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치의학 석사 학위논문

**Marginal Discoloration Pattern and Longevity of
Class V Resin Composite Restoration**

**V 급 복합레진 수복물의 변연변색 양상과
수명에 대한 분석**

2016년 2월

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치의학과

조준호

Marginal Discoloration Pattern and Longevity of Class V Resin Composite Restoration

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이 논문을 치의학 석사 학위논문으로 제출함

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- ABSTRACT -

Marginal Discoloration Pattern and Longevity of Class V Resin Composite Restoration

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In this retrospective study, for class V resin composite restorations, we investigated aspect of marginal discoloration, longevity and correlation between prognostic variables and longevity. Modified United States public health service (USPHS) criteria was used to evaluate the restorations. Forty-five patients were selected and their mean age was 66.2 (± 1.56) years. One hundred and eighty-seven restorations were selected. Among 187 restorations, 63 restorations (33.7%) showed marginal discoloration (MD) of Bravo or Charlie ratings. A total of 90 discrete MD sites from 63 restorations were evaluated. Marginal discoloration was classified into 7 modes, i.e., Staining on resin (SR, $n = 25$); Staining on tooth (ST, $n = 1$); Penetration (P, $n = 28$); Chipping and staining on resin (CSR, $n = 13$); Chipping and staining on tooth (CST, $n = 10$); Chipping and penetration (CP, $n = 12$); Secondary caries (SC, $n = 1$). There was no statistically significant difference between staining and penetration, and between presence or absence of chipping ($p = 0.079$). However, there was statistically significant difference between staining and penetration, and between Bravo and Charlie rating ($p = 0.016$). For 187 cervical resin

composite restorations, the mean and median of longevity of 11.8 (standard error, 0.294) years and 12.5 years, respectively, were obtained. Clearfil SE bond showed 12.7 times higher failure rate than Scotch Bond Multi-Purpose. Restorations with bleeding has 9.0 times higher failure rate than those with no bleeding.

Key Words: Resin composite restoration; Class 5; Marginal discoloration; Penetration; Stain; Chipping

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요약(국문초록)

V 급 복합레진 수복물의 변연변색 양상과 수명에 대한 분석

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본 후향적 연구에서는, 5급 복합레진 수복물에 대해 변연변색 양상, 수명 그리고 수명과 예후에 영향을 주는 변수들간의 상관관계를 조사하였다. 수복물을 평가하는데 Modified United States public health service (USPHS) criteria를 사용하였다. 45명의 환자들이 선별되었고 그들의 평균 연령은 $66.2 (\pm 1.56)$ 세였다. 187개의 수복물이 선별되었다. 187개의 수복물 중에서, 63개(33.7%)가 Bravo 또는 Charlie 등급의 변연변색을 보였다. 63개의 수복물에서의 90개의 변연변색 부위가 평가되었다. 변연변색은 7가지로 분류되었다. 레진면의 착색 (SR, $n = 25$); 치아면의 착색 (ST, $n = 1$); 침투 (P, $n = 28$); 깨짐과 레진면의 착색 (CSR, $n = 13$); 깨짐과 치아면의 착색 (CST, $n = 10$); 깨짐과 침투 (CP, $n = 12$); 이차우식 (SC, $n = 1$). 착색, 침투 그리고 깨짐 여부간에는 통계학적으로 유의한 차이가 없었다($p = 0.079$). 반면에 착색, 침투 그리고 Bravo 또는 Charlie 등급 간에는 통계학적으로 유의한 차이가 있었다($p = 0.016$). 187개의 치경부 복합레진 수복물에 대해, 수명의 평균값과 중위값은 각각 $11.8 (\pm 0.294)$ 년, 12.5년으로 조사되었다. Clearfil SE bond가 Scotch Bond Multi-Purpose보다 실패율이 12.7배 높았다.

Bleeding on probing (BOP)가 있는 수복물이 BOP가 없는 수복물에 비해 실패율이 9.0배 높았다.

