

Investigation into the Translucency of Tooth-Colored Restorative Materials

H. Torabzadeh^{1, 2}✉, R. Aminian³, A. Ghasemi^{1, 2}

¹Associate Professor, Department of Operative Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

²Associate Professor, Dental Research Center Dental, Shahid Beheshti University of Medical Sciences, Tehran, Iran

³Assistant Professor, Department of Operative Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Abstract:

Objective: The aim of this study was to investigate the translucency of resin-modified glass-ionomer cements (RMGIC) and polyacid-modified composite resin (PCMR) over a period of one year.

Materials and Methods: The study was done on three RMGIC (Fuji II LC, Photac-Fil Aplicap and Vitremer) and one PCMR (Dyract). A conventional GIC (Fuji Cap II) and two composite resins (Tetric and Z 100) were used for comparison. Five discs approximately 5 mm in diameter and 1.5 mm thick were made from each material using a Perspex mould. The specimens were kept in distilled water at 37°C during the test period. The optical density/mm (inverse of translucency) of each material was measured using a special photometric set up after preparation and after one week, six months, and one year. Means and standard deviations were calculated and subjected to Two-way ANOVA, One-way ANOVA and Scheffe tests.

Results: The results indicated that all of the materials, except Dyract, showed an increase of translucency over the test period. After one year, the conventional GIC was the least translucent material.

Conclusion: The translucency of the resin-modified GICs and Dyract was equivalent to that of the composite resins Tetric and Z 100.

Key Words: Glass Ionomer Cements; Fuji glass-ionomer lining cement; Dyract; Nuchal Translucency Measurement

✉ Corresponding author:
H. Torabzadeh, Department of Operative Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
5htorabzadeh@gmail.com

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INTRODUCTION

The demand for restorative materials that closely mimic the appearance of natural teeth is becoming increasingly important. Consequently, optical properties such as color and translucency have become important considerations in aesthetic restorative materials. Composite resins are generally acknowledged as superior to conventional glass-ionomer cements (GIC) in terms of optical properties. A major limitation of conventional GICs has

been the difficulty in achieving acceptable translucency.

In a study, translucency of GICs was reported to be lower than that of certain composite resins [1]; a finding that was confirmed later [2]. It was found that, in general, the translucency of early GICs and composite resins decreased as the material aged during the first 24 hours and that this effect was most marked in the first hours following immersion in water [1]. Little changes occurred from 24 hours to one

week and none thereafter. The researchers mentioned, however, that the test method employed, was not able to measure and detect further changes due to its limited precision [1]. In another study, the translucency of the new generation of conventional GICs was found to be similar to that of selected composite resins [3]. In contrast, a more recent study found that the translucency of a light-cured composite resin was far better than that of the conventional GICs tested [4].

It has been suggested that the final aesthetic result cannot be determined soon after placement of GIC restorations because it takes up to seven days for a conventional GIC to develop its final color and fully achieve its potential translucency [5]. It was demonstrated that the translucency of Fuji Cap II (GC International) significantly increased after one week of storage in water, whereas the translucency of Ketac-Fil Aplicap showed no significant difference [4].

With regard to the composite resins, a decrease in the translucency of specimens stored at 43°C and 90% relative humidity was reported [6]. In another investigation, changes of the translucency of some composite resins as they cured were investigated using a densitometer [7].

Upon curing, six of the resins showed an in-

crease in translucency while three became more opaque and one remained unchanged. These changes occurred within 20 seconds of curing [7]. Lightening of the composite resins has also been reported [8]. More recently, it was shown that the translucency and color of composites have changed over curing. The color change, however, was clinically unacceptable, and was claimed to be dependent on the brand of the composites.

Although the conventional GICs can develop sufficient translucency to be satisfactory in most cases, the newer resin-modified cements have an immediate translucency that is equivalent to that of composite resins. Furthermore, the aesthetic results of GIC restorations, whether conventional or resin-modified, should not be judged for at least one week because the restorations continue to mature, and translucency and physical properties will improve [9].

