Journal of Applied Sciences Research, 9(8): 5277-5282, 2013
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Effect of light curing on micro-hardness of resin-modified versus conventional glass-ionomer restoration as a function of depth and time

Mohamed H. Zaazou and Shaymaa M. Nagi

Restorative and Dental Materials Research department, National Research Center, Cairo, Egypt

ABSTRACT

Aim: To evaluate the micro-hardness of various thicknesses of resin-modified glass-ionomer (RMGI) restoration cured with either light emitting diodes (LED) or halogen curing unit, compared to conventional glass-ionomer (CGI) restoration, tested after one and seven days. Materials and Methods*:* 270 cylindrical specimens with different thicknesses were prepared from the two selected materials. Half of the RMGI specimens (n=90) were photopolymerized from the top surface by LED and the other half by halogen curing unit. Specimens were tested after one and seven days. Mean Vickers's micro-hardness values for the bottom and top surfaces of each thickness were calculated. Results: CGI showed a significantly higher mean micro-hardness top and bottom values compared to RMGI after one and seven days. There was no statistically significant difference in mean micro-hardness values between top and bottom surfaces for CGI at the different tested thicknesses. For the top surface, the mean micro-hardness values of RMGI cured with LED was significantly higher than that cured with halogen, while there was no statistically significant difference at the bottom surface using different curing systems. Mean micro-hardness of the bottom surfaces of 2 mm thickness was significantly higher than 3mm and 4mm thicknesses. Seven days storage revealed significant higher mean micro-hardness values compared to one day. Conclusion: Inclusion of resins in the RMGI does not improve the surface micro-hardness of these materials. The polymerization and acid/ base reactions produced in RMGI did not insure adequate polymerization especially in thicker layers. Curing efficiency of LED was comparable to halogen light.

Kew words: micro-hardness, resin-modified, glass-ionomer (RMGI), light emitting diodes (LED).

Introduction

Dental profession now embraces the concept of minimal intervention and conscious effect to practice maximum conservation of tooth structure. Resinous materials like composite, compomer, and resin-modified glass-ionomer (RMGIs), have the advantage of preservation of tooth structure, low thermal conductivity, and advanced physical and mechanical properties of the material (Bhalla *et al.,* 2012).

RMGIs are an important advancement in glass-ionomer technology (GI). They were developed to improve the mechanical properties and reduce the early moisture sensitivity of conventional GI materials (CGI) (Davidson *et al.,* 1997; Roberts *et al.,* 2009), while preserving their clinical advantage as esthetics, self adhesion to dental tissue, fluoride release, and thermal insulation (Bhalla *et al.,* 2012). RMGIs essentially consist of CGI components combined with organic photopolymerizable monomers and a visible-light initiation system (Roberts *et al.,* 2009 and Bhalla *et al.,* 2012). Setting reaction of RMGIs starts when two components are mixed together due to an acid-base reaction. Light exposure causes the creation of cross bonds between polymeric chains and polymerization of methacrylate (Di Lenarda *et al.,* 2000). Thus, the reaction may be finished immediately after light exposure, so that operators can have a longer working time (Bala *et al.,* 2012).

A concern when using RMGIs is the possibility that they will not adequately set when placed in bulk and activated by visible light, because the amount of light that reaches the deeper regions of the restoration may not be sufficient to initiate photopolymerization (Nicholson., 1998). To compensate for this potentially adverse effect, manufacturers have added chemically activated (i.e., auto-cure) components, which purportedly increase RMGI depth of cure (Mc Cabe., 1998). As a result, some clinicians assume RMGI materials can be placed without regard to depth because the deeper areas of compromised light penetration can polymerize sufficiently because of the presence of chemically polymerizing resins and by the conventional acid-base polyalkenoate reaction (Roberts *et al.,* 2009).

Quartz-tungsten-halogen lights (QTH) are the most frequently used curing units to photoactivate resin-based dental materials irrespective of the photoinitiator added (Araujo *et al.,* 2008; Bouillaguet *et al.,* 2005). Moreover they had the advantage of being low-cost technology curing unit. However, these light units develop high temperatures and have a declining power density over time due to bulb and filter aging (Cefaly *et al.,*

Corresponding Author: Mohamed H. Zaazou, Restorative and Dental Materials Research department, National Research Center, Cairo, Egypt.

