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EFFECT OF DIODE LASER ON SURFACE PROPERTIES AND MORPHOLOGY OF TWO SELF-SETTING GLASS IONOMER RESTORATIVES; IN-VITRO STUDY

Dina Mohamed Salah Eldine Abdelrahman * *and* Ahmed Fawzy Aboelezz**

ABSTRACT

Introduction: is to evaluate the effect of radiant heat by blue light diode laser (445 nm) wavelength on surface hardness of two self-cured glass ionomers and using scanning electron microscope for surface morphology for tested materials.

Materials: Two groups of conventional GICs were divided into (Equia IX Forte, Medifil forte IX), both triturated for 10 seconds by amalgamator then packed into Teflon mold (5 mm x2mm) In G1: control group specimens, 1.5 minutes time to 2.5 minutes till complete setting. G2: specimens were laser treated during setting time for 60 seconds. Diode laser tip was placed 1mm over GIC mold until complete set. All discs are tested for Vickers hardness number. All specimens were Scanned by SEM magn. 3000x on various surface areas to detect any alterations following conventional treatment and laser treatment. Surface hardness data of glass ionomer specimens were statistically analyzed using two-way ANOVA to detect the effect of type of glass ionomer and the use of laser on VHN.

Results: Showed that the use of laser and type of GIC had a statistically significant effect on the VHN. Yet, there was no interaction between the two tested variables. Laser had the same effect on the two tested groups.

Conclusion: Radiant heat produced from blue diode laser (445nm) increased VHN and affected surface morphology of both tested GICs.

KEYWORDS: Self-setting GICs, diode laser, VHN, Surface morphology, SEM

* Lecturer in Restorative Department, MIU University.
** Assistant Professor in Restorative Department, Suez Canal University

INTRODUCTION

Conventional glass ionomers (GICs) are commonly used with different dental restorative situations, due to their beneficial properties which is illustrated in its chemical adhesion to dental tissues and good biocompatibility.[1,2]

Most of conventional GICs are highly sensitive to moisture contamination, especially during its slow maturation process, which may extend in some types up to 72 hours, delaying the development of their final strength. They exhibit higher solubility and water sorption as well as lower mechanical properties compared to resin-based restorative materials, due to the nature of their setting reaction and composition.[3] Incomplete setting reactions and water contamination during the first stage of GIC setting results in a soft, porous, and fragile cement surface vulnerable to crack formation and propagation, therefore, decreased wear resistance.[4, 5]

In a trial to strengthen GIC, it has been proposed to deliver thermal energy by using dental light curing units (such as dental LED units) as well as laser, to catalyze their initial setting reaction.[6] Previous studies reported increased surface hardness of GIC, which may indicate clinical improvement of the behavior of these restorations, such improvement may have a positive impact on their surface and bulk properties. [7, 8]

Therefore, the aim of this in-vitro study was to evaluate the effect of radiant heat emitted by a blue light diode laser system (445 nm) on surface hardness of two self-cured GIC. Also scanning electron microscope (SEM) analysis was used for observation of the surface morphology of the tested materials after the treatment.

Two null hypotheses were formulated prior to the study. The first null hypothesis (H1) was that radiant heat produced from blue diode laser did not influence surface hardness of the tested materials. The second null hypothesis (H2) was that blue diode laser had no effect on surface morphology of both tested GICs.

MATERIALS AND METHODS

Two conventional glass ionomers GICs of 3.5 shade were investigated in this study (Equia IX Forte, Medifil forte IX). The technical characteristics of the tested materials are presented in Table 1.

TABLE (1) The technical characteristics of the tested glass ionomer restoratives:

Material	*Symbol*	*Category*	*Manufactu-rer*	*Composition*	*Lot nu-mber*
Equia forte	G_1	Glass Hybrid material which represents the latest in GC's glass ionomer (capsules)	GC Dental, Tokyo, Japan	Powder:70 wt% (95% strontium fluoro alumino silicate (FAS) glass+ 5% polyacrylic acid) Liquid: 30 wt% aqueous poly acrylic acid liquid	2234
Medifil IX forte	G_2	Radiopaque glass ionomer bulk filling material	Promedica, Neumrunste-rn, Germany	Powder: calcium fluoro-alumino-silicate glass with a formula of SiO_2–Al_2O_3–CaF_2–Na_3AlF_6–$AlPO_4$ Liquid: polyacrylic acid.	2617

