The effect of different restoration techniques on marginal discoloration in nanohybrid resin composites after immersion in coffee solution

S N Deviyanti, D Asrianti* and G Sutrisno
Department of Conservative Dentistry, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia

*Email: dini.rz@gmail.com

Abstract. Nanohybrid composite resins are widely used as restorative materials in anterior and posterior teeth. The incremental technique of resin composites is reported to reduce marginal discoloration; however, the effect of re-etching and re-bonding the restoration in order to minimize staining composites remains unclear. Therefore, we aimed to evaluate the effectiveness of the application of the incremental technique along with re-etching and re-bonding on nanohybrid composite restorations after immersion in coffee solution. Twenty-four third molars were divided into four groups where the teeth were restored with nanohybrid composite resins using the incremental (groups I and II) and bulk (groups III and IV) techniques. The re-etching and re-bonding technique after finishing was applied to samples in group I. Samples in groups I, II, and III were immersed in coffee solution, whereas those in group IV were immersed in saline (controls). The amount of marginal discoloration was measured in the samples on days 3, 6, and 12. Group I presented with the lowest values of marginal discoloration. Statistically significant (p < 0.05) changes in marginal discoloration were observed on days 6 and 12. In conclusion, incremental technique along with re-etching and re-bonding after finishing is effective in minimizing marginal discoloration in composite resins.

1. Introduction
Currently, composite resin restorative materials are most favored by patients and dentists because, in addition to restoring mastication and speech function, the aesthetic value generated by these materials is very satisfactory. Composite resins are known to be widely used for the restoration of anterior teeth; nevertheless, the use of these materials for posterior teeth restoration is gradually increasing over time.

One of the drawbacks of composite resins is the occurrence of microleakage between the resin and the dental tissue as a result of polymerization shrinkage. Microleakage can lead to the penetration of acids, enzymes, ions, and bacterial products through the gap resulting in marginal discoloration, post-treatment sensitivity, secondary caries, and pulp defects [1,2].
Marginal discoloration of composite resin restorations can be affected by several factors, including the steps and methods used for cavity preparation, the restoration technique, the finishing and polishing process, and other external factors such as the type of food and beverages consumed. Generally, all composite resin materials are easily discolored by the effects of tea, coffee, and cola within a week after restoration [3,4]. The study by Ertas et al. states that the intensity of composite staining is higher with coffee than it is with tea, cola, or water [5].

Efforts to minimize the risk of marginal discoloration, especially in posterior teeth, have been carried out by using the incremental restoration technique followed by re-etching and re-bonding after the restoration is finished and polished. According to Lopes et al., incremental restoration techniques can reduce the occurrence of marginal leakage when compared with the bulk technique. However, it is not known whether re-etching and re-bonding after finishing can minimize the occurrence of marginal discoloration in composite resin restorations. Therefore, this study was conducted to determine the effects of two different types of restoration techniques (incremental and bulk) with or without re-etching and re-bonding on marginal composite resin restorations in posterior teeth. Nanohybrid composites, one of the most commonly used resins for the restoration of anterior and posterior teeth, were used in this study.

2. Methods
This study comprised 24 third molars that were divided into four groups (n = 8) as follows: group I, molars were incrementally restored with the specimen followed by finishing; group II, molars were incrementally restored with the specimen, but no re-etching and re-bonding was performed after finishing; group III, molars were restored with specimen using the bulk technique, but no re-etching and re-bonding was performed after finishing; and group IV (controls), molars were restored with the specimen using the bulk technique without re-etching and re-bonding after finishing and then immersed in saline solution.

A circular cavity (diameter, 2 mm; thickness, 2.5 mm) was created in all 24 restoration samples, which were then etched with an etching gel kit containing 37% phosphoric acid (Dentamerica Gel Etch Kit). The samples were rinsed with water; excess water was absorbed with a cotton pellet, and the cavities were left moist for the bonding procedure. Bonding agent (Kerr OptiBond S,) was applied on to the entire cavity surface for 20 s and light cured for 10 s according to manufacturer’s instructions. Subsequently, an appropriately colored composite resin was placed in the cavity and light cured for 20 s. The restorations were placed incrementally or in bulk in the molars depending on the treatment group. After the finishing and polishing of the restorations, those in group I underwent re-etching and re-bonding.

