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Comparison of Mechanical Properties of Resin Composites with Resin Modified Glass Ionomers

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Abstract

Statement of Problem: There are controversial reports regarding physical and mechanical properties of resin composites and glass ionomer cements. Some revealed higher strength and hardness for resin composites while others showed a comparable value for glass ionomer cements. Evaluation of mechanical properties of different types of resin composites in comparison with resin modified glass ionomers is not widely studied.

Objectives: To measure and compare the flexural strength and Vickers hardness of three resin composites and two resins modified glass ionomer cements before and after ageing.

Materials and Methods: Three resin composites, i.e. Filtek Supreme XTE (3M ESPE), Ice (SDI), Gradia (GC), and two resins modified glass ionomers, i.e. Fuji II LC (GC) and Riva Light Cure (SDI), were selected. Ten bar-shaped specimens were prepared for each material and cured using LED curing light. After 24 hours storage in distilled water at 37oC, the specimens were randomly divided into two equal groups (n=5). The first group was tested as a baseline and the second group was restored at 37oC for another 29 days. Flexural strength was performed by four-point bending test using universal testing machine at crosshead speed of 0.5mm/min, and the maximum load at failure was recorded. The specimen's halves were used for evaluating Vickers hardness, using a Digital Hardness Tester (300 g/15 sec) and the Vickers hardness number (VHN) was recorded. Data were analyzed using one-way analysis of variance (ANOVA), Tukey's and student's t-test.

Results: After 24 hours of immersion, the highest hardness number was found for Filtek Supreme and Ice and the highest flexural strength was obtained for Gradia. After 30 days of storage, hardness of Fuji II LC and Gradia showed a significant decrease; flexural strength of Ice and Fuji II LC revealed a significant increase while Gradia and Filtek Supreme showed a significant decrease.

Conclusions: Resin modified glass ionomers showed a comparable result for hardness and flexural strength with some of the tested resin composites and lower values than some others.

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Introduction

A variety of direct aesthetic restorative materials are available to practitioners having different physical and mechanical properties. Those materials are categorized into two major groups of resin composites and glass ionomer cements. Resin composites comprise various types of hybrid, microhybrid, microfilled and nanofilled are more commonly used as aesthetic restoration.

Since the end of the 1980s, more developed glass ionomer cements (GICs) such as resin-modified glass-ionomer cements, (RM-GICs) have become available. Stronger and less brittle hybrid materials have been produced by addition of water-soluble polymers to create a light-curing GIC formulation and become compatible materials with resin composites [1]. RM-GICs maintain the desirable properties of GIC including fluoride release and chemical adhesion to tooth structure_and overcome the disadvantages such as moisture sensitivity during setting and poor early mechanical strength [2,3]. In addition, they provide better aesthetics than conventional glass ionomers and rapid hardening by visible light [2].

RMGIs contain acid-based and polymerizable components and thus are set by at least 2 mechanisms [2] which make them different from resin composites. Besides, the resin component of RM-GIC is usually hydroxyethyl methacrylate (HEMA) [4]. Since the HEMA, as a hydrophilic resin, can increase the water sorption, physical and mechanical properties of RM-GICs could be affected by storage in water [5]. Several studies investigated the effect of long-term water storage on the hardness and strength of RM-GICs. Although, compared to the conventional GICs, the flexural strengths of the RM-GICs were improved by resin reinforcing methods [6], it was claimed that their flexure strengths were still lower than those of most resin composites [6,7].

There are some controversial results comparing the hardness of RM-GICs and resin composites. While a lower hardness was reported for RM-GICs in some previous studies [8, 9], Li *et al*. reported that the microhardness of RM-GICs was close to that of the resin composite after storage in water [10].

Due to improvement in dental materials, nanocomposites are used extensively and encapsulated types of RM-GICs were preferred for common dental procedures. Therefore, this study focused on the hardness and flexural strength of encapsulated RM-GICs compared with micro- and nano-hybrid resin composites.

The objectives of the present study were to place two RM-GIC and three resin composites in distilled water for up to 30 days at 37°C and determine the resultant surface hardness and flexural strength, and [2] the effect of ageing on those properties. The null hypotheses are that there is no difference among the materials and that ageing does not affect those mechanical properties.