Sample size calculation:

This power analysis used Vicker hardness number as the primary outcome. The effect size f = (1.014326) was calculated based upon the results of Dionysopoulos et al 2017[(8)] and assuming that the standard deviation within each group = 4.5, using alpha level of 5% and Beta level of 95% i.e. power = 95%. The minimum estimated sample size was a total of 36 samples (9 samples per group). Sample size calculation was done using G*Power version 3.1.9.2 (acceptance of protocol needed)

Specimens preparation:

According to the manufacturer's instructions, 40 disc shaped specimens were prepared and divided into two groups according to the type of GIC used (G_1 or G_2), each group was further subdivided into two subgroups according to whether the material was subjected to laser during setting or not (T_0 or T_1).

The glass ionomer capsule were triturated for 10 seconds in an amalgamator, they were packed into a cylindrical teflon mold (a diameter of 5 mm and thickness of 2 mm) with a glass slab used on bottom side of the mold to make the free surface of the cement smooth. Another glass slab was placed on top of glass ionomer mix during setting. In T_0: control group specimens, there was 1.5 minutes time interval from the start of mixing with 2.5 minutes to complete setting of the cement. Meanwhile, T_1: specimens were laser treated with continuous wave during setting time for 60 seconds at 400 mW/cm^2 through each of the glass slabs.[9] The tip of the diode laser unit (Dens-lase, NY, USA) was placed 1 mm above the glass slide above the mold to cover the surface of the cement until complete hardening.[10] All the discs specimens were tested for surface hardness and subjected to surface Scanning electron microscope (SEM) to investigate the impact of diode laser on surface morphology alteration with different magnification powers.

Evaluation of surface hardness

After preparation, the specimens were immersed individually in 10 ml deionized water in plastic containers and stored at 37 ± 1 °C.[11] Measurements of surface hardness were performed after 24 hrs. The surface hardness of the glass ionomer was evaluated using Vickers method with a hardness tester (Wilson® Hardness Tester, Model Tukon 1102, Buehler, Lake Bluff, IL, USA). The test was carried out by using a load of 50 gf for 15 seconds dwell time. Three indentations were made on top surfaces of each glass ionomer specimen, one in the center of the surface and one in every quadrant (at least 100 μm from each other). The dimensions of the indentations were evaluated using the optical microscope of the hardness tester and the data were independently averaged and reported in Vickers Hardness Numbers (VHN).[12]

SEM surface evaluation

Five specimens of each experimental group of two types of Glass ionomers tested & were examined using a Scanning Electron Microscope (JEOL, JSM-6390LV, Tokyo, Japan) at 20 kV. Scanning electron microscopy analysis was performed to evaluate the changes in morphology of the restorative materials. In the literature, SEM images are used extremely often for surface analysis. Specimens were mounted on aluminum stubs, carbon sputter-coated to a thickness of approximately 200 Å in a vacuum evaporator (at low vacuum) and examined. Photomicrographs were taken at 3000X magnifications of various areas on the top surface of specimens and surface morphology was examined to detect any alterations following conventional treatment and laser treatment.[13,14]

Statistical analysis:

Numerical data from the experiment was be collected tabulated and checked for normality using tests of normality (Kolmogorov–Smirnov test and the Shapiro–Wilk tests). For parametric data, ANOVA tests was used to compare between different groups, and post-hoc test was used to detect significance if present. In case of non-parametric data, Kruskal-Wallis test was used to compare between different groups. Dunn's test was used for paired comparison in case of detection of significance. The significance level was set a p≤0.05. IBM SPSS statistics for windows, was used for statistical analysis.

RESULTS

Two way ANOVA followed by Tukey's post hoc test was done to evaluate the effect of the two tested variables, the first was the effect of the type of the GIC either Equia or Medifil, and the second was the effect of laser on VHN of GI table (2). The significance level was set at p≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

Two ways ANOVA showed that the use of laser had a statistically significant effect on the VHN of GIC at a p= 0.002, also significance was detected for the effect of the type of GIC (p=0.001). Yet, there was no interaction between the two tested variables, which means that, laser had the same effect on the two tested groups, by increasing VHN.