The internal opacity of three types of tooth colored restorative materials was measured using an accelerated test that includes storing specimens in 60°C water for 4 weeks [10]. It was found that light-cured composite resins showed negligible opacity change after four weeks while opacity gradually decreased (i.e. increase in translucency) for two chemically-cured macrofilled composites. All resin-

Table 1. Details of the materials used.

Name	Description	Manufacturer	Setting time	Working time	Powder:liquid	Curing time	Batch No
Fuji Cap II	Conventional GIC	GC International, Tokyo, Japan	225 Sec	105 Sec	encapsulated	-	911225
Fuji II LC	Resin-modified GIC	GC International, Tokyo, Japan	-	195 Sec	3.0:1.0	20 Sec	P:211212 L: 29111
Photac-Fil Aplicap	Resin-modified GIC	Espe GMBH, Seefeld/Oberbay Germany	-	180 Sec	encapsulated	20 Sec	0003
Dyract	Polyacid modified composite	Dentsply De Trey, Surrey England	-	-	-	40 Sec	921082
Tetric	Fluoridated Composite resin	Vivadent, Schaan, Liechtenstein	-	-	-	40 Sec	462284
Z 100	Composite resin	3M, Health Care, St Paul USA	-	-	-	40 Sec	19940413

P=Powder, L= Liquid

modified GICs tested showed an abrupt decrease of opacity at the initial stage and the opacity slightly decreased for Vitremer from two to four weeks. Fuji II LC showed a slight increase in opacity after two weeks, possibly due to exfoliation of the surface coating and slight surface deterioration during the four weeks of storage. The stability of color and translucency of composites after storage in salivary enzymes were also investigated and it was found that the enzymes have no deleterious effect on the properties tested.

It has been claimed that the translucency of the resin-modified GICs is better than that of the conventional cement and would appear to rival that of the light-cured composite resins. The effect of the resin on the stability of translucency is not yet clear and it cannot be assumed that the resin-modified GIC will perform in a similar manner to that of its parents.

The available information on the translucency of resin-modified GICs is very limited. This study was designed, therefore, to measure the optical density/mm (the inverse of translucency) of two resin-modified GICs immediately after preparation and also after one week, six months, and one year. The optical density/mm of a conventional cement, a polyacid-modified composite resin, and two composite resins was also measured for comparison.

MATERIALS AND METHODS

The present study was done on the following materials: Fuji Cap II, Fuji II LC, Photac-Fil Aplicap, Dyract, Tetric and Z100 (Table 1). Shade A2 was used for all materials except for

Fuji Cap II and Tetric for which the yellow-brown and YG shades were used, respectively, as these materials were not available in the A2 shade. The test specimens were prepared in a room set at 23°C (SD=1) and 55% (SD=2) relative humidity.

Five specimens were made from each material, each approximately 5mm in diameter and 1.5 mm thick. To make the specimens, holes 5 mm in diameter were drilled in perspex strips to form the mould. The materials were mixed and applied according to the manufacturers' instructions. Resting on a glass plate, the perspex mould was filled, to slight excess, with the materials. Another glass plate was then placed on top of the mould and pressure applied manually to displace excess material and produce a flat surface.

For Fuji Cap II, the specimens were left at 37°C and 100% humidity for 15 minutes, timed from the start of mixing. All other specimens were light-cured using Visilux 2 (3M) light-curing unit. Immediately after the setting of the materials, the specimens were removed from the moulds and their optical density was measured. The specimens were then placed in water at 37°C and their optical density measured at one week, six months, and one year thereafter.

A photometric set up consisted of a light source, the light dependent resistor (LDR), and a digital voltmeter was used to measure the resistance. The read resistance and thickness of each specimen were used to calculate the optical density/mm of the specimen. To perform these calculations automatically, a com-

Table 2. Optical density/mm of the tested materials at different time intervals.