Materials and Methods

Specimen preparation

Five aesthetic restorative materials of shade A2 were investigated (Table 1). A custom-made, brass and aluminum mould was used to prepare a total of 10 bar-shaped specimens of 25mm length, 2mm height and 5 mm width for each material. The mould was filled with the material and sandwiched between two plastic matrix strips and glass plates in order to extrude the excess. The materials were cured trough transparent strips according to the manufacturers' instructions for 40 seconds in each equal section of 3 using a light-polymerizing LED unit with a wavelength range of 440-480 nm at an output of 1500mW/cm^2 (Radii plus LED, SDI, Bayswater, Vic, Australia). Each specimen was removed from the mould and light-cured on the opposite side for an additional 40 seconds. The specimens were stored in distilled water at 37^{o}C for 24 hours, and then wet polished with a sequence of 1000, 1500-, 2000-grit silicon carbide papers. They were randomly divided into two equal groups of 5; one group was tested after 24 hours as the baseline and the second group was restored at 37^{o}C for another 29 days. The specimens were removed, blotted dry with paper towel and tested using universal testing machine (Zwick/Roll Z020, Zwick GmbH & Co, Germany).

Four-point bending test

Before testing, the width and height of each specimen were measured using a digital caliper with accuracy up to 0.1mm (Mitutoyo Crop, Kawasaki, Japan). The specimens were placed in the universal testing machine (Zwick/Roll Z020, Zwick GmbH & Co, Germany) using a four-point bend test jig, loaded at a cross-head speed of 0.5mm/min. The maximum load at specimen failure was recorded and the flexural strength was calculated using the following formula: $\delta=3.\ F.L/\ 2.b.d^2$;

Where F is the load at the fracture point (N), L is the length of the support span (L_1: outer span; L_2: in-

Table1: Materials Description

Name	Manufacture	Material Type	Filler(wt/vol) /Resin type	Batch #
Fuji II LC	GC Corporation, Tokyo, Japan	Resin-modified glass-ionomer cement	55vol% FSG/Poly-HEMA Average 5.9 µm	1405261
Gradia direct	GC Corporation, Tokyo, Japan	Microhybrid Composite	75%wt FAS, Silica, prepolimerized filler Average 0.85µm UDMA dimethacrylate	1311063
Riva Light Cure	SDI, Vic, Australia	Resin-modified glass-ionomer cement	53vol% Powder: FSG,Silica, Liquid:PA, TA, HEMA, Camphorquinone	K 1402032 EG
Ice	SDI, Vic, Australia	Nanohybrid Composite	(80 wt% / 61 vol%), SAS, AS (0.04 - 3 µm, Average 1µm) UD-MA/BisEMA/TEGDMA	2096SN
Filtek Supreme XTE	3M ESPE St. Paul, MN, USA	Nanohybrid Composites	(82 wt% / 63.3vol%) SF, ZF, AZSCF Nanocluster:0.6–1.4 lm Nanofiller:20 nm Bis-GMA, UDMA, TEGDMA, Bis-EMA	N395233

SF=Silica filler, ZF= Zirconia filler, AZSCF= Aggregated zirconia/silica cluster filler, SAS= Strontium alumino silicate, AS= amorphous silica, FSG= fluoroalumino silicate glass, PA=Polyacrylic acid, TA=Tartaric acid, HEMA= Hydroxyethylmethacrylate

ner span), b is specimen width (mm), and d is the specimen thickness (mm).

Vickers hardness test

The specimen's halves were used for hardness testing. For each group, 3 specimens were selected and each specimen was subjected to three indentations with 35µm apart across the specimen surface by applying a load of 300 g for 15 seconds using a digital hardness tester (MHV-1000Z , SCTMC, Shanghai China) (n=3 half x 3 indentation = 9) and the average was recorded as Vickers Hardness Number (VHN).

Statistical Analysis

The data were analyzed using SPSS software (version 18, SPSS Inc., Chicago, IL, USA). One-way ANOVA was used to show if any interaction existed between materials and storage time (p<0.05). Student's t-test (p<0.05) was used to show significant differences between storage times for each material and Tukey's test was performed to show significant differences between the materials in each storage time.