2009). Advances in the light curing area have been remarkably seen, mainly after the development of the blue light-emitting diodes lights (LED). They use a solid-state semiconductor (diode) that converts electrical energy directly into blue light (Yap *et al.,* 2003; Mills *et al.,* 1999). LED had the advantage of increased lifetime, in such case; their performance does not significantly reduce with time (Mills *et al.,* 1999). This characteristic is very important because an unsuitable potency can provoke a negative effect on the physical properties of resinous materials and increased risk of premature failure of restorations (Harrington., 1996; Nogueira *et al.,* 2007).

One of the ways of studying the setting/curing behavior and depth of cure of RMGI materials has been to measure their hardness (Burke *et al.,* 1990; Kanchanavasita *et al.,* 1998). Hardness has been used as an indicator of degree of conversion (i.e., extent of polymerization of monomers to polymers) in dental materials (Roberts *et al.,* 2009).

Thus this study was carried out to investigate the influence of introduction of different curing appliance, on the polymerization of bulk placed RMGI restoratives when penetration of the curing light is limited because of material thickness compared to CGI.

Materials and Method

Materials selection:

A CGI filling material (Ketac Fil Plus Aplicap), and a RMGI (Fuji II LC) were used in this study. The brand name, manufactures and setting reaction of these materials are listed in Table 1.

Table 1: Materials brand name, manufactures and setting reaction.

BRAND NAME	MANUFACTURER	SETTING REACTION
KETAC Fil Plus Aplicap	3M-ESPE (St Paul, MN, USA)	chemical
Fuji II LC	GC Corporation (Tokyo)	chemical + light cured

Sample Preparation:

A total of 270 cylindrical specimens were prepared and were divided into 18 groups with 15 specimens each, according to the glass-ionomer type, curing source, material thickness and time combinations used. Sectional Teflon molds of 6 mm diameter and with different depth (2 mm, 3mm and 4mm deep) were used to prepare the specimens. The molds were first mounted on top of a microscope slide and a Mylar strip. The materials were mixed according to their manufacturer's instructions and inserted into the molds slightly excessively. After insertion, another Mylar strip was applied to the surface of the unpolymerized materials and a microscope slide was pressed against the ring to adapt the materials completely to the inner portion of the ring. Not only the same restorative material volume was obtained, but also a flat top and bottom surfaces (Cefaly *et al.,* 2009 and Roberts *et al.,* 2009). The excess material was removed using sharp scalpel. For the light-curing RMGI (Fuji II LC), specimens were then photoactivated at the top surface. Two curing units were used to photopolymerize the specimens: a LED [Blue phase C5, Ivoclar Vivadent, Schaan, Leichtenstein] and a QTH [XL3000; 3M ESPE]. During light curing, the tip of the light guide was in contact with the Mylar on the mold's top surface. The power density of both light units was assessed with a hand-held radiometer [Curing Radiometer; Demetron Research Corp., Danbury, CT, USA]. The power density was around 600 mW/cm2. The exposure time was according to manufacturer's instructions for 20 seconds. After photoactivation, the specimens were removed from the molds and the top surfaces were identified with an indelible mark. Specimens were stored in light proof recipients in complete darkness at 37°C to prevent ambient light from causing additional post light-curing polymerization, until being tested at one and seven days after fabrication (Cefaly *et al.,* 2009; Roberts *et al.,* 2009 and Taher., 2011).

Micro-hardness testing:

The micro-hardness test was performed using Vickers micro-hardness tester (Nexsus 4503, INNOVATEST, The Netherlands, Europe). Six randomized indentations (3 on both the top and bottom surfaces) were made with a 100 g load, with a dwell time of 10 seconds (Roberts *et al.,* 2009 and Bhalla *et al.,* 2012). For randomization, specimens were arbitrarily rotated before indentations. Calculations were made using computer software (Hardness-Course Vickers/ Brinell/ Rockwell copy right IBS 2012 version 10.4.4).