TABLE (2) Two way ANOVA statistical evaluation for the effect of the type of glass ionomer and the laser treatment on VHN of glass ionomer.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
T	1299.917	1	1299.917	13.662	0.002
G	4602.578	1	4602.578	48.373	0.001
T * G	255.327	1	255.327	2.683	0.121

The results of the VHN of the tested glass ionomers are shown in table (3) and Figure (1). the highest VHN of all the tested groups was 123.4 for the Equia group treated by laser (G_1T_1), while the least VHN of 76.9 was for the Medifil group that did not receive any surface treatment(G_2T_0).

TABLE (3) Means, standard deviation, percent increase, and significance in VHN for the tested groups

	Control T_0		Laser T_1		Percent increase	Sig.
	Mean	SD	Mean	SD	%	
Equia (G_1)	100.102[b]	1.10201	123.372[a]	5.56039	23	0.001
Medifil (G_2)	76.908[d]	16.10337	85.886[c]	9.44156	11	
Sig.			0.001			

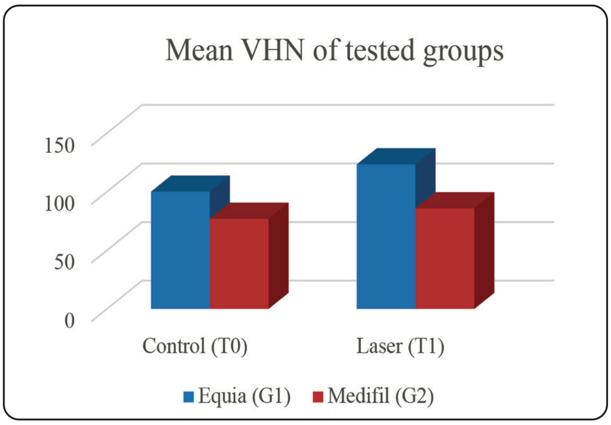

Fig. (2) Means, VHN for the tested groups

SEM observations

Representative photomicrographs of the surface of the control and laser-treated groups of the tested GICs are illustrated in Figs (2-a,b,c,&d) respectively. There were noticeable changes in surface morphology of the GICs after the laser treatment, in the form of radiating cracks. Moreover, SEM showed surface alterations among the materials. Thus, Medifil showed irregular topography with heterogenous large particles inducing surface roughness, cracks, spherical and crater like defects. On the other hand,

