. 이때 5가지의 광조사방법을 이용하여 5개의 군으로 나누어 중합하였다(Table 1).

수복된 치아들을 5℃와 55℃의 수조에서 번갈아 1분씩 총 500회의 온도변화를 주어 thermocycling을 실시한 후 근첨을 폐쇄하고 수복와동의 치은경계를 제외한 전 표면에 nail varnish를 2회 도포하였다. 2%의 methylene blue용액에 24시간 침적시키고 흐르는 물에 세척한 후 시편을 투명한 에폭시 레진에 매몰하였다. 매몰된 시편을 치아 장축에 평행하게 절단 연마하였다. 입체 현미경으로 미세변연누출을 관찰하고 Kruskal-Wallis One Way ANOVA 와 Dunn's Method로 통계처리 하였다.

Table 1. 광중합 방법 및 총에너지

	방 법	과 정	총 에너지
1군	Soft-start polymerization	$200mW/cm^2 \times 10sec$ and $400mW/cm^2 \times 35sec$	$16000mJ/cm^2$
2군	Pulse-activation	$300mW/cm^2 \times 3sec$ and 3-5min later $400mW/cm^2 \times 38sec$	$16100mJ/cm^2$
3군	Low-curing light intensity	$200mW/cm^2 \times 80sec$	$16000mJ/cm^2$
4군	Moderate-curing light intensity	$400mW/cm^2 \times 40sec$	$16000mJ/cm^2$
5군	High-curing light intensity	$600mW/cm^2 \times 27sec$	$16200mJ/cm^2$

결 과

1. 미세누출은 1군, 4군과 5군, 2군 3군 순으로 증가였다. 이때 1군, 4군과 5군은 통계적 유의성이 없었다($P>0.05$).
2. 2군의 경우 1군, 4군, 5군에 비교하여 유의성 있게 미세누출이 많았으며($P<0.05$) 3군에 비하여 유의성 있게 적게 나타났다($P<0.05$).
3. 3군의 경우 다른 방법들에 비교하여 통계적으로 유의성 있게 미세누출이 많았다($P<0.05$).

주요어 : Softstart polymerization, Pulse-activation, 중합 광강도, 미세변연누출, 구치부용 레진

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I. Introduction

The invention of light curing composite resin is a revolutionary event in the development of dental restorative materials. After composite resin was introduced in 1960's, many discussions arose concerning composite as a amalgam substitute. But for many years the use of composite resin had produced a significant number of short-term failures. Inadequate wear resistance, postoperative sensitivity, secondary caries, and fracture were the most serious problems. The idea of using composite as an amalgam substitute was abandoned[1]. During the past 30 years, most of these shortcomings have been overcome. The most significant weakness of posterior resins, wear resistance, has been improved and is now shown to be similar to that of amalgam[2]. Compared with amalgam restorations, posterior composite restorations are more complex, time-consuming, and technique sensitive in clinical application so far. Furthermore, because of incremental curing methods, posterior resin restorations are more time-consuming than amalgam restorations. It was reported that current posterior resin products could be cured to the depth of 5mm[3] and restoration time could be saved because more amount of resin could be cured at a time.

One of the shortcomings of posterior composite resin, polymerization shrinkage, is still remain. It is the most critical problem of not only posterior composite resin but also anterior composite resins. Polymerization shrinkage can create mechanical stresses in the resin composite and these stresses can break the marginal seal between the composite restoration and tooth substance. Resulting gap can be significantly large enough to allow for the invasion of oral and pulpal fluids and bacteria[4].

Some methods have been introduced to reduce marginal gaps due to polymerization shrinkage. The incremental curing technique can reduce the marginal gap better than bulk curing method[5]. But incremental curing technique takes more time than bulk curing method. Spending more time may cause clinical error.

Another method to minimize the polymerization shrinkage with short clinical time is to allow flow of composite resin during setting by means of controlled polymerization. This can be done by pre-polymerization at low light intensity followed by final cure at high light intensity. Uno[6] reported that the reduced rate of polymerization might allow for increased flow of the material, decreasing the contraction stress in the filling. Unterbrink and Muessner[7] reported that in clinically relevant layer thicknesses, curing a resin composite with a higher intensity light might demonstrate significant disadvantages due to increased shrinkage stress. Mehl *et al.*[8] reported that initial cure with low light intensity followed by final cure with high light intensity significantly improved the marginal integrity of light-cured composite fillings and also the material properties(Softstart-polymerization). Kanca and Suh[9] reported that prolonged gel state allowed flow to occur in the resin based composite. Pulse-activated group in their study(2 seconds at 300-350mW/cm^2 followed by 10 seconds at 600mW/cm^2)showed very little marginal leakage.