Statistical analysis:

Data were presented as means and standard deviation (SD) values. Three Way-ANOVA was used to study the effect of glass ionomer type, curing source, material thickness and time on mean micro-hardness. Duncan's

post-hoc test was used for pair-wise comparison between the means when ANOVA test is significant. One way-ANOVA was used to study the interaction between variables. Duncan's post-hoc test was used for pair-wise comparison between the means when ANOVA test is significant. Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 20 for Windows.

Results:

Three way-ANOVA showed a significant interaction at p≤0.001 for all the variables; where CGI produced the highest significant mean micro-hardness both after seven days followed by1 day.

For the top surface, Three way-ANOVA showed that glass ionomer type produced a significant difference in the mean micro-hardness at p≤0.001 where CGI produced the highest significant mean micro-hardness (74.73±10.13 VHN) followed by RMGI Cured with LED (53.90±5.43 VHN) followed by the RMGI cured with Halogen which showed the least significant mean micro-hardness (53.12±6.99 VHN). For the thickness of material; an insignificant difference were produced at p=0.948. Seven days storage produced significant higher values for micro-hardness compared to one day (67.54±12.25 VHN and 53.63±8.62 respectively).

While for the bottom surface, Three way-ANOVA shows that glass ionomer type produced a significant difference in the mean micro-hardness at p≤0.001 where CGI produced the highest significant mean micro-hardness (74.79±10.51 VHN) followed by RMGI with insignificant difference between different curing source (51.57±6.71 VHN) for Halogen and (51.66±6.88 VHN) for LED. For the thickness of material; 2 mm produced the highest significant mean micro-hardness (60.24±12.77 VHN) followed by 3mm and 4mm with an insignificant difference between each other (59.15±13.59 VHN and 58.64±14.68 VHN respectively). Seven days storage produced significant higher values for micro-hardness compared to one day (66.81±13.12 VHN and 51.88±9.52 respectively).

All the variables showed a significant interaction at p≤0.001; were CGI produced the highest significant mean micro-hardness both after 7 days followed by one day. Table 2: Showing the mean and SD for the interaction between variables for the top and bottom surfaces.

Table 2: The mean and SD for the interaction between variables for the top and bottom surfaces.

Specimens surface	Specimen thickness	Storage time	Glass Ionomer						p-Value
			CGI		RMGI				
					LED		Halogen		
			Mean	SD	Mean	SD	Mean	SD	
Top surface	2 mm	24 Hours	64.36^{b}	2.72	47.13^{fg}	1.63	49.77^{e}	2.26	
		7 days	84.93^{a}	2.45	59.57^{cd}	2.06	57.64^{d}	1.63	
	3 mm	24 Hours	65.74^{b}	2.33	46.24^{g}	2.19	49.95^{e}	3.83	
		7 days	83.60^{a}	2.57	59.67^{cd}	2.16	58.71^{cd}	2.35	
	4 mm	24 Hours	64.97^{b}	3.42	46.08^{g}	1.61	48.39^{ef}	3.69	
		7 days	84.77^{a}	2.72	60.04^{c}	2.69	58.93^{cd}	3.37	≤0.001*
Bottom surface	2 mm	24 Hours	64.91^{b}	3.10	47.10^{de}	2.58	48.54^{d}	2.06	
		7 days	84.58^{a}	2.56	58.20^{c}	2.33	58.12^{c}	2.38	
	3 mm	24 Hours	64.44^{b}	2.90	45.02^{f}	2.20	45.49^{ef}	2.17	
		7 days	84.56^{a}	2.65	57.92^{c}	2.25	57.45^{c}	2.10	
	4 mm	24 Hours	64.74^{b}	2.96	43.79^{fg}	1.85	42.86^{g}	1.37	
		7 days	85.51^{a}	2.62	57.95^{c}	3.12	56.98^{c}	4.54	

Means with the same letter are not significantly different at p=0.05. *= Significant