Time	Fuji Cap II		Fuji II LC*		Photac-Fil Aplicap		Dyract		Tetric		Z100	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Immediate	0.345	0.020	^b 0.220	0.010	^d 0.226	0.004	^f 0.183	0.004	^g 0.201	0.009	ⁱ 0.197	0.004
One week	^a 0.308	0.010	^b 0.211	0.009	^d 0.232	0.014	^f 0.187	0.015	^g 0.190	0.006	^j 0.191	0.004
Six months	^a 0.293	0.009	^c 0.175	0.006	^e 0.158	0.008	^f 0.187	0.017	^h 0.172	0.009	^j 0.187	0.011
One year	0.262	0.007	^c 0.166	0.008	^e 0.149	0.004	^f 0.166	0.003	^h 0.167	0.009	^j 0.179	0.008

Values with the same letter are not significantly different (Scheffe test).

puter program was written. Three items of data were required in order to produce the actual optical density of a specimen: the resistance with no specimen, the resistance with the specimen over the LDR, and the thickness of the specimen. Details of the set up and theory of the method have been described elsewhere [4]. Having ensured that the light was correctly set to give a constant reading with no specimen present, the light was turned off, and the specimen placed in the hole of the card. The light was then switched on and the resistance of the LDR was measured using the digital voltmeter. Immediately after recording the resistance reading, the exact specimen thickness was measured using a micrometer. Then the specimen was returned to the water bottle and the light was turned off to prevent a build up of heat, which might have caused dehydration of subsequent specimens. In addition, the measurement procedure was carried out as rapidly as possible to prevent any possible dehydration of the specimen under test.

Any visible moisture was removed from the surface of the specimens that had previously been stored in water with tissue paper. Great care was taken not to dehydrate the GIC specimens.

The results were statistically analyzed by subjecting the data to parametric statistical tests. Two-way ANOVA was used to determine the effect of two kinds of influences (i.e. time and type of material) on the optical density/mm. The difference among the means of various

groups was tested by subjecting the data to one-way ANOVA. The Scheffe test was used to determine the level of significance. A level of $P < 0.05$ was considered as statistically significant.

RESULTS

The results of the optical density/mm are shown collectively in Fig 1 and Table 2. Two-way ANOVA indicated that both the type of material and time had significant effect on the optical density/mm ($P < 0.05$). One-way ANOVA and the Scheffe test, therefore, served to investigate the differences between the optical density/mm at different time intervals for each material as well as the differences between materials at a given time interval.

The optical density/mm of all materials generally decreased over time. One-way ANOVA revealed that significant difference existed among the optical density/mm of all materials at different time intervals. The results of Scheffe test (Table 2) revealed that Fuji II LC and Photac-Fil Aplicap reached their optimum optical density/mm at six months whereas the optical density/mm of the chemically cured GIC (Fuji Cap II) decreased over the test period (one year).

Tetric performed similar to the two resin-modified GICs; however, the results of the other composite resin (Z100) showed only a significant difference between the optical density/mm of immediately after preparation and that at one year. Scheffe test showed no signif-

Table 3. Comparison between the optical density/mm of materials at different time intervals.

Materials	Time Interval			
	One-week		One-year	
	Mean	SD	Mean	SD
Fuji Cap II	0.308	0.010	0.261	0.008
Fuji II LC	^a 0.211	0.009	^b 0.166	0.008
Photac-Fil Aplicap	0.232	0.014	0.149	0.004
Dyract	^a 0.187	0.015	^b 0.166	0.003
Tetric	^a 0.190	0.006	^b 0.167	0.009
Z100	^a 0.191	0.004	^b 0.179	0.008

Values with the same letter are not significantly different (Scheffe test).