주요어: 복합래진수복; 5급 와동; 변연변색; 침투; 착색; 깨짐

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1. Introduction

In daily dental practice, practitioners face non-carious cervical lesions, which are caused by cervical caries, cervical abrasion, abfraction, erosion, etc.[1, 2] Resin composite is widely used for restoration of those lesions, because adequate strength and tooth-colored property fulfill the esthetic demands of patients.[3] At first, it was usually used for anterior teeth and for cervical lesions due to weak mechanical properties and short longevity.[2, 4, 5] Nowadays, resin composite is more widely used, even for stress-bearing area of posterior teeth, by means of the development of techniques and materials.[6, 7, 8] However, the biggest problem of resin composite is polymerization shrinkage, which causes micro-gap between tooth and composite.[9, 10] Micro-gap causes marginal leakage that leads to post-operative hypersensitivity, marginal discoloration, secondary caries, pulpal inflammation, loss of restoration, etc., as time passes.[11, 12, 13]

Many studies have tried to report the lifespan and failure reasons of resin composite restorations. Lifespan of resin composite restorations replaced ranges from 0 to 19 years.[14] Median longevity of resin composites were slightly less than 5 years.[15] Major causes of failure of class V resin composite restoration are loss of restorations and secondary caries.[16] However, according to observations for 1 to 17 years, failure rates ranged from 0 to 45% for posterior resin composite restorations and there was a linear correlation between failure rate and observation period.[17]

Hayashi and Wilson reported that marginal deterioration and marginal discoloration are predictors of the failure of posterior resin composite restorations.

[18] The study revealed that restorations with marginal deterioration, marginal discoloration, and both marginal deterioration and marginal discoloration at 3 years were 5.3, 3.8 and 8.7 times more likely to have failed at 5 years.[18] Therefore, marginal deterioration and marginal discoloration of resin composite restorations were suggested as predictors of failure of resin composite restorations. In addition, heavy smoking and tea drinking also cause severe marginal discoloration.[19] Thus, various habits might contribute to the longevity of restorations. Discoloration of composite is caused by intrinsic factors such as denaturation of resin matrix, and extrinsic factors such as staining by adsorption of colorant or percolation through contraction gap resulted from polymerization shrinkage stress.[20, 21, 22]

However, although difficult to distinguish with naked eye, all marginal discoloration were not identical under microscope and discoloration by staining on tooth or resin need to be differentiated from that by penetration into the interface between the restorative and dentin or enamel. When staining was simply accumulated on marginal chipping area, it may have different prognosis and longevity from the discoloration by penetration, and could be treated differently. For example, some of those such as slight staining can be polished away, but the others such as gross staining or obvious penetration under the margin need to be replaced.[23, 24, 25] To our best knowledge, there has been no study on the prognosis and treatment of marginal discoloration under differentiation between stain and penetration.

In this retrospective clinical study, we assessed the aspect of marginal discoloration and longevity of class V resin composite restorations, which were

restored in our department at more than 1 year before the recall date. In addition to the clinical evaluation of the cervical restorations according to the United States public health services (USPHS) criteria, epoxy resin replicas were fabricated and investigated under a microscope by comparison with clinical photographs. The aspect of marginal discolorations were classified and analyzed with Pearson Chi-square test. Clinical longevity was investigated with Kaplan-Meier survival analysis. Also, the correlation between longevity and prognostic variables such as age, sex, material, various habits, etc., were analyzed with multivariate Cox proportional hazard model.

2. Methods and Materials

Forty-six patients who had received cervical resin composite restorations more than 1 year ago at Department of Conservative Dentistry, Seoul National University Dental Hospital (SNUDH), participated in this retrospective clinical study between April 1, 2014 and Feb 28, 2015. The study protocol was approved by Institutional Review Board (IRB) of the Seoul National University Dental Hospital (IRB No., CRI14007). Before the patient visits to the department, their dental records were reviewed by a researcher (CJH). Patients with severe or systemic diseases which may affect the longevity of restorations were excluded. Information on the patient and the cervical resin composite restoration, such as age, sex, tooth number, operator, tooth preparation, adhesive, restorative material, diagnosis, etc., were recorded.

