Chameleon effect of nano-filled composite resin restorations in artificial acrylic teeth of various shades

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Abstract. Composite resins are tooth-colored restorative materials commonly used for esthetic purposes. These resins sometimes exhibit a chameleon effect, defined as their ability to adjust their color to suit that of their surroundings. This is typically marked by a shift in the shade of the composite resin. The aim of this study was to demonstrate the chameleon effect of nano-filled composite resins. This laboratory-based experimental study included one control group, which consisted of isolated composite resins filled into a mold, and four treatment groups consisting of composite resins filled in artificial acrylic teeth of varying shades. The color test was carried out based on the spectrophotometer principle using vita easy shade on days 0, 1, and 7 of restoration and immersion in distilled water. The bivariate analysis showed that the nano-filled composite resins in the test groups exhibited a shift in color.

1. Introduction
Composite resins are commonly used for esthetic treatments, such as restoration for tooth structure loss, modification of tooth color and contour, which are becoming increasingly popular among patients [1,2,3]. Since their introduction approximately 50 years ago, these resins have undergone gradual development and modification in order to enhance their properties as an esthetic restorative material [3,4]. These include modification of the composite resin filler types, decreased polymerization shrinkage [5], advanced enamel and dentin adhesive systems, increased strength and longevity, and better esthetic properties [6]. The key advantages of composite resins with regard to their esthetic properties lie in the ability to precisely select the correct shade-fluorescence [7], translucency [8], gloss, value, chroma, hue [2], and chameleon effect [9]. Successful esthetic treatments largely depend on precise matching of the shade of the restoration to that of the neighboring teeth and accurate adaption of the restoration to the surrounding structures [10].

Initially only 4 shades of composite resins were available for use by clinicians; however, this has now increased to 32 shades [3]. Moreover, several varieties of composite resins are available, ranging from those specifically for use in the anterior teeth to universal composite resins with different degrees of translucency and opacity [3,8].

Correct shade selection is crucial for successful esthetic restorations, and mismatched restorations may occur due to improper shade selection, discrepancies between the shade of the material and the shade guide, or miscommunications with the laboratory in case of indirect restorations [10,11].
Development of an understanding of the optical characteristics of teeth, such as color and translucency, and the ways in which they differ from restorative materials is essential for consistently accurate shade selection [12].

Composite resins such as Estelite Σ quick™ may result in complex light movements through the tooth structure, and this is typically known as the chameleon effect. Such resins contain nano-fillers that imitate the transmission, diffusion, and reflection of complex light, thus mimicking the tooth color, which is dependent on the thickness of the enamel and the shade of the dentin base [2,13]. The interaction of colors between the layers of hard tooth structure, restorative material, or both is often described as the double layers effect. When restoration material is filled into a cavity, there will be a color interaction between the restoration material and the hard tooth structures, which come from translucency, double layers, and chameleon effect [10].

The chameleon effect is an esthetic property that enables the restorative material to match the color of its surroundings [14]. Composite resins that exhibit this property eliminate esthetic faults dramatically, and 90% of such restorations can be successfully achieved using a single shade [13].

Previous study evaluated the chameleon effect of composite resins and reported that it was affected by the size of the restoration, differences in the initial color, and the translucency of the composite resin [9]. Moreover, the chameleon effect was seen to increase in smaller restorations, decrease with differences in the initial color, and increase with translucency [9]. In 2008, Pavarina et al. also demonstrated that the color of the composite resin could be changed by layering it with another composite resin, and the greatest shift in color was seen to occur with Estelite Σ quick™. Therefore, it was concluded that there was a potential for adjustment of the composite resin shade, and this was dependent on the choice of the resin and the initial shade itself [10].

This study aims to demonstrate a shift in the color of nano-filled composite resins exhibiting the chameleon effect. The shift in color is expected to be close to the shade of teeth around the composite resin.

2. Methods
This laboratory-based study included 25 composite resin specimens that were divided into five groups (one control group and four test groups). The test groups were as follows: Group A- Shade A2 composite resin filled into Shade A2 artificial acrylic teeth; Group B- Shade A2 composite resin filled into Shade A3 artificial acrylic teeth; Group C- Shade A2 composite resin filled into Shade A3.5 artificial acrylic teeth; and Group D- Shade A2 composite resin filled into Shade A4 artificial acrylic teeth. The artificial acrylic teeth were selected for this experiment as they exhibited a standard tooth shade. The control group consisted of isolated composite resin that had been filled into a mold.