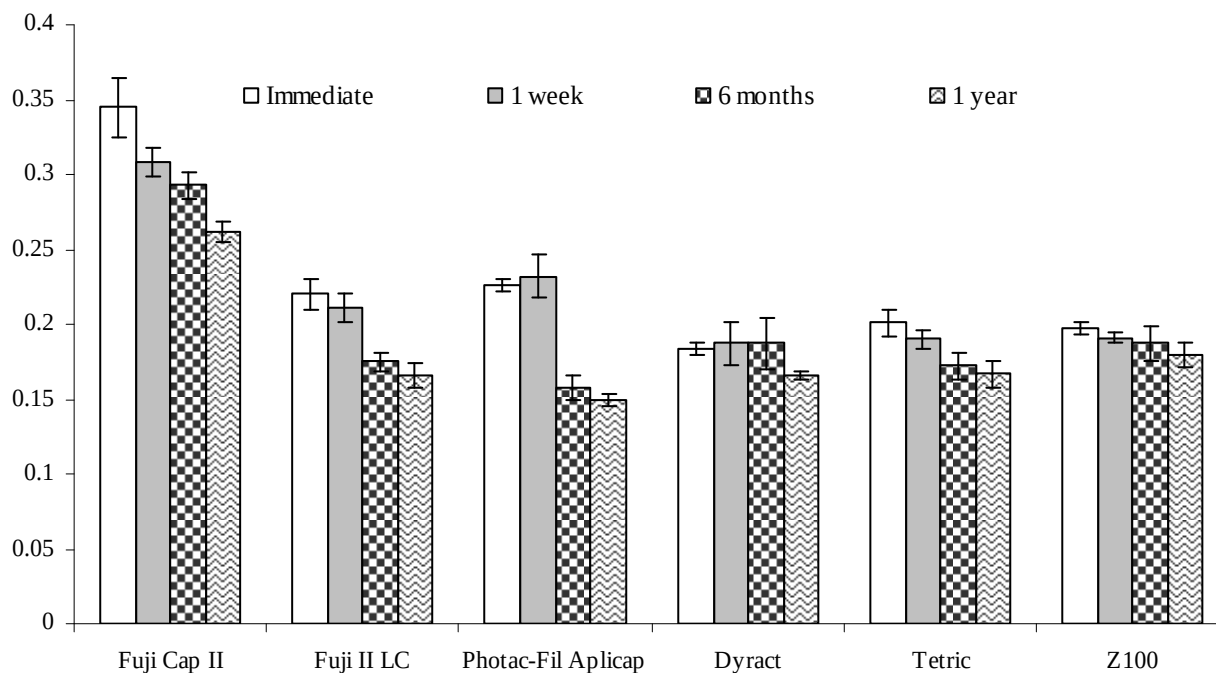


Fig 1. Optical density / mm of materials at various time intervals

icant difference between the results of the four groups of Dyract.

To compare the optical density/mm of the test materials, the results at one week and one year were used. Each set of data was analyzed using the one-way ANOVA. The results indicated significant differences between materials at both time intervals. The Scheffe test was used, therefore, to investigate the differences (Table 3).

It was found that Fuji Cap II was the least translucent material at both time intervals. The differences between Fuji II LC, Dyract, Tetric and Z100 were not significant at both time intervals. Photac-Fil Aplicap showed significantly less translucency than other materials, except Fuji Cap II, at 1 week whereas at 1 year, Photac-Fil Aplicap was the most translucent material.

DISCUSSION

A standard method for testing the opacity of GICs was recommended by the International Organization for Standardization [11]. This

was based on the procedures used by Crisp, Abel et al [1] in 1979, and Asmussen [2] in 1983. It was indicated, however, that the precision of this test method was not sufficient to detect the effect of powder: liquid ratio and also ageing, on the translucency of GICs [1]. Thus, in the current study an alternative test method was developed which, as explained, used a photometric device to measure the optical density. This, in contrast to the procedure recommended by the ISO, made the measurements simpler to perform and gave reproducible results (judged by the relatively low coefficients of variation recorded). The photometer used proved to be sensitive to changes in the light traveling through the specimens and was able to detect very small differences. A set-up similar to the one employed in this study has been also reported but the measuring devices were much more complicated and costly compared to those used in this study [3]. Photographs have also been produced to determine the differences among the translucency of various GIC specimens [5]. Such an assessment

procedure, however, seems to be more inaccurate than one which employs a photometric device. On the other hand, it must be acknowledged that the ability to detect very small differences, which might not be clinically recognizable by a laboratory based technique, is welcome. Furthermore, one should not underestimate the usefulness of such test methods in determining the potential optical property of materials and verifying their place in comparison with other available materials.