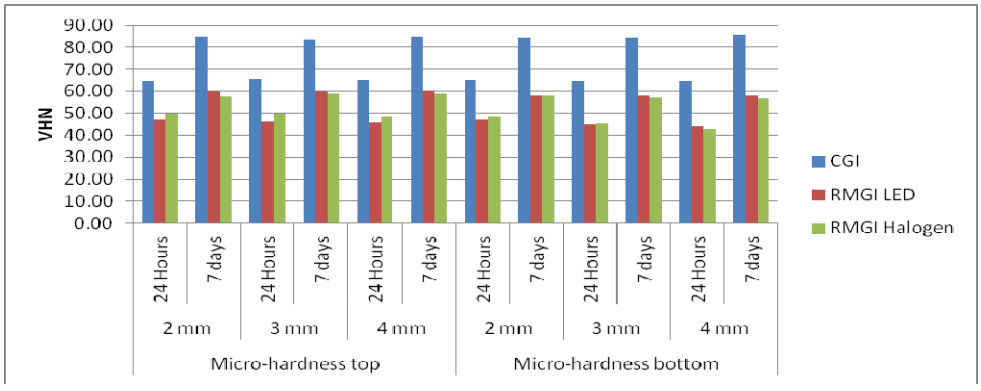

Fig. 1: Histogram showing the mean and SD for the interaction between variables for the top and bottom surfaces.

J. Appl. Sci. Res., 9(8): 5277-5282, 2013

Discussion:

In the present study; CGI showed the highest mean micro-hardness value compared to RMGI at both top and bottom surfaces after one and seven days. Many studies Xie *et al.,* 2000; Aliping-Mckenzie *et al.,* 2003; Ellakuria *et al.,* 2003 and Bhalla *et al.,* 2012 supported our finding. It has been claimed that the inclusion of resins in the RMGIs does not improve the surface micro-hardness of these materials. Resin-modified glass ionomers (RMGIs) essentially consist of (CGI) components combined with organic -soluble, hotopolymerizable 2-hydroxyethylmethacrylate (HEMA) monomer and a visible-light initiation system (Mc Lean *et al.,* 1994; De Gee *et al.,* 1998). So the setting reaction of RMGIs is complex compared with that of CGI materials, especially in terms of the interactions that occur between HEMA and other constituents (Nicholson. 1998). It has been reported that HEMA affect the polyacrylic acid's configuration and has been theorized to induce possible phase separation because components in polymerized HEMA are water insoluble and may precipitate out of solution (Culbertson., 2001). HEMA also decreases polyacrylic acid solubility, reducing its availability for reacting (Anstice and Nicholson., 1994). The overall effect of adding HEMA to a conventional GI material as in RMGI material is a decreased acid-base curing reaction, which may result in a material with inferior physical properties (Anstice and Nicholson., 1994; Nicholson., 1998; Roberts *et al.,* 2009 and Bhalla *et al.,* 2012).

Regarding comparing the values seen at the top and bottom surfaces for each material (either CGI or RMGI) at different prepared specimens' thicknesses. There was no significantly difference was seen for CGI, this was explained due to the uniform acid/glass reaction that occurs into these materials. While for RMGI similar micro-hardness values seen at the top and bottom surfaces were showed only for specimens with 2mm thicknesses. While for 3mm and 4mm thicknesses specimens bottom surfaces revealed significant lower micro-hardness valves compared to top surface. This might be explained by understanding the polymerization process. There is minimal light attenuation at the top irradiated surface and the polymerization process proceeds very quickly because virtually all photoinitiators were activated (Rueggeberg *et al.,* 1993). Deeper in the resin-based photoactivated material, however, light attenuation and scattering cause a decrease in conversion as fewer molecules of camphorquinone are activated leading to a much reduced extent of reaction (Davidson-Kaban. et al, 1997; Rueggeberg. et al, 1999 and Cefaly *et al.,* 2009). Depending on the number of photons, less light will be able to penetrate to deeper depths of restorative material, decreasing the probability of raising a large number of photoabsorbing molecules to the excited state, increasing total conversion (Rueggeberg. et al, 1999, Roberts *et al.,* 2009).

