Conversion Degrees of a Colored Compomer in Different Colors Utilized by Various Curing Times

Didem Atabek, PhD Haluk Bodur, PhD
Şükrü Kalayci, PhD Özgül Baygin, PhD
Ebru Tirali, PhD

ABSTRACT

Purpose: Compomers are widely used in primary teeth and are manufactured in different colors in order to make dental treatment acceptable in children. The aim of this in vitro study was to evaluate the degree of conversion (DC) of different colored compomers and of compomers with various curing times.
Methods: Sixty three cylindrical samples were prepared from a colored compomer (Twinky Star). These samples were of 7 different color groups, with 9 samples of each color. Each group was divided into 3 sub-groups, according to the curing time (20-30-40 seconds) with a light emitting diode light curing unit. The DC values from 3 different regions and depths were evaluated with a Fourier Transform Infrared Spectrometer before and after curing procedures for all groups. Data were calculated by using the baseline values; statistical analyses were done by using ANOVA test.
Results: Significant differences in DC results before and after curing were found among the groups ($P<0.05$). For all curing times, the silver colored samples showed the poorest DC results, which ranged from 13% to 18%.
Conclusions: It was concluded that DC values of different colors were variable. The material properties could be improved by defining the proper polymerization time for each color.

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Polyacid-modified composite resins, known commonly as compomers, are a group of esthetic materials for the restoration of teeth damaged by dental caries.[1] Since their introduction in 1993, the indicationsforcompomershave been expandedto include anterior and posterior restorations forprimary teeth.[2] Compomers were presented as a new class of dental material designed to combine the esthetics of traditional composite resins and the fluoride release and adhesion properties of glass ionomer cements.[3] Since then, compomers have become preferred for the same clinical applications as conventional composites. These indications include Class II and Class V cavities, fissure sealants, and bonding agents for orthodontic bands. Additionally their fluoride release is seen as a useful feature for use in pediatric dentistry, with certain brands specifically aimed at children.[4-6]

In the spirit of making dental visits even more appealing to children, alternative-colored compomers have been available for use in the restoration of primary molars for over 5 years. Compared to conventional compomers, a small amount of glitter particles are included to produce a color effect in shades of red, blue, gold, etc.[7]

Dr. Atabek is research assistant, and Drs. Bodur and Kalayci are associate professors, Department of Pedodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey; Dr. Baygin is research assistant, Department of Pedodontics, Faculty of Dentistry, KaradenizTeknik University, Trabzon, Turkey; and Dr. Tirali is research assistant, Department of Pedodontics, Faculty of Dentistry, Başkent University, Ankara.
Correspond with Dr. Atabek at dtdidem@hotmail.com

As with conventional compomers, colored compomers also resemble traditional composite resinsin that their setting reaction includes polymerization. This polymerization is usually light-initiated, with a camphorquinone with an amine accelerator as the initiator, which is sensitive to blue light at 470 nm.[7,8] Several studies have demonstrated that the degree of polymerization of conventional compomers is restricted with the degree of cure depending on many parameters, such as the: silane coupling between filler and matrix; shade of the material; wavelength distribution; intensity of the incident light; irradiation time; and specific formulation of the material[9,10]. An insufficient degree of cure affects the chemical and physical properties of the compomers, including water absorption, wear resistance, strength, and clinical performance.[11]

Resin-based material evaluation includes tests for mechanical strength, modulus of elasticity, and hardness—of the materials emphasizing the importance of polymer conversion. During the polymerization reaction, some of the monomer converts to a polymer. Some dimethacrylate monomers, however, exhibit considerable residual unsaturation in the final product, with a degree of conversion (**DC**) ranging from 55% to 75% under conventional irradiation conditions. The DC of the single to double bonds is desirable if a good performance of the material is to be achieved.

The final DC of a resin depends on the dimethacrylate monomer's chemical structure and polymerization conditions, such as: atmosphere; temperature; proper polymerization time; light intensity; and photoinitiator concentration. Since the use of colored compomers is recommended mainly for restorations in the primary dentition, the DC is an important aspect.[12,13] Because clinical experience is limited, a definite evaluation of the DC of colored compomers is important.