Following preparation, the shades of the specimens in the control and test groups were evaluated using Vita® Easy Shade. The specimens were immersed in aquadest, incubated for 24 hours at 37°C, and the specimen shades were evaluated upon removal. Thereafter, the specimens were re-immersed in aquadest, incubated for 7 days at 37 °C, and the shades were evaluated once again. The L*a*b* scores for each specimen were measured after light curing, on day 0, following immersion in aquadest for 1 day, and after immersion in aquadest for 7 days.

The Shapiro–Wilk tests showed that the data were not normally distributed (p > 0.05). Therefore, a non-parametric statistical test, the Kruskal–Wallis test, was used for analysis. This selection was based on the following criteria: a) this study had a comparative measurement scale, b) the data were not paired, and c) there were more than two groups. Post hoc Man–Whitney test was used to compare the shift in color between the test groups and the control group. Through the Kruskal–Wallis test, the same data variation was obtained (p > 0.05), and it was followed by the post hoc test with a significance score of p < 0.05.
3. Results

The results showed that the test groups exhibited higher L*a*b* scores compared with the control group and the artificial acrylic teeth prior to restoration (Table 1).

| Color test | Isolated RK A (A2) | Initial artificial acrylic teeth A (A3) | B (A3.5) | C (A4) | D (B4) | Composite resins filled in artificial acrylic teeth A | B | C | D |
|------------|--------------------|----------------------------------------|---------|--------|--------|--------------------------------|---|---|---|
| L* 0 day   | 73.64              | 80.68                                  | 28.07   | 22.04  | 74.04  | 81.04                                  | 79.16 | 79.42 | 79.43 |
| L* 1 day   | 73.00              | 79.98                                  | 28.00   | 22.00  | 73.84  | 79.04                                  | 79.16 | 79.42 | 79.43 |
| L* 7 day   | 73.84              | 79.04                                  | 27.84   | 22.84  | 72.26  | 81.04                                  | 79.16 | 79.42 | 79.43 |
| a* 0 day   | 0.28               | 2.06                                   | 2.90    | 2.70   | 2.54   | 2.90                                   | 2.70  | 2.70  | 2.70  |
| a* 1 day   | 0.88               | 2.42                                   | 3.24    | 3.14   | 3.26   | 3.24                                   | 3.14  | 3.14  | 3.14  |
| a* 7 day   | 0.76               | 2.42                                   | 2.52    | 2.62   | 2.75   | 2.52                                   | 2.62  | 2.62  | 2.62  |
| b* 0 day   | 22.20              | 28.30                                  | 28.56   | 28.56  | 28.32  | 28.90                                  | 28.56 | 28.56 | 28.56 |
| b* 1 day   | 22.56              | 29.28                                  | 29.48   | 29.48  | 29.94  | 29.38                                  | 29.48 | 29.48 | 29.48 |
| b* 7 day   | 22.80              | 29.30                                  | 27.90   | 27.90  | 28.68  | 27.64                                  | 27.90 | 27.90 | 27.90 |

The test groups exhibited no significant shift in the shade compared with the control group following immersion in aquadest for 24 hours [Kruskal–Wallis p = 0.263 on day 1 (Table 2)].

| N | Median (minimum-maximum) | Mean | P |
|---|--------------------------|------|---|
| Control Group | 5 | 0.67 (0.27 – 0.97) | 0.67 | --- |
| Group A | 5 | 1.64 (0.27 – 3.23) | 1.56 | --- |
| Group B | 5 | 0.47 (0.07 – 1.78) | 0.77 | 0.263 |
| Group C | 5 | 1.50 (0.22 – 4.03) | 1.80 | --- |
| Group D | 5 | 1.61 (0.50 – 3.84) | 2.06 | --- |

p<0.05 (significant difference)

However, following immersion in aquadest for 7 days, a significant shift in shade was seen in the test groups compared with the control group [Kruskal–Wallis test p = 0.014 (Table 3)]

| N | Median (minimum-maximum) | Mean | P |
|---|--------------------------|------|---|
| Control Group | 5 | 0.13 (0.07 – 3.02) | 1.05 | --- |
| Group A | 5 | 0.61 (0.05 – 1.63) | 0.83 | --- |
| Group B | 5 | 7.65 (1.67 – 9.47) | 6.66 | 0.014 |
| Group C | 5 | 6.61 (0.00 – 12.02) | 5.55 | --- |
| Group D | 5 | 1.63 (0.97 – 7.50) | 2.60 | --- |

p<0.05 (significant difference)
4. Discussion
The results of this study showed that the test groups exhibited higher mean L*a*b* scores compared with the control group and the pre-restoration artificial acrylic teeth, and this could be attributed to shade assimilation between the composite resin and the artificial acrylic teeth. Therefore, in accordance with previous study, it can be concluded that composite resins alone differ considerably from those that have been filled into a tooth [10].