RMGI top surface micro-hardness values showed to be dependent on the light curing units used for photo-polymerization. LED provided an additional polymerization at the top surfaces compared to halogen curing units. This might be due to that LED uses a single high intensity LED for light generation (Yap and Soh., 2005). This intensity LED uses a substantially larger semi-conductor, which increase both the illuminated area and light intensity. Beside that, LED present a specific pattern of light emission, which is similar to the absorption spectrum of the photo-initiator of RMGI (Stahl *et al.,* 2000 and Althoff and Hartung., 2000). On the other hand, the bottom surface micro-hardness values showed to be independent on the light curing units used, which might be due to the effect of light attenuation and scattering that occurs in deep areas of the restorations as discussed before.

It has been pointed out by (Sidhu and Watson., 1995; Mount., 2001 and Mount *et al.,* 2002) that the setting reaction of all glass-ionomers is slow and prolonged and therefore a steady increase in strength can be anticipated for months following placement. The present study confirms these observations as there was an increase in the micro-hardness in all the materials from one to seven days.

Conclusions:

1-Inclusion of resins in the RMGI does not improve the surface micro-hardness of these materials.
2-Although the tested RMGI materials demonstrate a potential for post light-activation chemically initiated resin polymerization and/or polyalkenoate acid/base reaction, these reactions may not be sufficient to ensure that the material is adequately polymerized for long-term success. This is particularly true when RMGI materials are placed in thicker layers where curing light penetration may be compromised.
3- Curing efficiency of LED was comparable to halogen light.

Recommendation

In deep cavity preparations it is recommended that a RMGI restoration should be built in increments no greater than 2mm in depth. This technique will take advantage of the higher physical properties that can be developed through irradiation.

References

Aliping-McKenzie, M., R.W. Linden, J.W. Nicholson, 2003. The effect of saliva on surface hardness and water sorption of glass-ionomers and "compomers". Journal of Materials Science**:** Materials in Medicine, 14: 869-873.

Althoff, O., M. Hartung, 2000. Advances in light curing. American journal of Dentistry, 13: 77-81.

Anstice, H.M., J.W. Nicholson, 1994. Studies in the setting of polyelectrolyte materials. Part II: the effect of organic compounds on a glass poly (alkenoate) cement. Journal of Materials Science**:** Materials in Medicine, 5: 299-302.

Araujo, C.S., M.T. Schein, C.H. Zanchi, S.A. Jr Rodrigues, F.F. Demarco, 2008. Composite resin microhardness: the influence of light curing method, composite shade, and depth of cure. Journal of Contemporary Dental Practice, 9: 43-50.

Bala, O., H. Arisu, I. Yikilgan, S. Arslan, A. Gullu, 2012. Evaluation of surface roughness and hardness of different glass ionomer cements. European Journal of Dentistry, 6: 79-86.

Bhalla, M., D. Patel, N.D. Shashikiran, R.M. Mallikarjuna, T.M. Nalawade, H.K. Reddy, 2012. Effect of light-emitting diode and halogen light curing on the micro-hardness of dental composite and resin-modified glass ionomer cement: An in vitro study. Journal of Indian Society of Pedodontics and Preventive Dentistry, 30: 201-205.

Bouillaguet, S., G. Caillot, J. Forchelet, M. Cattani-Lorente, J.C. Wataha, I. Krejci, 2005. Thermal risks from LED- and high-intensity QTH-curing units during polymerization of dental resins. Journal of Biomedical Material Research, 72: 260-7.

Burke, F.M., P.D. Hamlin, E.J. Lynch, 1990. Depth of cure of light-cured glass-ionomer cements. Quintessence International, 21: 977-81.

Cefaly, D.F., L.C. Liliam De Mello, L. Wang, J.R. Lauris, P.H. D'Alpino, 2009. Effect of light curing unit on resin-modified glass-ionomer cements: a micro-hardness assessment. Journal of Applied Oral Science 17: 150-4.

Culbertson, B.M., 2001. Glass-ionomer dental restoratives. Progress in Polymer Science, 26: 577-604.

Davidson-Kaban, S.S., C.L. Davidson, A.J. Feilzer, A.J. Gee, N. Erdilek, 1997. The effect of curing light variations on bulk curing and wall-to-wall quality of two types and various shades of resin composites. Dental Materials, 13: 344-52.