The purpose of this present study was to investigate the degree of conversion of different colored compomers, using various curing times, through the use of the Fourier transform infrared spectroscopy (**FTIR**) technique.

METHODS

The colored compomer investigated in the present study, Twinky Star (Voco, Cuxhaven, Germany), was tested in 7 different colors (blue, gold, green, lemon, orange, pink, and silver).

All experiments were performed in an air conditioned room set at 22°C. Sixty-three standard cylindrical compomer samples were prepared from colored compomer and allocated to 7 different groups based on color, with 9 samples is each group. These 9 samples were divided into 3 subgroups, according to polymerization time (20, 30, or 40 seconds) using a light emitting diode light curing unit (**LED LCU**; EliparFreelight, 3M ESPE, Seefeld, Germany) containing 19 blue LEDs. The light from the LED LCU was concentrated to a measured output diameter of 8 mm. The irradiance of the LED was 400 mW cm^{-2}, with a wavelength of 440 to 490 nm.

Light intensity was measured with a radiometer (Eliper Free Light, 3M ESPE, St. Paul, Minn). Samples of the respective colors were prepared by injecting the material into a cylindrical teflon mold (6 mm diameter x 2 mm depth) placed on a dark PVC background. The top of the mold was covered with a celluloid matrix strip, and excess material was removed by pressing a glass slide against the strip. The glass slidewas then removed and the mold covered with aspecifically designed light tip (10 mm diameter) of the curing unit positioned concentrically with the cavity in the mold and 0.5 mm above the sample. The materials were then light-cured from the top for 20, 30, or 40 seconds.

Afterwards, the samples were removed from the molds to evaluate the DC by FTIR spectroscopy (Mattson 1000 FTIR, Cambridge, UK) method.[8,12,15] The unpolymerized samples were smeared on potassium bromide (**KBr**) pellets, using Merck's spectroscopically pure KBr, with a press (GrasebySpecac, Unicom, Ankara, Turkey). The polymerized samples were ground into a fine powder with a mortar and pestle immediately after curing. Fifty µg of the ground powder was mixed with 5 mg of KBr powder, and KBr pellets were prepared under a pressure of 10 tons. This same method was used for all samples in all groups.

The infrared spectrum of unpolymerized and polymerized samples was then obtained via FTIR using 20 scans at a 0.2 cm^{-1} resolution. A range of 4,000 to 400 cm^{-1} was scanned, and a range of 1,560 to 1,670 cm^{-1} was expanded. The spectrum was recorded initially as the transmission mode by the microprocessor of the spectrometer. The DC was calculated by using the standard baseline technique.[14-16]

The DC of samples was determined by comparing the aliphatic carbon-carbon double bond (**C=C**) with that of aromatic component for the cured and uncured states. By using the change in the ratio of the aliphatic C=C before and after curing, the DC of the aliphatic C=C into C-C could be calculated using the following formula.[1]

$$DC(\%) = 1- \frac{[abs(aliphatic C = C)/abs(aromatic C = C)polymer}{[abs(aliphatic C = C)/abs(aromatic C = C)]monomer} \; x\ 100$$

Because of the small number of observations, the statistical analysis of the measured DCs was performed by nonparametric tests. Friedman's S test was used for comparison of repeated measures (20, 30, or 40 seconds). To compare groups (blue, green, etc.), the Kruskal Wallis H test was used. For multiple comparisons, Dunn's test was used.

RESULTS

The FTIR examination showed that DC values obtained for the different colors and time schedules had significant differences before and after curing among all of the groups ($P<.05$; Tables 1-2; Figure 1). For all of the color groups, the 40-second curing time produced increased DC values, while the other time periods created reduced DC values. On the other hand, there were significant differences in the levels of monomer polymerization among the different colors at the same times of light polymerization ($P<.05$).

