Scattering properties of a composite resin: Influence on color perception

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Abstract

Background: The properties of the composite materials and the clinical expertise while layering them carry many esthetic implications in restorative dentistry. **Aims:** The aim of the present study is to assess the influence of scattering properties of G-aenial A2 shade on color perception when used in esthetic restorations. **Materials and Methods:** Two composite resins were evaluated in this study: Gradia Direct (shade A3) and G-aenial (shade A2). A colorimetric evaluation according to the CIE L*a*b* system, relative to standard illuminant A against a white background, was performed to assess the referred chameleonic properties of G-aenial when used in simulated clinical situations. **Statistical Analysis Used:** The differences in color change between the test group G-aenial and the test Group Gradia Direct were considered clinically not perceptible ($\Delta E^* < 3.3$). Differently, the differences in color change were considered clinically perceptible ($\Delta E^* > 3.3$) between the control group G-aenial and the control group Gradia Direct and between the test group G-aenial and the control specimens obtained with G-aenial. The CIE Lab parameters which brought to ΔE were investigated using *t*-test ($P < 0.05$). **Results and Conclusions:** Color harmonization in simulated clinical conditions depends on different factors related to dentine and to composite resins. In this study dentine variables were dropped in order to analyze the influence of thickness and of the composition of the composite resin.

Keywords: CIE Lab, color perception, composite resin, esthetic restorations, layering technique

Introduction

Tooth color perception is an important target not only for the dentist who needs choose the correct tooth shade for esthetic restorations but also for patients and consumers who desire to enhance their smiles.[1] Natural tooth color is determined by the paths of light inside the tooth and absorption along these paths, and the light paths inside the tooth are determined by scattering.[2] Light scattering along with opacity and gloss influence the perception of tooth color and appearance. Resin composite materials are widely used due to their good esthetic properties which make them the appropriate answer to the steadily increasing demand of patients for imperceptible esthetic restorations. Due to

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this fact the color selection gained an important role in the clinical procedure. As a general rule, dentine is covered by the enamel layer which is highly transparent. Several studies have reported that enamel correlated strongly with the final color of tooth.[2,3] In order to successfully mimic the color properties of natural posterior teeth, in clinical practice the layering technique allows to gain acceptable results with resin composites of different shades used in variable thickness. Recently resin composite's manufacturers tried to develop restorative systems, which allows to simplify both the layering technique both the esthetic restoration. G-aenial, a nanohybrid resin composite, is presented as the restorative material which could allow an esthetic restoration using a single color shade, without differentiation between dentinal-layer and enamel-layer. Beside this fact this product might be useful when the color selection is difficult because of different anatomical or environmental reasons, such as when there is no matching of the color of the tooth with any of the color shade, or when the color selection is performed with the rubber dam. Two possible approaches, qualitative and quantitative, have been proposed in the literature to evaluate color. The qualitative method is based on the subjective comparison of the sample to a shade guide. However, to avoid bias due to human perception limits, according to previous studies,[4-6] was decided to use a quantitative approach by using a spectrophotometer. The parameters taken into account (according to CIE 1976 color space parameters) were L* (luminosity), a* (quantity of green-red) and b* (quantity of blue-yellow) for each sample. In this study the hypothesis that G-aenial's scattering properties influence the color perception will be critically examined and compared with a control composite resin which defects this property (Gradia Direct). The null hypothesis is that there is no difference in

color perception between the two composite resins when applied in similar conditions.

Material and Methods

Two nanohybrid composite resins were evaluated in this study: Gradia Direct and G-aenial. For Gradia Direct composite resin the A3 shade of the Vita scale was selected. For G-aenial composite resin the A2 shade of the Vita scale was selected. Table 1 shows details concerning the restorative materials used in this study. Flow-chart [Figure 1] clarifies the preparation of the specimens.