On the day of visit, the patient was informed about the study and signed a consent form. Two investigators (LYH and CBH) evaluated the clinical status and

quality of restorations. Modified United States Public Health Service (USPHS) criteria was used to evaluate the restorations (Table 1).[26] Retention, color match, marginal discoloration (MD), secondary caries, wear, marginal adaptation and postoperative sensitivity of modified USPHS criteria, pulp vitality, tooth/restoration fracture, tooth wear, occlusal guidance, occlusal interference, plaque index, gingival index, bleeding on probing (BOP), mobility, meal frequency, brushing frequency, brushing method, dental aids and smoking habits were investigated. If there is discrepancy between two investigators, it was agreed by consensus. Clinical photographs for teeth with cervical resin composite restorations were taken by a digital camera. Also, using addition-type silicon rubber impression materials, impressions of the cervical restorations were taken for fabrication of epoxy resin replicas.

i) To investigate the prevalence of the modes of MD, the number of restorations classified in each MD modes were compared by Chi-square test and Fisher's exact test. Restorations with MD of Bravo or Charlie ratings were selected. For each restoration, MD modes (i.e. staining or penetration with or without marginal chipping, etc.) were determined by comparing clinical photographs and epoxy replica models. For a restoration with more than 2 discrete MD sites, each site was evaluated separately. The difference between staining and penetration and between presence or absence of chipping were analyzed with Pearson Chi-square test. Whether the distribution of the MD sites with staining or penetration was related to the USPHS rating was also evaluated with Fisher's exact test.

- ii) The longevity of cervical composite restorations was investigated by Kaplan Meier survival analysis. Restorations with MD of Alpha or Bravo ratings were considered as ‘censored’. Restorations with MD of Charlie were considered as failure or ‘event’ occurred. If the restoration was not retreated, the longevity was calculated by the period from the date of treatment to the date of examination. If the restoration was retreated, the longevity was calculated by the period from the date of initial treatment to the date of retreatment.
- iii) The correlation of longevity and various prognostic variables was analyzed by multivariate Cox regression hazard model. Age (at treatment and evaluation), sex, PMH, PDH, operator, cavity preparation, bonding system, restoration material, diagnosis, retreatment, tooth location, tooth number, tooth classification, MD mode, pulp vitality, dental/restoration fracture, tooth wear, occlusal guidance, occlusal interference, plaque index, gingival index, BOP, mobility, meal frequency, brushing frequency, brushing method, dental aids and smoking habits were tested as prognostic variables.
- iv) Finally, the correlation between MD modes and various prognostic variables were also investigated.

3. Results

Among Forty-six patients, one patient and 31 restorations were excluded due to loss of restoration ($n = 20$), extraction ($n = 3$), restoration of full coverage ($n = 2$) and unknown reasons ($n = 6$). Forty-five patients were selected and their mean age was

66.2 (\pm 1.56) years. Also, one hundred and eighty-seven restorations were selected.

Among 187 restorations, 63 restorations (33.7%) showed MD of Bravo or Charlie ratings.

i) Classification of marginal discoloration

A total of 90 discrete MD sites from 63 restorations were evaluated. Marginal discoloration was classified into 7 modes, i.e., Staining on resin (SR, $n = 25$); Staining on tooth (ST, $n = 1$); Penetration (P, $n = 28$); Chipping and staining on resin (CSR, $n = 13$); Chipping and staining on tooth (CST, $n = 10$); Chipping and penetration (CP, $n = 12$); Secondary caries (SC, $n = 1$) (Figure 1).

According to their clinical significance for the possibility of repair and prolonged use of the restoration, MD sites were regrouped into 4 groups, i.e., Staining (SR + ST, $n = 26$); Penetration (P, $n = 28$); Chipping and staining (CSR + CST, $n = 23$); Chipping and penetration (CP, $n = 12$), and analyzed with Pearson Chi-square test. There was no statistically significant difference between staining and penetration, and between presence and absence of chipping ($p = 0.157$, Table 2).

Among 90 discrete MD sites, 76 sites were MD with Bravo rating and 14 sites were MD with Charlie rating. Among 76 sites of MD with Bravo rating, 30 sites (39.5%) showed penetration (P, $n = 19$) or chipping and penetration (CP, $n = 11$). Among 14 sites of MD with Charlie rating, 3 sites (21.4%) showed staining on resin (S, $n = 1$) or chipping and staining on tooth (CST, $n = 2$). Remaining 11 MD sites with Charlie rating were resulted from penetration (P, $n = 9$), chipping and penetration (CP, $n = 1$), and secondary caries (SC, $n = 1$). The distribution of the MD sites with

staining or penetration was related to whether they were rated as Bravo or Charlie according to the USPHS rating (Table 3, Fisher's Exact test, $p = 0.016$). Among 35 chipping sites (CSR + CST + CP), chipping were occurred at occlusal margin in 31 sites (91.4%).