The aim of this study was to compare the microleakages of class II posterior composite resins cured with 5 different curing methods. Low intensity light curing, moderate intensity light curing, high intensity light curing, pulse-activation and Softstart-polymerization, were used.

II. Materials and Methods

One hundred extracted human molars stored in 0.5% chloramines solution were used. All teeth were caries-free and the length between the cemento-enamel junction and the occlusal surface was longer than 4mm. Class II cavities were prepared with #557 fissure-type carbide bur. The box had a bucco-lingual width of 4mm, an axial depth of 2mm and depth from the occlusal surface to the gingival surface of 4mm. The gingival margin was on the cemento-enamel junction. If the length between the cemento-enamel junction and the occlusal surface was longer than 4mm, occlusal surface was reduced. The teeth were set in base plate wax with adjacent teeth and metal matrix band were applied. The teeth were randomly divided into 5 groups of twenty. Surefil(Dentsply, Konstanz, Germany) resin was applied according to the manufacturer's instructions

Table 1. *Curing methods and procedures used in this study*

Curing methods		Procedure	Total energy
Group 1	Soft-start polymerization	$200mW/cm^2 \times 10sec$ and $400mW/cm^2 \times 35sec$	$16000mJ/cm^2$
Group 2	Pulse-activation	$300mW/cm^2 \times 3sec$ and 3-5min later $400mW/cm^2 \times 38sec$	$16100mJ/cm^2$
Group 3	Low-curing light intensity	$200mW/cm^2 \times 80sec$	$16000mJ/cm^2$
Group 4	Moderate-curing light intensity	$400mW/cm^2 \times 40sec$	$16000mJ/cm^2$
Group 5	High-curing light intensity	$600mW/cm^2 \times 27sec$	$16200mJ/cm^2$

Table 2. Averages and standard deviations of microleakage scores

Curing methods	Average	SD
Group 1 Softstart-polymerizarion	2.30	1.03
Group 2 Pulse-activation	3.30	0.86
Group 3 Low-curing light intensity	4.00	0.00
Group 4 Moderate-curing light intensity	2.45	1.00
Group 5 High-curing light intensity	2.45	0.83

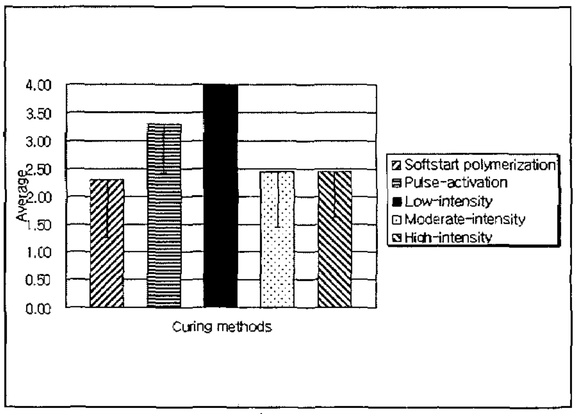

Fig. 1. Averages and standard deviations of microleakage scores.

with etchant and Prime & Bond(Dentsply, Konstanz, Germany). Five different light curing methods were applied(Table 1). A recently developed light curing unit, VIP(variable intensity polymerizer, BISCO, Inc., Schamburg, IL., USA)was used

Group Ⅰ (Softstart-polymerization, Mehl *et al.*[8] 1997)

The initial curing light intensity was $200mW/cm^2$ and the final curing light intensity was $400mW/cm^2$. Because the manufacturer recommended 40seconds at $400mW/cm^2$ with total curing energy of $16000mJ/m^2$, 10 seconds was applied for initial curing and 35 seconds for final curing in this study.

Group Ⅱ (pulse-activation Kanca, Suh[9] 1999)

The initial curing was 3 seconds at $300mW/cm^2$ and 3-5minutes later 38 seconds at $400mW/cm^2$ was applied for final cure. The total energy was $16100mJ/cm^2$.