Preparation of the composite basement

One hundred discs of Gradia Direct were prepared in accordance with manufacturer's instructions using a silicon ring (8 mm in internal diameter and 2 mm in thickness). The composite discs were prepared by condensing the material in the ring, placed on a white opaque paper background covered by a Mylar strip (Henry Schein; Melville, NY). A second Mylar strip was placed on the top of the filled space and a glass slide was pressed against the upper Mylar strip to extrude the excess composite resin and to form a flat surface. The distal end of the light guide was placed against the surface of the matrix

strip; the material was then light-cured from the top with the curing light Celalux II (Voco, Cuxhaven, Germany). One light polymerization mode was used for each material - standard: 1000 mW/cm^2 for 40 s. The cordless curing unit was maintained at full charge before use, and irradiance was monitored periodically by using a radiometer (SDS Kerr, Orange, CA). The composite discs obtained measured 8 mm in diameter internally and 2 mm in thickness.

Preparation of the rings

One hundred rings of Gradia Direct were prepared in accordance with manufacturer's instructions using a silicon disk (6 mm in diameter and 2 mm in thickness) and, externally, a silicon ring (8 mm in internal diameter and 2 mm in thickness). The composite rings were prepared by condensing the material between the disk and the silicon ring, placed on a white opaque paper background covered by a Mylar strip (Henry Schein; Melville, NY). A second Mylar strip was placed on the top of the filled space and a glass slide was pressed against the upper Mylar strip to extrude the excess composite resin and to form a flat surface. The distal end of the light guide was placed against the surface of the matrix strip; the material was then light-cured from the top with the curing light Celalux II (Voco, Cuxhaven, Germany). One light

Table 1: Composite resins used in this study

Product	Batch no.	Type	Matrix	Filler	Total filler content w/w (vol%)	Manufacturer
GD	1102101	Microhybrid	Methacrylate monomers	Silicates prepolimerized fillers	73	GC Corporation, Tokyo, Japan
GN	1109262	Nanohybrid	Methacrylate monomers	Prepolimerized filler with silicon	76	GC Corporation, Tokyo, Japan

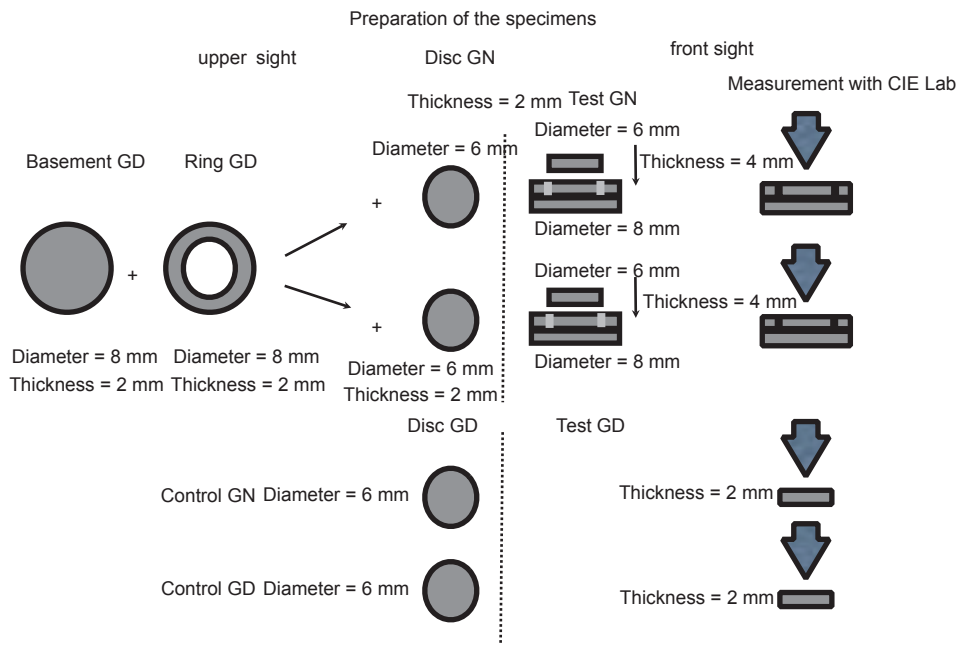GD: Gradia direct; GN: G-aenial

Figure 1: Preparation of the specimens

polymerization mode was used for each material - standard: 1000 mW/cm² for 40 s. The cordless curing unit was maintained at full charge before use, and irradiance was monitored periodically by using a radiometer (SDS Kerr, Orange, CA). The composite rings obtained measured 6 mm in diameter internally, 8 mm in diameter externally, and 2 mm in thickness.