Results

Results of one-way ANOVA showed a significant interaction between materials and storage time (p<0.001). Since the effect of storage time on the hardness and flexural strength was material dependent, Student's t-test (p<0.05) was performed; the results are presented in Tables 2 and 3.

Table 2: Hardness (mean ± SD) of all material after immersion in distilled water for 2 time intervals

Material	Average ± SD		P value
	24 hours	30 days	
Filtek Supreme XT	68.7 (±3.3) [c]	67.0 (±3.2) [c]	0.279
Ice	60.5 (±2.2) [b]	59.7 (± 3.5) [ab]	0.454
Fuji II LC	45 (±6.1) [a]	29.5 (±5.4) [a]	0.001
Riva Light Cure	43.2 (±3.4) [a]	42.7 (±6.1) [b]	0.851
Gradia direct	41.0 (±4.2) [a]	33.9 (±2.9) [a]	0.001
P value*	<0.001	<0.001	

*shows a significant interaction between materials and storage time which was achieved by performing one-way ANOVA
shows significance level of student's t test between two storage time in each material
[a-c] Different letter shows significance level of differences showed by Tukey's test between all materials in each storage time

Table 3: Flexural strength (mean ± SD) of all material after immersion in distilled water for 2 time intervals

Material	Average ± SD		P value
	24 hours	30 days	
Gradia direct	72.4 (±11.1) [b]	47.8 (±18) [a]	0.048
Ice	51.2 (±25.7) [ab]	83.9 (±11.5) [c]	0.082
Filtek Supreme XTE	39.8 (±1.5) [a]	19.2 (±5.4) [b]	0.001
Fuji II LC	32.1 (±3.3) [a]	47 (±4.1) [a]	0.001
Riva Light Cure	21.8 (±4.7) [ac]	21.6 (±11.9) [b]	0.987
P value*	<0.001	<0.001	

*shows a significant interaction between materials and storage time which was achieved by performing One way ANOVA
shows significance level of student's t test between two storage time in each material
[a-c]Different letter shows significance level of differences showed by Tukey's test between all materials in each storage time

Hardness

After 24 hours, the highest hardness was for Filtek Supreme (68.7) and Ice (60.5) with a significant difference, while Fuji II LC (45), Riva Light Cure (43.2) and Gradia (41) had very close hardness values with no significant difference. After 30 days of storage in distilled water, hardness of Filtek Supreme, Ice and Riva Light Cure slightly changed while Fuji II LC and Gradia showed a significant decrease (Table 2 and Figure 1).

Flexural strength

After 24 hours of storage, Gradia showed the highest strength followed by Ice, Filtek Supreme XTE, Fuji II LC and Riva Light Cure. There was no significant difference between Fuji II LC, Riva Bond LC and Filtek Supreme. There was also no significant difference between Gradia and Ice; yet, there was a significant difference between Gradia and all other three materials. 30 days immersion in distilled water led to a dramatic increase of Ice (p = 0.082) and a significant increase of Fuji II LC (*p*= 0.001). While a significant decrease of Gradia (*p*= 048) and Filtek Supreme (*p*= 001) was obtained, Riva Light Cure showed no difference value (Table 3 and Figure 2).

Discussion

Based on the results of our study, nanohybrid resin composites (Filtek Supreme XTE and Ice) showed the highest value of surface hardness followed by RM-GICs (Fuji II LC and Riva Light Cure) and microhybrid resin composite (Gradia) respectively.