Group Ⅲ (Low-curing light intensity)

The curing light intensity was $200mW/cm^2$ and the curing time was 80 seconds. The total energy was $16000mJ/cm^2$.

Group Ⅳ (Moderate-curing light intensity)

The curing light intensity was $400mW/cm^2$ and the curing time was 40 seconds. The total energy was $16000mJ/cm^2$.

Group Ⅴ (High-curing light intensity)

The curing light intensity was $600mW/cm^2$ and the curing time was 27 seconds. The total energy was $16200mJ/cm^2$.

After the restored teeth were removed from the base plate wax, proximal surfaces were polished with Soflex (3M Dental product, St Paul, MN, USA) disks. After 24hours of storage in saline, the teeth were thermocycled (500 cycles at 5℃ and 55℃, 1 minute each time). All the surfaces except gingival margins were coated with two layers of nail vanish and the teeth were immersed in 2% methylene blue dye solution for 24 hours.. After being embedded in acrylic resin, the teeth were sectioned in the center of the resin restorations in a mesio-distal direction with diamond saw (Isomet, Buehler co., USA)

Microleakage was evaluated according to a 5-point rating scale using ×20 stereomicroscope(Stereo Zoom Microscope, Olympus, Japan).

0: no leakage
1: leakage to the 1/3 point
2: leakage to the 2/3 point
3: leakage to the axio-gingival line angle
4: leakage to the axial wall

The means and standard deviations of microleakage for each group were compared for statistically significant differences using Kruskal-Wallis one way ANOVA and Dunn's method

Ⅲ. Result

Microleakages measured, in increasing order are as follow, group 1, group 4 and 5, group 2, group 3. Among the results of group 1, group 4 and group 5, there was no statistical significant difference in microleakage. The results of group 2 were significantly higher than those of group 1, group 4 and group 5($p<0.05$). In turn this was also significantly lesser than that of the group 3($p<0.05$). The microleakage of group 3 was higher than that of the other groups and this difference was statistically significant ($p<0.05$)(Table 2, Fig. 1).

Ⅳ. Discussion

Light curing composite resin made it possible not only to do minimally invasive dental restoration but also to replace amalgam. In the early days of light curing composite resin, it had a lot of disadvantages such as low abrasion resistance, incomplete curing, color instability, polymerization contraction, marginal microleakage, and so on. New filler, new filler ratio, new photo-activator and new accelerator made it possible to overcome these disadvantages. Light curing with higher intensity was thought to improve the degree of conversion, so dentists were recommended to check the light intensity of curing unit[10]. But in the 1990s, this theory have been challenged. Myazaki[11], Mehl[8], Sakaguchi[12] reported that curing with low light curing intensity exhibited equivalent mechanical properties and low intensity curing might be beneficial to resin and tooth structure adaptation[13,14].

Davidson and deGee[15] reported that shrinkage stresses could be reduced by the capacity for flow to occur in a restoration. Again, flow is thought to be the ability of molecules to slip into new orientations during the polymerization process. Flow is typically severely limited in resin-based composites which undergo rapid polymerization, as light-activated materials typically do. Another author[7] reported that curing direct composite restorations with high intensity lights might lead to reductions in marginal quality. The development of the modulus was influenced by the light intensity and this was probably representing the most important contribution towards alteration of shrinkage stress. It was reported that initial cure with 57% and 70% intensity of final cure for 20 seconds followed by final cure at 100% for 40 seconds significantly decreased the marginal gap[8]. On the basis of the result the author introduced Softstart-polymerization. In our study, this method was modified to 10 seconds for initial cure at 50%(200mW/cm^2) light intensity and 35 seconds for final cure at 100%(400mW/cm^2)light intensity, was used to equalize the total energy. Kanca and Suh[9] reported that the pulse activation method caused the slowest rate in surface hardness development at the top surface of the resin-based composite sample. Slowing down the rate of polymerization, and thus the development of modulus potentially had significant benefits. Goracci *et al*[16] reported almost the same result, that is, the adaptation of resin composites to the dentinal surface could be improved by reducing the speed of polymerization. Silikas et al[17] reported that the correlation between degree of conversion and shrinkage strain values meant that some reduction in the problems of shrinkage might be achieved by an acceptable deduction in the degree of conversion. Although most researchers have demonstrated positive results with slow or Softstart curing, Sakaguchi and Karren[18] reported no significant difference in microleakage at the gingival or the occlusal margins when restorations were cured using neutral density filters to decrease the output of a laser-curing unit. They reported that reduced output did not improve marginal integrity compared to conventionally or chemically cured restorations.