Preparation of the test specimens

Fifty composite discs were prepared for each restorative material in accordance with manufacturer's instructions. The composite discs were prepared condensing the material into the composite rings previously assembled with Gradia Direct, placed on a white opaque paper background covered by a Mylar strip (Henry Schein; Melville, NY). A second Mylar strip was placed on the top of the filled space and a glass slide was pressed against the upper Mylar strip to extrude the excess composite resin and to form a flat surface. The distal end of the light guide was placed against the surface of the matrix strip; the material was then light-cured from the top with the curing light Celalux II (Voco, Cuxhaven, Germany). One light polymerization mode was used for each material - standard: 1000 mW/cm² for 40 s. The cordless curing unit was maintained at full charge before use, and irradiance was monitored periodically by using a radiometer (SDS Kerr, Orange, CA). Each test specimen, together with the corresponding Gradia Direct ring, was placed on the composite basement Gradia Direct disc to simulate a clinical restoration.

The two test groups obtained were:
- Group GD test: Including specimens assembled with a Gradia Direct composite basement supporting a Gradia Direct composite ring containing a Gradia Direct composite disc
- Group GN test: Including specimens assembled with a Gradia Direct composite basement supporting a Gradia Direct composite ring containing a G-aenial composite disc.

Preparation of the control specimens

The preparation of control specimens, for each brand, involved the creation, in accordance with manufacturer's instructions, of 50 discs using a silicon ring (6 mm in internal diameter and 2 mm in thickness). The composite discs were prepared by condensing the material in the ring, placed on a white opaque paper background covered by a Mylar strip (Henry Schein; Melville, NY). A second Mylar strip was placed on the top of the filled space and a glass slide was pressed against the upper Mylar strip to extrude the excess composite resin and to form a flat surface. The distal end of the light guide was placed against the surface of the matrix strip; the material was then light-cured from the top with the curing light Celalux II (Voco, Cuxhaven, Germany). One light polymerization mode was used for each material - standard: 1000 mW/cm² for 40 s. The

cordless curing unit was maintained at full charge before use, and irradiance was monitored periodically by using a radiometer (SDS Kerr, Orange, CA). The composite discs obtained measured 6 mm in diameter internally and 2 mm in thickness.

All specimens were stored in distilled water for 24 hours in complete darkness at 37° C.

The two control groups obtained were:
- Group GD control: Including specimens assembled with Gradia Direct
- Group GN control: Including specimens assembled with G-aenial.

Color testing

A colorimetric evaluation according to the CIE L*a*b* system, relative to standard illuminant A against a white background, was performed by a blind trained operator. Color of the specimens and of the composite rings was measured with a spectrophotometer (SP820λ; Techkon Gmbh, Konig-Stein, Germany) against a white background. Before each measurement session, the colorimeter was calibrated according to the manufacturer's recommendations by using the supplied white calibration standard. All specimens and all composite rings were chromatically measured 4 times and the average values were calculated; then each color parameter for each specimens of the same shade was averaged. The values obtained from the test groups were compared with the values obtained from the specimens of the respective control groups. In a second phase of the study the analysis was conducted between the CIE Lab values of the two test groups in order to evaluate the color perception and the influence of scattering properties of G-aenial. The CIE 1976 L* a* b* color system is used for the determination of color differences.[7,8] The L* value refers to "lightness"; the higher is the L value, the higher is the lightness (a value of 100 corresponds to perfect white and that of zero to black). CIE L* a* b* values are called the "chromaticity coordinates"; "a*" shows red color on positive values and green color on negative values (+a* = red; -a* = green); "b*" shows yellow color on positive values and blue color on negative values (+b* = yellow; -b* = blue).

To improve the analysis of the scattering coefficient on the color perception ΔE was calculated from mean ΔL*, Δa* Δb* values for each group of specimen using the following formula:

$$\Delta E\ (L^*a^*b^*) = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

where ΔL*, Δa*, Δb* are the differences in L*, a*, b* values of the different groups.

The differences in color change were considered clinically perceptible when ΔE* >3.3.