All samples underwent thermal cycle tests at 5°C and 55°C. Those in groups I, II, and III were immersed in a coffee solution with an initial immersion temperature of 55°C for 10 h per day for 3, 6, and 12 days after which, the marginal discolorations were measured. The samples in group IV (control group) were immersed in saline solution.

Marginal discoloration was measured by calculating the length of the marginal portion stained within the circular form, using a two-needle bow. The two needles were placed at two points that made up a line and transferred on to a white paper in order to measure the angle formed by the arc, which was then expressed in percentage. This method was chosen because discoloration usually occurs in the form of curved lines, therefore, measuring the size of angles will produce more accurate results. The nonparametric test (Kruskal–Wallis test with Mann–Whitney post hoc analysis) was used to analyze the data, which was processed using computer program. The significance level was set at 5%.
3. Results
As shown in Table 1, Kruskal–Wallis test on the 3rd day demonstrated a p value = 0.135.

Table 1. Marginal discoloration of composite resin after 3 days immersion in coffee solution.

|                      | n   | Median (minimum-maximum) | Mean   | P       |
|----------------------|-----|--------------------------|--------|---------|
| Score Group I        | 6   | 0 (0–2,22)               | 0,37   | 0.135   |
| Group II             | 6   | 0 (0–4,17)               | 0,695  |         |
| Group III            | 6   | 3,335 (0–12,50)          | 4,583  |         |
| Group IV             | 6   | 0                        | 0      |         |

Kruskal–Wallis test; p < 0.05

After the Mann–Whitney post hoc analysis, the p values obtained between groups I and II, I and III, I and IV, II and III, II and IV, and III and IV were 0.902, 0.153, 0.317, 0.153, 0.317, and 0.059, respectively. Therefore, no significant discoloration was noted after immersion of restoration in the coffee solution on day 3.

As seen in Table 2, the results of the Kruskal–Wallis test on day 6 yielded a p value = 0.002.

Table 2. Marginal discoloration of composite resin after 6 days immersion in coffee solution.

|                      | n   | Median (minimum-maximum) | Mean   | P       |
|----------------------|-----|--------------------------|--------|---------|
| Score Group I        | 6   | 0 (0–3,06)               | 0,927  | 0.002   |
| Group II             | 6   | 0 (0–12,50)              | 2,778  |         |
| Group III            | 6   | 8,33 (6,67–15,20)        | 10,125 |         |
| Group IV             | 6   | 0                        | 0      |         |

Kruskal–Wallis test; p < 0.05

Mann–Whitney post hoc analysis on day 6 revealed the following results: between groups I and II, p value = 0.703; between groups I and III, p value = 0.003; between groups I and IV, p value = 0.140; between groups II and III, p value = 0.022; between group II and IV, p value = 0.140; and between groups III and IV, p value = 0.002. Thus, significant changes in discoloration were observed between groups I and III, II and III, and III and IV, whereas no significant changes were noted between groups I and II, I and IV, and II and IV after immersion in coffee solution on day 6.

As seen in Table 3, the results of the Kruskal–Wallis test reveal a p value = 0.004 on day 12.

Table 3. Analysis of marginal discoloration in composite resin restoration after 12 days of immersion in coffee solution.

|                      | n   | Median (minimum-maximum) | Mean   | P       |
|----------------------|-----|--------------------------|--------|---------|
| Score Group I        | 6   | 2,085 (0–6,38)           | 2,73   | 0.004   |
| Group II             | 6   | 3,47 (0–16,67)           | 6,342  |         |
| Group III            | 6   | 9,305 (8,33–20,83)       | 12,128 |         |
| Group IV             | 6   | 0                        | 0      |         |

Kruskal–Wallis test; p < 0.05
The results of the Mann–Whitney post hoc analysis on day 12 were as follows: between groups I and II, \( p = 0.442 \); between groups I and III, \( p = 0.004 \); between group I and IV, \( p \) value = 0.059; between groups II and III, \( p \) value = 0.124; between groups II and IV, \( p \) value = 0.059; and between groups III and IV, \( p \) value = 0.002. Thus, on day 12, significant changes in discoloration were observed between groups I and III and groups III and IV, whereas no significant discoloration was noted between groups I and II, I and IV, II and III, and II and IV.