ii) Longevity of cervical resin composite restorations

For 187 cervical resin composite restorations, the mean and median of longevity were 11.8 (standard error, 0.294) years and 12.5 years, respectively (Figure 2). One hundred and seventy-nine cases were censored and 8 cases were failed due to loss of restoration, extraction, and restoration of full coverage.

iii) Correlation of longevity and prognostic variables

According to the multivariate Cox proportional hazard model and Wald statistics, the bonding system and BOP affected the lifetime of the restorations ($p < 0.05$, Table 4). As for the bonding systems, Clearfil SE bond showed 12.7 times higher failure rate than Scotch Bond Multi-Purpose. As for BOP, those restorations with bleeding has 9.0 times higher failure rate than those without bleeding.

4. Discussion

The MD of cervical resin composite restorations were classified according to careful comparison of clinical photograph and microscopic observation of the replica under surgical microscope. Firsts of all, staining and penetration was distinguished by location of discoloration. It is known that slight staining can be polished away and patient can use the restoration more, whereas gross staining and obvious penetration

under the margin need to be replaced.[23, 24, 25] However, there is no criteria and evidence that gross staining should be replaced. Thus, in this study, we firstly classified discoloration into staining and penetration. Staining showed discoloration confined in some region which can be small or large. On the other hand, penetration showed tendency of diffusion into the interface between restorative material and tooth substance. Staining and penetration can occur simultaneously, and the discoloration was included as penetration. By careful observation, according to the site where staining was located, it was classified as staining on resin (SR) when it was located on the lateral side of the restoration margin, and staining on tooth (ST) when located beyond the margin. Secondly, presence of chipping was judged by the chipping surface and discontinuity. If there was discontinuity but no chipping surface, it was considered as poor marginal adaptation, not chipping. Chipping sometimes occurred with small angle and staining on the exposed resin surface showed more broad discoloration. If chipping occurred with large angle, staining on chipped resin surface showed narrow discoloration. Lastly, carious dentin was observed in a site and it was classified as secondary caries.

By Pearson Chi-square test, there was no statistically significant correlation among staining (SR+ST), penetration (P), chipping and staining (CSR+CST) and chipping and penetration (CP). It means that chipping of restoration margin did not statistically increase the frequency of discoloration (i.e. staining or penetration). It might be because 25 SR and 28 P decreased to 13 CSR and 12 CP, respectively, even though 1 ST increased to 10 CST. One ST definitely increased to 10 CST. It can be

plausibly demonstrated. If there is chipping of restoration margin, staining on tooth easily occurs since there remains bevel mark on tooth which can be observed under a microscope. These bevels were usually prepared by rough diamond points on occlusal cavosurface margin, so that discolored or bacteria could easily stick to the rough surface. On the other hand, there is no plausible reason to demonstrate the decrease of frequency of staining or penetration when chipping exists. Larger sample studies need to be investigated to determine whether staining and penetration increase or decrease when chipping occurs. When there is no chipping, staining on resin was much more frequent than the staining on tooth surface. It seems that, as time passes, tooth surface remains smooth, whereas polished resin surface easily turns to rough one.

Among 76 sites of MD of Bravo rating, 30 sites (39.5%) showed penetration (P, $n = 19$) or chipping and penetration (CP, $n = 11$). In modified USPHS criteria, Bravo rating is ‘superficial discoloration on the margin’ and ‘clinically acceptable discoloration’, and Charlie rating is ‘deep discoloration penetrated in a pulpal direction’ and ‘clinically unacceptable discoloration’, respectively. However, by naked eye during clinical examination, it is not easy to determine whether the discoloration is penetrated or not. In this study, we tried to follow the modified USPHS criteria during clinical examination, but there were many discrepancies between the clinically judged Bravo and Charlie ratings and microscopic evaluation. Some of these Bravo sites were easily discriminated as penetration by careful comparison using photographs and microscopic inspection later. According to Hayashi’s study, these Bravo rating MD by penetration should be regarded as

'restoration failure' since these penetrations can progress into the interface between restoration and tooth surface to the pulpal direction. Thus, in cases of P or CP, although looks clinically acceptable, dentists need to expect the restoration 'failed' or high possibility of 'failure' in a few years. On the other hand, among 14 sites of MD of Charlie, 3 sites (21.4%) showed staining on resin (*S*, $n = 1$) or chipping and staining on tooth (CST, $n = 2$), i.e., neither P nor CP. It means that considerable number of restorations with Charlie rating were neither P nor CP. Charlie means clinically unacceptable discoloration. These can easily be regarded as P or CP, and as clinical failure if overlooked. However, staining on resin or tooth surface can be polished away, whereas penetration with or without chipping cannot. This point of view was the initial idea of this study.