Statistical analysis

Firstly the data were analyzed with student *t*-test comparing the CIE Lab mean values of the control specimens obtained with G-aenial with the respective test groups' ones (Group GN), and comparing the CIE Lab values of the control specimens obtained with Gradia Direct with the respective test groups' ones (Group GD). Then the analysis of the color behavior of the composite resins was conducted with Student *t*-test comparing the CIE Lab values of the specimens of the test group GD with the CIE Lab values of the specimens of the test group GN. In the present study, $P < 0.05$ was considered as the level of significance. The statistical analysis was performed using statistical software (Stata 12; College Station, TX, USA).

Results

Data obtained are summarized in Tables 2 and 3 CIE L* values measured in the test Group GN ranged from 40.85 to 45.27, while the CIE L* values measured in the control specimens obtained with G-aenial ranged from 44.88 to 49.97. The *t*-test analysis showed a statistically significant difference in lightness between the two groups of specimens ($P < 0.05$). CIE a* values measured in the test Group GN ranged from -0,92 to -1,17, while the CIE a* values measured in the control specimens obtained with G-aenial ranged from 0.63 to 0.79. The *t*-test analysis showed a statistically significant difference in redness/greenness between the two groups of specimens ($P < 0.05$). The same analysis was developed for CIE b* values which ranged from 1.77 to

2.11 in the test Group GN, while ranged from 1.74 to 1.99 in the control specimens. The *t*-test analysis showed no significant differences in yellowness/blueness between the test Group GN and the control group ($P > 0.05$). CIE L* values measured in the test Group GD ranged from 40.15 to 45.12, while the CIE L* values measured in the control specimens obtained with Gradia Direct ranged from 42,98 to 47,22. The *t*-test analysis showed the presence of a statistically significant difference in lightness between the two groups of specimens ($P < 0.05$). CIE a* values measured in the test Group GD ranged from -0.86 to -1.15, while CIE a* values measured in the control specimens obtained with Gradia Direct ranged from -0.36 to -0.53. The *t*-test analysis showed a statistically significant difference in redness/greenness between the two groups of specimens ($P < 0.05$). CIE b* values measured in the same test Group GD ranged from 1.78 to 2.01, while CIE b* values measured in the control specimens obtained with Gradia Direct ranged from 1.75 to 1.99. The *t*-test analysis showed no significant differences in yellowness/blueness between the test Group GD and the control group ($P > 0.05$). The statistical comparison conducted with *t*-test analysis between CIE L* values measured in test Group GN (range from 40.85 to 45.27) and CIE L* values measured in test Group GD (range from 40.15 to 45.12) underlined no significant differences in lightness ($P > 0.05$). The results of the *t*-test analysis conducted on CIE a* values and CIE b* values measured on the two test groups confirmed the absence of significant differences in redness/greenness and yellowness/blueness ($P > 0.05$).

The differences in color change between the test Group GN and the test Group GD were considered clinically no perceptible (ΔE* <3.3). Differently, the differences in color change were considered clinically perceptible (ΔE* >3.3) between the control Group GN and the control Group GD and between the test Group GN and the control specimens obtained with G-aenial.

Discussion

There have been studies determined whether the color of the identical shade designated resin composites was actually similar. Based on the color coordinates of four kinds of esthetic restoratives for three shades, color differences between the identical shade designated materials were determined, and 16 of the 18 combinations presented perceptible color differences (ΔE(L*a*b*) >2).[9] This study compared two composite resins prepared by the same manufacturer. The original Vita scale might be different but the linkage between A2 shade and A3 shade is clear and respected. However, to harmonize the color of different restorative materials, several methods would be considered, which can be grouped into a visual method or an instrumental method. The first method might be suggested, however, it should be confirmed through multidirectional confirmations in independent studies and

Table 2: Mean±standard deviation of CIE L* a* b* values measured in test and control groups obtained with Gradia Direct

| | CIE L*a*b* values | | |
	L*	a*	b*
GD control	44.88±2.31	−0.70±0.04	1.90±0.08[c]
GD test	42.67±2.54[a]	−0.98±0.11[b]	1.88±0.09[c]
ΔE	2.23±0.67		

Different superscript letters indicate no significant differences (*P*>0.05) between groups with the same letter. Groups with no superscript letter indicate significant differences between groups in vertical column (*P*<0.05). [I]Differences in color change are considered clinically perceptible. GD: Gradia direct; CIE: Commission Internationale de l'éclairage