As shown in Figure 1, group III (bulk technique restoration) presented with the highest discoloration value when compared with groups I and II. Marginal discoloration values were higher in group II than in group I, whereas no discoloration was observed in group IV. A significant increase in marginal discoloration was noted between day 3 and day 6, but not between day 6 and day 12.

![Figure 1](image_url)

**Figure 1.** Graph showing mean values of discoloration after immersion in coffee solution on days 3, 6, and 12.

4. **Discussion**

Marginal discoloration was measured using a two-needle bow owing to the circularly-formed restoration in the current study. To the best of our knowledge, this is the first study to clinically measure the amount of marginal discoloration in a composite resin restoration. In this method, the angle of the arc formed by the two arms of the needles is measured and converted from degrees to percentage in order to produce a more accurate value when compared with the linear measurements.

In this study, the results obtained on the third day of measurement demonstrated a change in values, especially in group III; however, owing to the lack of statistical significance in the tests, the amount of discoloration at the margin of the nanohybrid composite resin restoration was not considered as significant. On the other hand, a significant increase in values was noted on the sixth day, in group III indicating significant marginal discoloration of the nanohybrid composite resin restoration in this group. Similarly, significant marginal discoloration of the nanohybrid composite resin restoration was noted on day 12 in the same group.

Unlike the study by Owens and Johnson, which aimed to measure the depth of ink penetration in order to evaluate and compare the amount of microleakage in the enamel and dentin [6], the current study aimed to measure the amount of marginal discoloration in a restoration that is clinically visible on the surface of the restoration. Since the restoration was circular in shape, a bow and arc method was used to
calculate the value in degrees, which was then converted to percentages by considering the value of one circle as 100%.

The results of the present study demonstrated no significant discoloration after immersion in coffee solution on day 3, whereas on day 6, significant differences in marginal discoloration were observed between groups I and III, II and III, and III and IV. Similarly, significant differences in marginal discoloration were observed between groups I and III and groups III and IV on day 12. The most significant increase in staining was observed in group III (bulk technique restoration); nonetheless, group II (incremental technique without re-etching and re-bonding) also demonstrated a significant increase in marginal discoloration on day 12.

Thus, the findings of the present study indicated that the samples in group I (incremental restoration with re-etching and re-bonding) demonstrated lower marginal discoloration when compared with those in group II (incremental restoration without re-etching and re-bonding). This is in accordance with the results of the study by Owens and Johnson, which stated that the application of sealant materials can reduce the risk of marginal staining [6].

However, the rate of marginal discoloration in group II was lower than that of group III. On the other hand, the samples in group IV (control group) presented with constant values because they were not immersed in the coffee solution. These results are in accordance with those reported in another study where the authors evaluated the manner in which resin-based composites attach to posterior restorations by incremental and bulk attachment; subsequently, they examined the presence of gaps or leaks between the restorations and the teeth. The results of their study revealed a gap of 6.1% with the incremental technique and 18.7% with the bulk technique. Hence, the incremental technique appears to provide better reduction in marginal leakage when compared with the bulk technique [7].

5. Conclusions
Statistically significant marginal discoloration of the restoration was noted on days 6 and 12 in group III. The highest amount of discoloration was seen in group III and the lowest in group I. The incremental restoration technique with re-etching and re-bonding after finishing appears to be more effective in reducing marginal discoloration in nanohybrid composites when compared with restoration techniques without re-etching and re-bonding. Similarly, incremental restoration technique without re-etching and re-bonding after finishing is more effective than the bulk technique.

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