It has been well known that pigmentation influences the translucency of materials. At the planning stage of this study, a decision was made to use materials of the same shade. It was confirmed that the translucency of a darker shade of a given tooth-colored material is less than that of a lighter shade [1,2]. Due to limited shade availability, however, the yellow-brown and YG shades were used for Fuji Cap II and Tetric, respectively, whereas the A2 shade was used for Fuji II LC, Dyract and Z100. Great care was taken to choose, visually, the closest shade to the A2 shade, which was used for the other materials.

To investigate the effect of time on the translucency of the materials in the present study, the specimens were stored at 37°C for 1 year. For screening purposes, various procedures such as irradiation with UV-light, dry heating at 60°C for 23 hours, and storage in 60°C for four weeks have been used to provide accelerated ageing of materials [12]. After storage in water for one year, changes in optical properties were thought to be a more reliable measure of the changes that might occur in the clinical situation.

The translucency of materials is very sensitive to surface roughness. This is because a roughened surface increases the random reflection at the surface, leading to a decrease in the translucency [10,13]. For this reason, the specimen surfaces were cured against glass slides to produce flat and smooth surfaces, and were used without any further surface polishing.

The results of this study indicate that the translucency of all materials, except Dyract, increased significantly during the test period. The pattern of this increase was different for different materials. All the resin-modified GICs and Tetric behaved similarly since their translucency only showed a significant increase at 6 months in comparison to that of the one-week result. On the other hand, Fuji Cap II showed a significant increase during the first week and maintained this level for six months, then showed a further significant increase at one year. The only significant difference observed with Z 100 was between the translucency of specimens measured immediately after preparation and that measured at one year. An increase in the translucency of conventional GICs and composite resins during the first week of storage in water has been reported previously [1,4]. It was stated that the translucency of conventional and resin-modified GICs would improve due to continuous maturation [9]. Recently, an abrupt increase in the translucency of resin-modified GICs at the initial stage and a slight increase from two to four weeks were reported [10]. The researchers also found that two chemically cured composites showed a significant increase in translucency, while the light-cured composite exhibited only a negligible change [10].

Although the results of this study cannot be compared directly with the results of other studies due to the different testing methods and time schedule, it is clear that generally the translucency of the tooth-colored materials tends to increase with time. The magnitude and pattern of such an increase depends on the material used and the precision of the test method. Two mechanisms could be involved in the observed increase of the translucency of GICs. The first is the presence of the continuous acid-base reaction, which is more pronounced in the conventional cement. In fact, the observed increase at one week for Fuji Cap

It could be regarded as an indication of an ongoing setting reaction, which was not present at a similar rate in resin-modified GICs. Secondly, GICs are composed of inorganic particles and a surrounding matrix phase. The higher the refractive index difference between the two phases, the lower the translucency of the material.

This is due to multiple reflection and refraction at the matrix particle interfaces. Any change in the refractive index of the matrix phase of a material that would cause a decrease in the refractive index between the particles and the matrix, would increase the translucency.

Possibly, the high water absorption rate of resin-modified GICs might have led to such changes in the matrix. The increase in the translucency of composite resins might also be attributed to a similar mechanism. The clinical implication of the current results is that an increase in the translucency of a material means that dentists should expect a better aesthetic result as the restoration ages.

The results indicated that the conventional GIC was the least translucent material. This finding is in agreement with the general assumption that the aesthetic appearance of resin-modified GICs is an improvement over conventional cements. The current results also showed that the translucency of resin-modified GICs did not differ significantly from those of composite resins and polyacid-modified composite resin, Dyract. No similar research results were available in the literature for comparison.

Photac-Fil Aplicap was the most translucent material at one-year interval. However, its translucency was significantly lower than that of other materials except Fuji Cap II at one-week interval. This significant improvement can be attributed to a slower acid-base reaction in Photac-Fil Aplicap and/or a higher water uptake rate by the material [14]. It has been found previously that Photac-Fil Aplicap re-

quired prolonged protection (four weeks) in order to minimize color change over time [15].

CONCLUSION

The translucency of all tested materials, except Dyract, increased as the specimens aged. The pattern of change was different among the materials. Fuji Cap II was the least translucent material, while Photac-Fil Aplicap exhibited the highest translucency at one-year interval. The translucency of resin-modified GICs and Dyract was equivalent to that of the composite resins Tetric and Z100.

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