Table 3: Mean±standard deviation of CIE L* a* b* values measured in test and control groups obtained with G-aenial

| | CIE L*a*b* values | | |
	L*	a*	b*
GN control	47.11±2.43	0.72±0.06	1.87±0.10[c]
GN test	42.91±3.11[a]	−1.05±0.08[b]	1.94±0.14[c]
ΔE	4.56±0.91[I]		

Different superscript letters indicate no significant differences (*P*>0.05) between groups with the same letter. Groups with no superscript letter indicate significant differences between groups in vertical column (*P*<0.05). [I]Differences in color change are considered clinically perceptible. GN: G-aenial

centers. As an instrumental method, threshold values for the allowable differences in color, or in each color coordinates, might be provided based on the color coordinates of the referenced shade tabs. Above and before using this method some aspects should be marked and respected during preparation; in fact color coordinates values vary by the measurement method such as the specimen conditions including thickness, surface polishing and the degree of polymerization; measurement geometry such as the illuminating and measuring geometry, type of illuminant, measuring aperture size and the kind of instrument; color difference formula and influence of other optical properties such as translucency, fluorescence and opalescence. Nakajima *et al.*[10] stated that even filler composition, pigment and additives could influence the scattering properties because of the different light diffusion and reflection at the resin/filler particle interface.[11] In addition, as reported by Vichi *et al.*,[12] also thickness is a crucial aspect for the final esthetic result; in fact to enable the reproduction of the esthetic aspects of natural teeth texture, thickness, opacity, and translucency are important characteristics, not only color. In this study the thickness was set at 2 mm that is the maximum depth the light acts on monomers of the resin; however, while measuring the CIE Lab parameters with the spectrophotometer the thickness of test groups was 4 mm; and that is why brightness L is definitely higher for both the control groups if compared with paired test group. Under these considerations many issues risk to affect the final esthetic restoration, and the choice of the right composite material and of the right technique become essential. In this study the values measured by the spectrophotometer reflect a clinically color harmonization which defines the scattering properties of G-aenial. The shade compatibility of this material allows the general practitioner to simplify the shade choice techniques while layering restorative materials; in fact the basic idea is that the color of the materials should not be perceptibly different from that of the tooth by naked eyes under a standard viewing condition. This clinical condition is always verified when ΔE is less than 3.3. Nevertheless, as widely agreed,[13-15] it is reported that while ageing dentinal tissue influences the light scattering because of the changes that occur within the dentinal tubules. The orientation and the content of the tubules might affect the light transmission characteristics of the dentine and, as a result, of the esthetic restoration but, within the limitations of the laboratory experiment conducted *in vitro* no data were collected about this matter. In this study the variables related to dentine ageing were dropped considering as substrate for esthetic restoration a composite resin. This procedure allowed comparing the influence of thickness and of the composition of composite resin on color perception in posterior teeth restoration. As showed in Table 2 the influence of thickness on the values measured with CIE Lab system was recorded in GD group when compared with GD control. The unique difference between the groups is the thickness of the specimens which brings to a different luminosity value. The groups obtained with G-aenial presented an additional kind of variable: The composition of the composite resin. In fact the values

obtained in GN test group are not significantly different to those acquired for GD test group despite the different original shade. This potential skill could be useful when, while layering of composite resins under rubber dam, some difficulties in the choice of the right shade occur. However, as reported above, the attention should be then focused on the thickness of the layer in order to prevent lower final color harmonization. Thereby, this kind of product should not be adopted to restore anterior teeth in case of high esthetic requests, in fact, as reported by Friebel *et al.*[16] the clinical recommendation for front teeth would be to use a dentin composite to mask the dark background of the oral cavity and have a translucent edge of about 1-2 mm at the crown of the tooth, making the reconstruction appear more natural by using the layering technique with translucent enamel shades.

Conclusions

Within the limitation of this *in vitro* study G-aenial could be an interesting help when the choice of tooth color presents technical difficulties; however, as widely demonstrated in literature, even for this composite resin the thickness of the layer is a critical issue for the final color perception of the restoration.

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