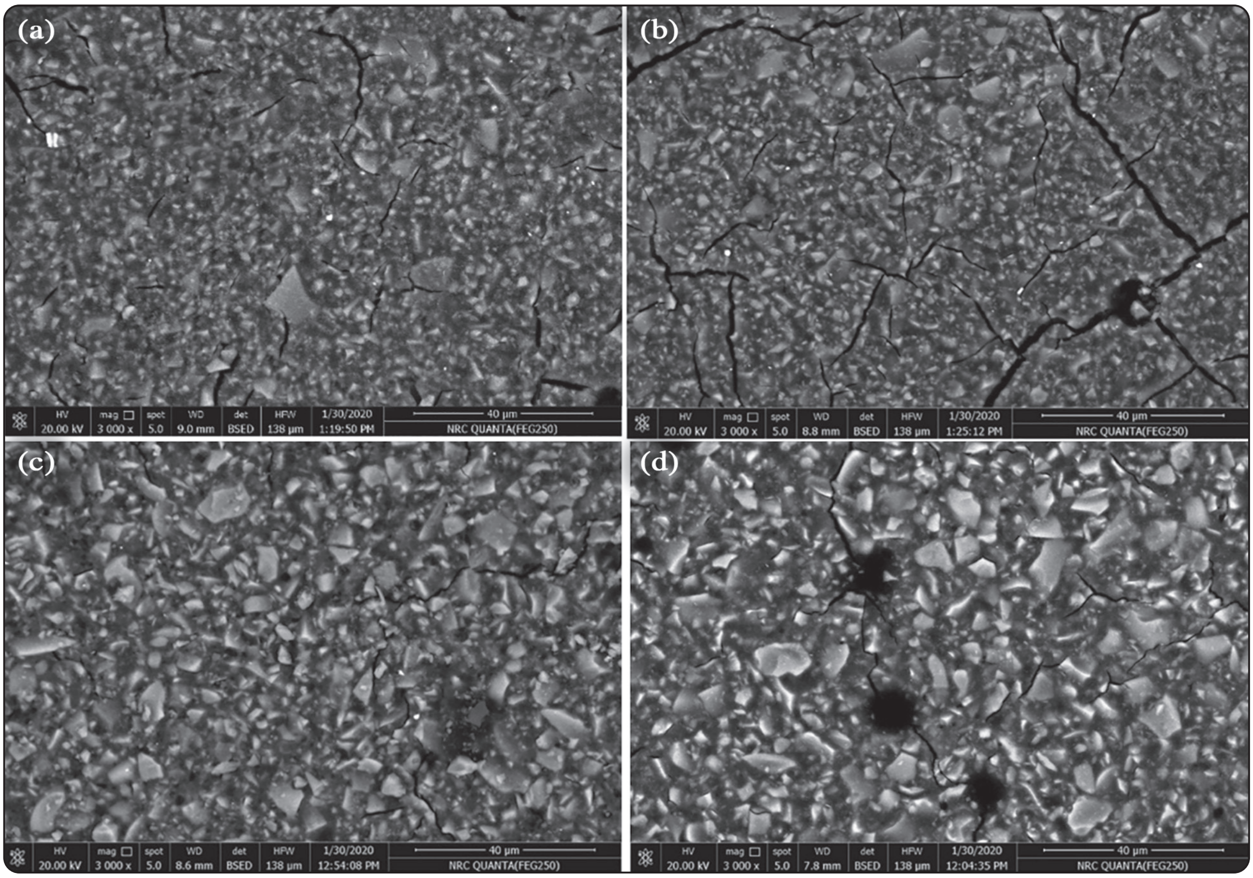

Fig. (2-a,b,c,&d) Representative photomicrographs of the surface of the control and laser-treated groups of the tested GICs. (a=Equia control, b=Equia laser, c=Medifil control, d=Medifil laser)

Equia GC exhibited homogenous topography with smaller particle size with smooth, uniform surface with minor cracks. [15-18]

DISCUSSION

Several attempts have been done to reduce the total setting time of glass ionomer cements using radiant heat. These attempts depended on the use of different light sources as QTH, and LED units.[19-21] Recently, laser use has also been introduced into dentistry as an alternative radiant heat delivery source, for improving the setting process of GICs.[10,15, 22-24]

The results of our present study rejected the null hypothesis. The use of diode laser with wavelength 445nm for one minute as a source of radiant heat, positively influenced the setting reaction of glass ionomers. This is expressed as an increase of Vickers hardness number of glass ionomers. [7,8,10, 25]

Literature reviews confirm the idea that, heat would improve the diffusion rates of the various ions leached from the glass.[11] Hence, our VHN results were in agreement with Woolford in 1994 [26], who claimed that, acceleration of the ion leaching from the glass phase of GIC is due to increasing the reactivity of the acid which led to more rapid

GIC maturation. Radiant heat is claimed to have the ability to increase ion mobility favoring the acid base reaction, accelerating the immediate cross linking of poly acid chains, by the bivalent calcium ions making the cement ready for the 2nd phase of setting, which is the final setting reaction, mediated by the trivalent aluminium ions, rendering the GIC mature. The surface of GIC is expected to acquire higher surface hardness with a compacted setting time. [27]

Some literature was in alignment with our SEM interpretation as Xie et al in 2004, since he suggested a strong correlation between micro-hardness values and microstructures of the GICs.[23] The dense surface texture of the tightly packed glass particles in the matrix, resulted in a higher VHN.[28] On the contrary, presence of large sizes and shapes of the glass particles dispersed in the polymer matrix is apparently a reason leading for drop in VHN of Medifil values. So, it is safe to say that, as only a highly integrated glass particle–polymer matrix resulted in the highest VHN for Equia GIC. [29]

Upon inspecting the particle size, homogeneity and VHN of the tested GICs, some connections could be detected. The surface properties and morphology of GICs are controlled by particle size, due to the increase in the glass phase total reactive surface area which is responsible for leaching of ions in acid base reaction. This reaction was accelerated by radiant heat.[30]

CONCLUSIONS

1. Radiant heat produced from blue diode laser (445nm) increased VHN of both tested GICs.
2. Blue diode laser (445nm) affected surface morphology of both tested GICs.
3. The type and shape of glass phase had an effect on the VHN and surface morphology of both tested GICs.

Future recommendation:

Further clinical studies are suggested to test the potential effect of diode laser and its thermal impact on dental pulp and other properties of the glass polyalkenoate cement.

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