Under microscope, the MD of resin composite restorations were observed both simple staining (SR, ST, CSR and CST) and penetration (P and CP). In making decision on simple polishing, partial repair, or replacement of the restoration, differentiation of MD between staining and penetration is clinically more significant than the MD ratings of USPHS criteria. In this study, slight discolorations were not always staining and severe discolorations are not always penetration. By Fisher's exact test, staining was more frequently observed in restorations with Bravo rating and penetration was more frequently observed in restorations with Charlie rating. However, it is noted that not all Bravo rating is staining and not all Charlie rating is penetration as mentioned before. Therefore, it is highly recommended that the

decision whether resin composite restorations with MD be simply polished or partially or totally replaced should be made under microscope.

Among 35 chipping sites (CSR + CST + CP), chipping occurred at occlusal margin in 31 sites (91.4%) and at gingival margin in 4 sites (8.6%). For resin composite restoration, bevel is frequently prepared at non-stress bearing margin to increase the bonding strength. For cervical resin composite restorations, bevel is usually prepared at only occlusal margin, not gingival margin. Thin composite layer at cavosurface margin is very brittle. In most exposed surface by chipping had very shallow-angled surface, which indicated that the chipped resin was very thin. It is not certain that chipping leads to staining or penetration in this study. However, at least chipping would be regarded as marginal deterioration and leading to higher failure rate according to Hayashi's study. Since chipping occurred much frequently at the beveled surface and flexural stress is, in general, known to affect the prognosis of the restorations for abfraction, occlusal bevel is not really essential or recommended, especially when the material angle will be too acute after bevel preparation, such as, in saucer-shaped abrasion.

During evaluation, marginal chipping is regarded as discontinuity and marginal adaptation (MA) with Bravo or Charlie ratings. In comparison to Hayashi's study, chipping, staining and penetration seems to match with 'marginal deterioration', 'marginal discoloration' and 'failure', respectively, in Hayashi's study. It is not certain that whether Hayashi distinguished the staining on resin and staining on tooth. In fact, many staining was confirmed as staining on tooth, especially when chipping

exists, by microscope which were overlooked as staining on resin at clinical examination. Both CSR and CST might have been classified into marginal deterioration with marginal discoloration in Hayashi's study, since staining on tooth might have been regarded as staining on resin. In the case, CST should be regarded as marginal deterioration in Hayashi's study. In this study, restoration with marginal chipping without discoloration was not included since it didn't show discoloration. However, in clinic, restorations with chipping without discoloration may be easily encountered with explorer tip during oral examination. At least for easily determined chipped restoration, it will be suggested to notify the patients of high possibility of failure in a few years, according to Hayashi's results.

Through the comparison of photographs and epoxy replica under microscope, it was found that several sites of MD were related to the plaque accumulation area and that it was easy to decide the MD by discoloration of accumulated plaque as penetration in many cases. They should be classified as staining on tooth (ST). Plaque index might affect the discoloration and longevity of restorations. They can be easily removed simply with polishing.

Usually, it is known that longevity of composite restorations around 10 years. In this study, the mean and median longevity were 11.8 (± 0.294) years and 12.5 years, respectively. Bonding system and BOP were proved as statistically significant prognostic variables for longevity. It has been generally accepted that 4th generation 3-step etch&rinse bonding system (i.e. Scotch Bond Multi-Purpose) was the standard of bonding systems, because of the excellent *in vitro* results and their clinical

performance. Although Clearfil SE bond (5th generation 2-step self-etch system) was reported an excellent adhesive system in many studies, the hazard ratio of Clearfil SE bond was significantly higher than Scotch Bond Multi-Purpose. BOP positive indicates the gingival inflammation and accumulation of plaque or calculus. Poor oral hygiene and resulting gingival inflammation can induce discoloration or secondary caries easily.