De Gee, A.J., G. Leloup, A. Werner, *et al*., 1998. Structural integrity of resin-modified glass ionomers as affected by the delay or omission of light activation. Journal of Dental Research, 77: 1658-63.

Di Lenarda, R., M. Cadenaro, D.E. De Stefano, 2000. Cervical compomer restorations: The role of cavity etching in a 48-month clinical evaluation. Operative Dentistry, 25: 382-387.

Ellakuria, J., R. Triana, N. Mínguez, I. Soler, G. Ibaseta, J. Maza, F. García-Godoy, 2003. Effect of one-year water storage on the surface microhardness of resin-modified versus conventional glass-ionomer cements. Dental Materials, 19: 286- 290.

Harrington, E., H.J. Wilson, A.C. Shortall, 1996. Light-activated restorative materials: a method of determining effective radiation times. Journal of Oral Rehabilitation, 23: 210-218.

Kanchanavasita, W., H.M. Anstice, G.J. Pearson, 1998. Long-term surface micro-hardness of resin-modified glass ionomers. Journal of Dentistry, 26: 707-12.

Mc Cabe, J.F., 1998. Resin-modified glass-ionomers. Biomaterials, 19: 521-527.

McLean, J.W., J.W. Nicholson, A.D. Wilson, 1994. Proposed nomenclature for glass-ionomer cements and related materials. Quintessence International, 25: 587-9.

Mills, R.W., K.D. Jandt, S.H. Ashworth, 1999. Dental composite depth of cure with halogen and blue light emitting diode technology. Brazilian Dental Journal, 186: 338-391.

Mount, G.J., 2001. An Atlas of Glass-Ionomer Cements – A Clinician's Guild. 3rd edn. London: Martin Dunitz, 75-93.

Mount, G.J., C. Patel, O.F. Makinson, 2002. Resin modified glass-ionomers: Strength, cure depth and translucency. Australian Dental Journal, 47: 339-343.

Nadia Malek Taher, 2011. Degree of conversion and surface hardness of two nanocomposites compared to three other tooth-colored restorative materials. Pakistan Oral & Dental Journal, 31: 457-463.

Nicholson, J.W., 1998. Chemistry of glassionomer cements: a review. Biomaterials, 19: 485-94.

Nogueira, J.C., W.C. Zaronia, M.A. Chinelattib, R.G. Dibbb, 2007. Influence of different light-curing units on the surface roughness of restorative materials. In situ study. Materials Research, 10: 253-256.

Roberts, H.W., D.W. Berzins, D.G. Charlton, 2009. Hardness of three resin-modified glass ionomer restorative materials as a function of depth and time. Journal of Esthetic and Restorative Dentistry, 21: 262-274.

Rueggeberg, F.A., W.F. Caughman, J.W. Jr Curtis, H.C. Davis, 1993. Factors affecting cure at depths within light-activated resin composites. American Journal of Dentistry, 6: 91-5.

Rueggeberg, F., 1999. Contemporary issues in photocuring. Compendium of Continuing Education in Dentistry, 25: 4-15.

Sidhu, S.K., T.F. Watson, 1995. Resin-modified glass ionomer materials. A status report for the American Journal of Dentistry, 8: 59-67.

Stahl, F., S.H. Ashworth, K.D. Jandt, R.W. Mills, 2000. Light emitting diode (LED) polymerization of dental composites. Flexural properties and polymerization potential. Biomaterials, 21: 1379-85.

Taher, N.M., 2001. Degree of conversion and surface hardness of two nanocomposites compared to three other tooth-colored restorative materials. Pakistan Oral & Dental Journal, 31: 457-463.

Yap, A.U., M.S. Soh, 2005. Curing efficacy of a new generation high-power LED lamp. Operative Dentistry, 30: 758-63.

Yap, A.U., P. Wattanapayungkul, S.M. Chung, 2003. Influence of the polymerization process on composite resistence to chemical degration by foodsimulating liquids. Operative Dentistry, 28: 723-727.

Xie, D., W.A. Brantley, B.M. Culbertson, G. Wang, 2000. Mechanical properties and microstructures of glass-ionomer cements. Dental Materials, 16: 129-138.