For the 20-second curing time, the highest DC values were seen for the blue and green samples, with degrees of conversion not higher than 43%. The orange- and silver-colored samples presented the poorest DC results (14% and 13%, respectively).

For the 30-second curing time, the highest DC value occurred with the blue-colored samples, which presented a 53% degree of conversion rate. As with the 20-second curing time, the orange- and silver-colored samples showed the poorest DC results (19% and 15%, respectively).

For the 40-second curing time, the blue- and pink-colored samples appeared to be the most chemically stable of the materials examined. The same curing time, however, presented the lowest DC for the silver-colored samples (18%).

Table 1. The Mean Ranks of the Colored Compomer in 20, 30–, or 40–second Testing Schedules*

Color groups	Mean ranks 20 s	30 s	40 s
Blue	20[a]	20[a]	17
Gold	14	8.5	8
Green	17	17	5
Lemon	11	10.5	11.33
Orange	5	5	13.67
Pink	8	14	20[a]
Silver	2[a]	2[a]	2[a]
Kruskal-Wallis	19.64	19.45	19.50
P-value	.003	.003	.003

* Friedman's S statistics= 42; P= .00. Means followed by the same small letter in the same column indicate statistical differences (P<.05).

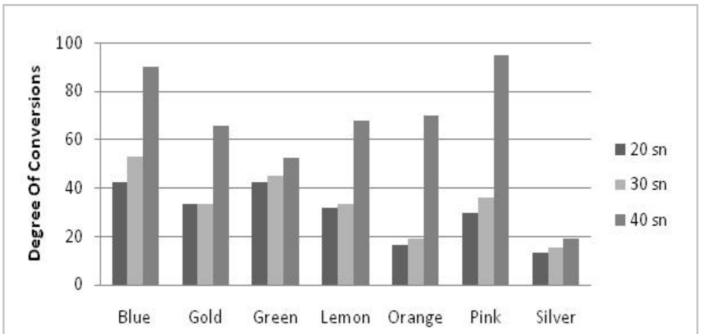

Figure 1. Differences in degree of conversion according to curing times among all groups.

DISCUSSION

In recent years, there has been an increased desire by the public for alternatives to amalgam as a restorative material in primary teeth.[17] Compomers have been widely used and studied for pediatric dentistry, although not exclusively so.[13] Recently, multicolored compomers with glitter inclusions have appeared in dental journals.[7,13]

MagicFill (Zenith/DMG, Englewood, NJ) is available in 4 colors and has a dual-cure feature, whereas Twinky Star, which is available in 7 colors, hardens only by photopolymerization, with both products releasing fluoride. When compared to conventional compomers, the colored compomers have a small amount of different colored glitter particles included to produce a color effect; however, the filler content is comparable to conventional compomers.[7,13] The polymerization process is a very important stage that affects the physical properties of the material, but the effect of color inclusions on the polymerization is not well known.

A 40 sec curing time has been proposed by the manufacturers, even though there are no studies to support this curing time. Hence, the present study of DC used Twinky Star, in 7 different colors and evaluated curing times of 20, 30, or 40 seconds. The present study evaluated the DCs at 20 and 30 seconds of curing times in order to compare DCs obtained at these lower levels with the DCs obtained at the recommended curing time. Variable DC values were obtained for each color at the same curing time periods. The silver samples had the poorest values, whereas the blue samples had the highest values at all curing times.

The most efficient wavelength for the DC of light-activated materials is reported to be 470 nm when camphorquinone was used as the initiator. The most important advantage of the LED LCU used in this current study is the ability to choose the most efficient wavelength (440-490 nm) expressed by the manufacturer.[12] As the initiator of the colored compomer evaluated in this study was camphorquinone, the LED LCU was used to coincide with the very narrow wavelength preference of camphorquinone.