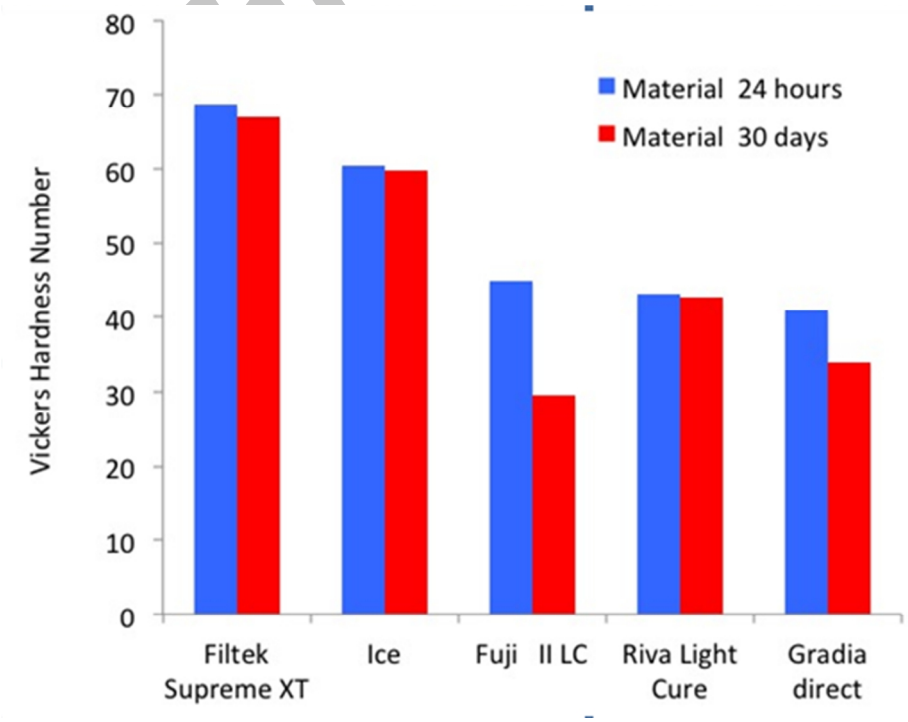

Figure 1: Vickers hardness of all materials in both time intervals

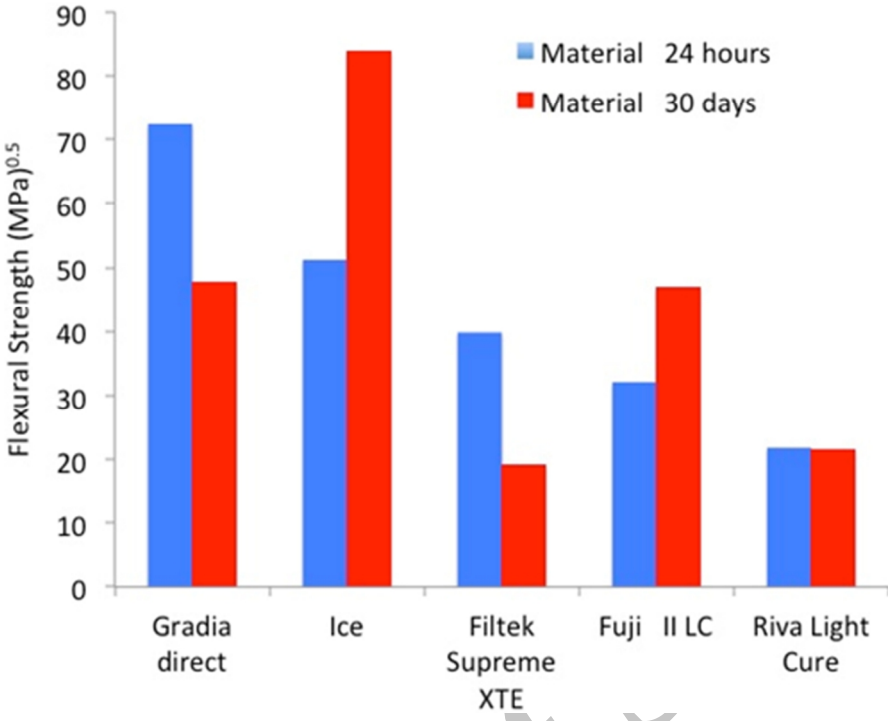

Figure 2: Flexural strength of all materials in both time intervals

It has been shown that the hardness of resin composites is influenced by the size and amount of filler particles [11]. The higher hardness of Filtek Supreme and Ice, compared to Gradia, may be attributed to their higher level of filler particles (82 and 80 wt%, respectively) compared to that of Gradia (75 wt%). This is in agreement with the report of previous studies showing a positive correlation between hardness and filler volum [12]. Topcu *et al.* demonstrated that Clearfil Majesty Posterior with 92 wt% of filler load showed the highest hardness among other eight different groups of nanofilled, nanohybrid and hybrid composites with lower load of filler particles [13].