5. Conclusions

Under the microscope, there were lots of difference from clinical assessment using USPHS criteria. With respect to the longevity of restorations, it is worthy to investigate the marginal discoloration under microscope and distinguish between staining and penetration, not just simple polishing or replacement. Chipping occurred at the enamel margin which is prepared with bevel. For chipping with no penetration, it is recommended to retain the restoration with polishing.

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Table 1: Modified United States Public Health Service (USPHS) criteria used in this study

| Category | Scale | Criteria |
|---------------------------|--------------|--|
| Retention | Alpha | Present |
| | Bravo | partial loss |
| | Charlie | absent |
| Color match | Alpha | no mismatch to the adjacent tooth structure |
| | Bravo | slight mismatch but clinically acceptable |
| | Charlie | esthetically unacceptable mismatch |
| Marginal Discoloration | Alpha | no discoloration on the margin |
| | Bravo | superficial discoloration on the margin |
| | Charlie | deep discoloration penetrated in a pulpal direction |
| Secondary caries | Alpha | no caries present |
| | Charlie | caries present |
| Wear (anatomic form) | Alpha | anatomy resembles original restoration |
| | Bravo | anatomy shows change in contour but not requiring replacement |
| | Charlie | excessive wear with dentin exposure requiring replacement |
| Marginal adaptation | Alpha | continuity at the margin (no ledge or ditch) |
| | Bravo | slight discontinuity detectable with an explorer but not requiring replacement |
| | Charlie | marginal ledge or crevice requiring replacement |
| Postoperative sensitivity | Alpha | absent |
| | Charlie | present |

Table 2. Distribution of the restorations with marginal discoloration that were categorized according to staining or penetration and the presence or absence of chipping

| | | discoloration | | |
|----------|-----|---------------|-------------|----|
| | | staining | penetration | |
| chipping | No | 26 | 28 | 54 |
| | yes | 23 | 12 | 35 |
| | | 49 | 40 | 89 |

There was no statistically significant difference between staining and penetration, and between presence or absence of chipping ($p = 0.079$).

Table 3. Distribution of the restorations with marginal discoloration that were categorized according to staining or penetration and the marginal discoloration rating

| | | discoloration | | |
|--|---------|---------------|-------------|----|
| | | staining | penetration | |
| Modified USPHS marginal discoloration | Bravo | 46 | 30 | 76 |
| | Charlie | 3 | 10 | 13 |
| | | 49 | 40 | 89 |

There was statistically significant difference between staining and penetration, and between Bravo and Charlie rating ($p = 0.016$).

Table 4. Relative risk of failure in cervical resin composite restorations according to prognostic variables.

| Prognostic variables | | Multivariate Cox Hazard model | | | |
|----------------------|----------|-------------------------------|---------------|-------------------------|---------|
| | | Wald | Hazards ratio | 95% Confidence interval | P-value |
| Bonding system | SBMP | 4.811 | | | 0.09 |
| | Clearfil | 4.808 | 12.707 | 1.310 | 123.288 |
| | SE bond | | | | 0.028 |
| BOP | | 4.545 | 8.960 | 1.194 | 67.264 |
| | | | | | 0.033 |