Layering of materials results in mixing of the shades of the individual materials, producing a final shade that may differ considerably from the originals. This new shade is further affected by the optical characteristics of the material in the outer layers (composite resin in this case) and the shade of the material in the inner layers (artificial acrylic teeth in this case).

The translucency of the artificial acrylic teeth may range from opaque to total translucency and is typically affected by four factors including color, thickness, surface texture, and the degree of translucency of the composite resin [8]. The nano-fillers are typically smaller than the light waves, causing the light to pass through the composite resins without affecting the refractive index and resulting in a high degree of translucency [15]. Moreover, the translucency of the nano-filled composite resins affects the shade of the resin restoration in the artificial acrylic teeth.

The final shade of the composite resin restoration may also be affected by the color of the artificial acrylic teeth. The current study included four test groups comprised of different shades of artificial acrylic, including Shade A2 in Group A, Shade A3 in Group B, Shade A3.5 in Group C, and Shade A4 in Group D. From the four shades used, in order from Shade A2, A3, A3.5, and A4, the L* score (degree of brightness) decreases, a* score (degree of red to green shade) increases to red, and the b* score (degree of yellow to blue shade) increases to yellow. Therefore, the color of the composite resin was seen to become gradually darker as the shades progressed from A2 to A4, and this affected the way in which the shade of the composite resin restoration shifted toward its basic color [10].

The brightness of the resin restoration is generally greater than that of the isolated composite or the artificial acrylic teeth themselves, and this is usually a result of assimilation of the shades of the composite resin and artificial acrylic teeth.

Moreover, composite resin restorations in artificial acrylic teeth have a greater degree of red compared with isolated composite resins. In the current study, Groups A and B had a greater degree of red compared with their initial shades, whereas Groups C and D exhibited a lesser degree of red compared with their initial shades. This may be due to the large difference between the degree of red shade of artificial acrylic teeth in Group C and D with the control group, causing insufficient chameleon effect of the composite resin, where it cannot reach the desired degree of red shade.

Similar results were observed with regard to the distribution of the yellow and blue shades, with the test groups exhibiting higher degrees of yellow compared with the control group. However, only test groups A and B exhibited higher degrees of yellow compared with the initial shade of the artificial acrylic teeth, whereas groups C and D demonstrated lower degrees of yellow compared with the initial shade of the artificial acrylic teeth. This may be due to the large difference between the degree of yellow shade of acrylic artificial teeth in Group C and D with the control group, causing insufficient chameleon effect of the composite resin, where it cannot reach the desired degree of yellow shade.

The differences in the L*a*b* scores between composite resin restorations in artificial acrylic teeth, isolated composite resins, and artificial acrylic teeth could be attributed to the differences in the initial shades of the composite resin and artificial acrylic teeth. The chameleon effect of the composite resin is affected by the size of the restoration, the translucency of the composite resin, and the differences in the initial shades, and this may have had a role to play [9].

The results of the current study showed that isolated composite resins and 1-day-old composite resin restorations in artificial acrylic teeth exhibited a shift in shade. However, the Kruskal–Wallis test showed that the ΔE* score exhibited a p-value that was greater than 0.05, suggesting that the shift in shade following immersion for 1 day was not statistically significant. This shade change could be attributed to imperfect polymerization of composite resin and low absorption of water due to the short
duration of immersion of the composite resin. This was in accordance with Malekipour et al. who concluded that the duration of immersion affected the stability of the composite resin shade [16].

However, statistical analysis of the ΔE* score between the test groups and the control group following immersion in aquadest for 7 days exhibited a p-value that was less than 0.05, suggesting that the statistically significant shift in shade exhibited by the composite resin was a result of complete polymerization and absorption of water, which affected the stability of the resin shade. The Estelite Σ quick™ composite resin matrix contains Bis-GMA (bisphenol A-glycidyl methacrylate) and TEGDMA (triethylene glycol dimethacrylate), which are hydrophilic and therefore increase water absorption over longer immersion durations [17]. A study by Diamantopoulou (2013) on the change in the optical characteristics of composite resin after it was immersed in water for 1 week and 1 month. The study showed that there was a difference in shade and translucency of composite resin after it was immersed in water [18].

5. Conclusion

Based on the results of this study, it can be concluded that nano-filled composite resins exhibit a chameleon effect whereby they can adjust their color to suit that of their surroundings. This change in shade is typically similar to the color of the base that is layered with composite resin. The chameleon effect of composite resin has limitations in its color adjustment. Therefore, one shade of composite resin cannot be used to restore every tooth.

6. References

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