Although the marginal microleakages were reduced by the reduced initial light curing intensity, change of physical properties were another problem. In a previous article[6], it was reported that the initial cure with decreased light intensity followed by final cure with high light intensity had no influence on microhardness and increased flexural modulus and flexural strength. But the variation in light intensity did not significantly affect post-cure hardness profiles to a depth of 4.5mm[7].

According to the result of this study, microleakage of Softstart-polymerization, moderate intensity curing and high intensity curing were not significantly different. Mehl *et al*[8] reported that with different initial curing intensities, 20 seconds at 37%, 56%, 70% and 100% followed by 40 seconds at 450mW/cm^2, the dye penetration test showed no statistically significant difference. In this case the specimen had diameter of 2.0mm and depth of 1.8mm. And the dye penetrations were tested on the dentin and resin interfaces. In our study, pulse-activation method showed more leakage than Softstart polymerization, moderate intensity and high intensity curings. Most of all, the curing intensity of 300mW/cm^2 only for 3 seconds was not enough to reach the gingival margin and with this condition, matrix band was not stable to maintain the marginal integrity during 3~4 minutes. According to these studies, the microleakage of resin-dentin bonding is almost the same regardless of the curing method if the method can cure all the resin to the dentin margin. But if the curing method can not reach the bottom of the resin filling, marginal integrity is questionable. In our study, all the specimens in the 80 seconds at 200mW/cm^2 group showed maximum microleakage. This does not mean that lower intensity light curing affect the microleakage of resin margin. The light curing intensity of 200mW/cm^2 is not enough to reach the gingival margin. Rueggeberg *et al*[19] reported that sources with intensity values less than 233mW/cm^2 should not be used because of their poor cure characteristics. Combined method of low intensity light curing and high intensity light curing showed minimum marginal leakage.

The aim in using lower light intensity is reducing the polymerization contraction strain without reduction in degree of conversion. Sakaguchi *et al*[12] reported that application of light at less than the maximum intensity of the curing light resulted in significant reduction of polymerization contraction strain without significantly affecting the degree of conversion. Strain was linearly related to light intensity density. Application of light at two intensities resulted in degree of conversion values that were not significantly different from those cured at either the higher or lower intensity for 40 seconds. Strain of the sample cured at two intensities was not significantly different from the sample cured at the lower intensity alone for 40 seconds.

In our study the same amount of light curing energies were used. Miyazaki *et al*[11] reported that the fracture toughness and the flexural strength were the same when irradiations with the same amount of energy (light intensity multiplied by curing time) were used. It was found that, at lower light intensity, longer curing time was required to provide comparable mechanical properties. An accumulated irradiation energy obtained through a product of the light intensity and curing time may serve as a guideline to produce samples exhibiting equivalent fracture toughness as well as flexural strengths. Hinoura *et al*[20] reported that an extension of the application time could compensate for intensities that were insufficient to activate the photopolymerization process.

Polymerization shrinkage has not been overcome yet. Many researchers have studied other methods to reduce microleakage such as alternative preparation designs, restoration techniques[21,22], transilluminating posts[23] and flowable composite resins. Alternative curing methods can be used to reduce the polymerization shrinkage and marginal microleakage of posterior composite resin. Combination with other methods show added benefits. Clinically, curing time is an important factor because reducing chair time can decrease clinical errors in class Ⅱ posterior composite resin restorations. More researches on reducing microleakage of posterior class Ⅱ composite resin restorations are needed.

V. Conclusion

1. Microleakages measured, in increasing order are as follow, group 1, group 4 and 5, group 2, group 3. Among group 1, group 4 and group 5, there were no statistically significant differences in microleakage($p>0.05$).
2. Group 2 showed significantly higher microleakage compared with group 1, group 4 and group 5 and showed significantly lower microleakage than group 3($p<0.05$).
3. Group 3 showed significantly higher microleakage than the other groups($p<0.05$).

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