In addition, both Filtek Supreme and Ice, which showed the highest hardness, are classified as nanohybrid composites. Moraes *et al.*[14] indicated that nanohybrid composite (Filtek Supreme) had higher Knoop hardness values compared to microhybrid (Filtek Z250) composite while both of them including approximately the same load (82% wt) of filler particles [13]. Therefore, it is speculated that surface hardness not only depends on the filler load but also filler sizes and the way of distribution of the fillers in the free spaces [15].

Both encapsulated RM-GICs used in our study showed higher surface hardness than microhybrid composite. Some of the previous studies [8, 9] showed lower hardness for RM-GICs compared to microhybrid composites while some others [16] indicated th opposite. Momoi *et al.* in their study evaluating the surface hardness of hand mixed Fuji II LC and encapsulated one, as well as a microhybrid composite (Filtek Z100), showed a significantly lower value for manual mixing GICs compared to the microhybrid and there was no significant difference between the hardness of encapsulated Ketac-Fil and Filtek Z100 [16]. The possible explanation couldfig be related to the less of porosity of the encapsulated GICs triturated by machine compared with the manual mixing system [17]. Lower porosity and more integration can improve the surface hardness of glass ionomer materials [9].

The effect of 30 days of immersion in distilled water was material dependent. While the water storage significantly decreased the hardness of Gradia and Fuji II LC, the hardness of Filtek Supreme, Ice and Riva Light Cure was not significantly affected. For Gradia, this effect may be explained by its lower filler volume and higher resin matrix compared to the other two nanohybrid composites. Higher amounts of resin matrix lead to an increase in water sorption [11], soften the material, and consequently a decrease in the surface hardness. For Fuji II LC, the reduction could be attributed to the presence of the HEMA (Hydroxyethylmethacrylate) as a hydrophilic resin component which absorbs considerable amounts of water [18,19]

which is shown [5] to be affected by approximately 50% decrease in the Vickers hardness.

Based on the result of present study, Gradia showed the highest value of flexural strength followed by Ice, Fuji II LC and Filtek Supreme, respectively. The lowest amount of flexural strength was related to Riva Light Cure. However, after 30 days of immersion in distilled water either Gradia or Filtek Supreme showed a significant reduction in strength. Polymeric matrix of Gradia mainly consisted of UDMA which can explain the high amount of its flexural strength. Asmussen *et al.* [20] investigated flexural strength of a composition of resin with variable percentages of TEGDMA, BisGMA, and UDMA. They reported that substitution of TEGDMA or BisGMA by UDMA in resin matrix resulted in an increase in flexural strength. While flexural strength of composition of (30% TEGDMA+ 70%BisGMA) was 140 MPa, flexural strength of (30% TEGDMA+ 70% UDMA) increased to 164 MPa. That is, due to the percentage of change in the oligomeres, the best results were achieved when the amount of UDMA increased above 30% [20].

In comparison with resin composites, the flexural strength of RMGICs was not only diminished by 30 days of water storage, but it also significantly increased for Fuji II LC. The flexural strength of Fuji II LC was comparable to that of Gradia and even much more than Filtek Supreme. This improvement in the strength of RM-GIC could be contributed to their dual cure setting reaction. Although the resin polymerization starts with light curing but acid base reaction progresses slowly until further maturation occurs over extended times [21,22] and until the maximum strength of the material is reached.

Conclusions

Within the limitation of this study, the following conclusions were drawn: RM-GICs used in this study had compatible mechanical properties with either microhybrid or nanohybrid composites. Both RM-GICs used in this study showed slightly higher hardness than microhybrid (Gradia). Flexural strength of Fuji II LC after 24 hours was comparable to that of Filtek Supreme (nanohybrid) and even significantly higher after one month. Therefore, it seems that the RM-GICs are approaching strengths of some of the resin composites and placement of RM-GICs could be as successful as restoration of resin composites for non-extended posterior restorations with low load bearing area.

Conflicts of interest

The authors of this manuscript declare that there are no conflicts of interest.

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