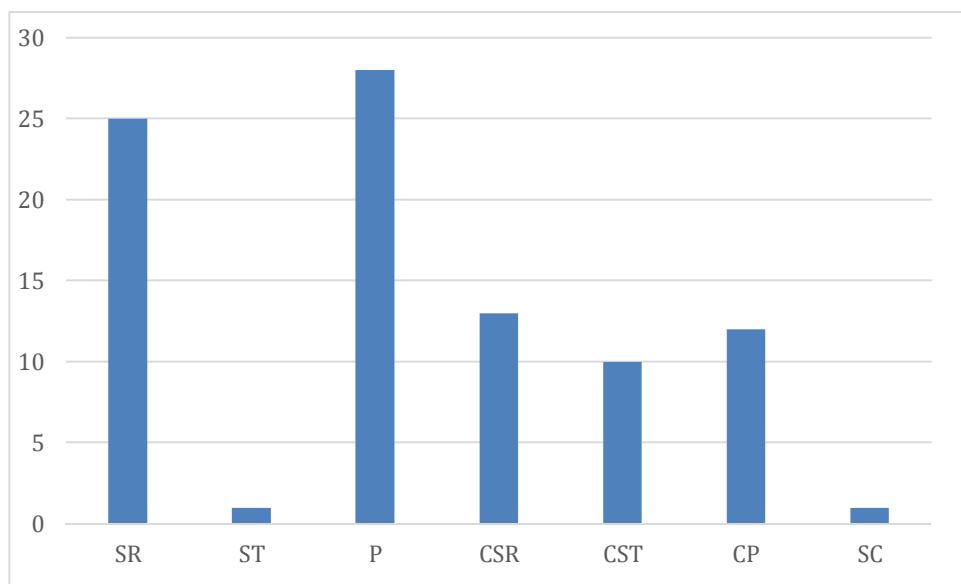


Figure 1. Distribution of cervical resin composite restorations in each mode of marginal discoloration classified in this study. SR, Staining on resin; ST, Staining on tooth; P, Penetration; CSR, Chipping and staining on resin; CST, Chipping and staining on tooth; CP, Chipping and penetration; SC, caries.

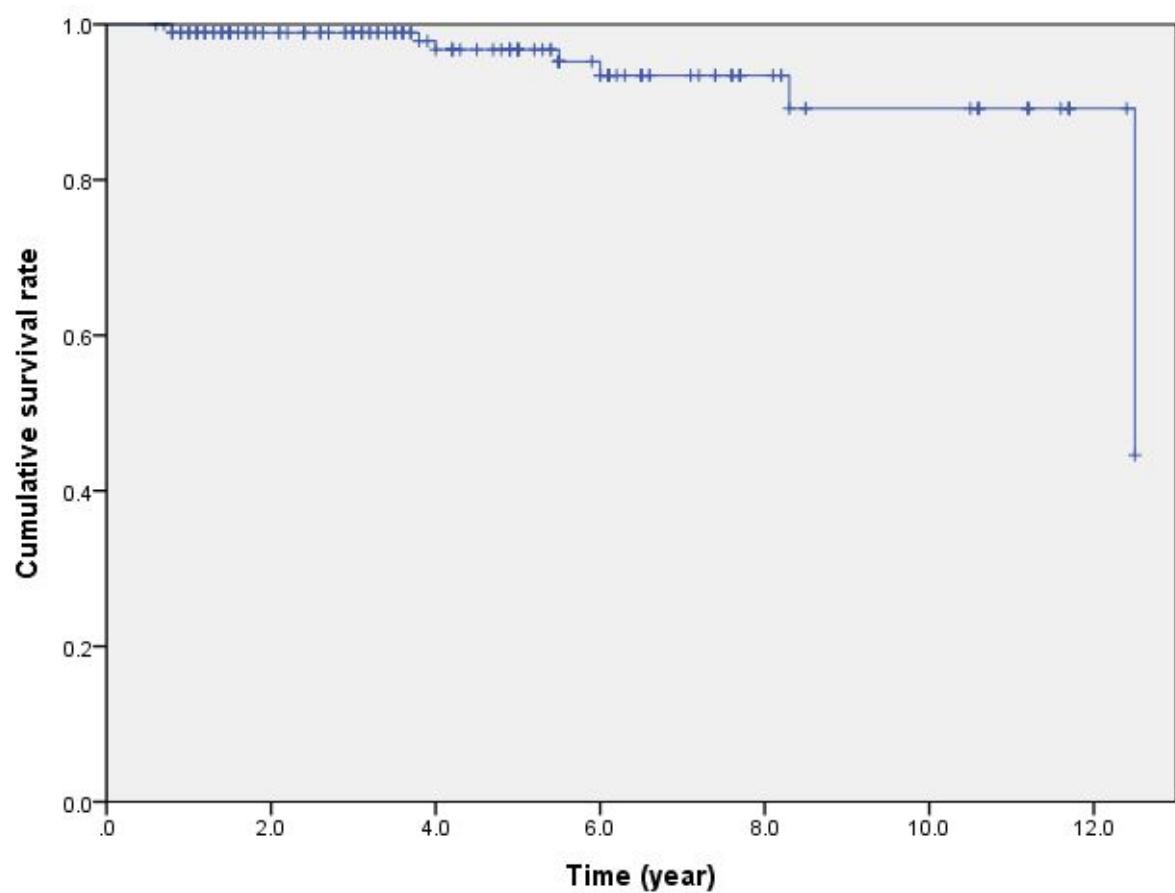


Figure 2. Cumulative survival estimates of cervical resin composite restorations evaluated in this study.