The polymerization process in compomers appears to continue after irradiation is complete.[18] Under conventional irradiation conditions, all of the dimethacrylate monomers exhibit considerable residual unsaturation in the final product, with an acceptable DC ranging between 55% to 75%.[15,16,19] In general, the DC of double bonds provide the greater mechanical strength. The unreacted double bonds may either be present in free monomers or as pendant groups on the network. The unreacted monomer may leach from the polymerized material and irritate the soft tissue.[15]

Table 2. Degree of Conversion Percentages of the Colored Compomer in 7 Different Colors*

Color groups	20-sec polymerization %	30-sec polymerization %	40-sec polymerization %
Blue	$42.21 \pm 0.37^{A,a}$	$53.15 \pm 0.12^{A,b}$	$90.10 \pm 0.14^{A,c}$
Gold	$33.19 \pm 0.28^{B,a}$	$33.43 \pm 0.16^{B,b}$	$65.96 \pm 0.11^{B,c}$
Green	$42.68 \pm 0.11^{C,a}$	$45.13 \pm 0.12^{C,b}$	$52.34 \pm 0.27^{C,c}$
Lemon	$31.73 \pm 0.15^{D,a}$	$33.58 \pm 0.06^{B,b}$	$67.98 \pm 0.58^{B,c}$
Orange	$14.68 \pm 0.08^{E,a}$	$19.09 \pm 0.36^{D,b}$	$69.98 \pm 0.39^{D,c}$
Pink	$29.73 \pm 0.35^{F,a}$	$35.99 \pm 0.19^{E,b}$	$94.67 \pm 0.12^{E,c}$
Silver	$13.28 \pm 0.53^{G,a}$	$15.58 \pm 0.17^{F,b}$	$18.94 \pm 0.09^{F,c}$

** Means followed by the same small letter in the same row and capital letter in the same column indicate no statistical differences (P<.05).*

Commonly used methods to evaluate DC in light-activated restorative materials—such as composite resins, compomers, or glass ionomer cements—are infrared spectroscopy, surface hardness, scraping, and optical methods.[12,15,16] Most studies have shown that the optical and scraping methods present good correlation, but overestimated the depth of cure when compared with hardness and DC values. On the other hand, although the hardness method correlated well with DC, it has been suggested that DC reduced more drastically as depth increased. Therefore, infrared spectroscopy has been suggested as the most sensitive method for investigating DC's in light-activated dental materials.[14,16,19,20]

Polymerization in compomers is associated with contraction stress, as found in conventional composite resins. Furthermore, cure depths vary widely, depending on the brand and shade of compomers.[13] Koupis et al.[11] reported that shade A2 of a compomer resulted in significantly greater values for curing depth when compared to shade A4. Additionally, it was found that light shades of resin-based materials cured to a greater depth than darker shades due to the scattering of light in the materials, based on particle size, amount, and type of filler particles.[21-24] In accordance with these findings, this current study shows that color differences affect the final DC of compomers. While the curing times were the same for each subgroup, different colors created variable DC results. In the 40-second curing time groups, especially for the green-, gold-, lemon-, orange-, and silver-colored samples, the DC results were lower (~19-70%) than for the blue- and the pink-colored samples (~90-95%), which had significantly higher DC results. This contradiction may be due to differences in particle size, amount, and type of glitters.

There are only two clinical reports on the performance of the colored compomers. Akbayet al.[25] evaluated the clinical performance of the Twinky Star-colored compomer material in primary molars and indicated that the clinical success of the material was acceptable. Ertugrul et al.[17] also evaluated the clinical performance of the same material compared with tooth-colored compomers for proximal restorations in primary molars and concluded that colored compomers are suitable restorative materials for primary teeth.

Although colored compomers seem to be a useful adjunct to children's acceptance of dental work, the clinicians must be careful about the DC. A low DC results in poor resistance to wear and color stability. This current study reveals that a 40-second curing time is not adequate to achieve an acceptable final DC, especially for silver- and green-colored materials.

Few studies on the performance of colored compomers are found in the literature. Therefore, further in vitro and in vivo investigations are required.

CONCLUSIONS

The results of this investigation support the following conclusions:

1. The degree of conversion values of different colors were variable in the same curing time periods.
2. For silver and green colored materials the recommended curing time is not adequate to achieve an acceptable DC.

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