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Effect of two oxygen-inhibiting agents on the surface microhardness of giomer restorative materials

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ABSTRACT

Giomers are bioactive hybrid restorative materials consisting of composite resin and glass ionomer filler pre-reacted on the surface, which maintain acceptable clinical qualities over time. One of the main factors that explains this is the surface hardness that is achieved by inhibiting the oxygen layer. ***Aim:*** *To compare the effect of blue and conventional Mylar strips used as oxygen inhibiting agents on the surface microhardness of giomer restorative materials.* ***Materials and Method:*** *A total 96 giomer specimens were prepared in disc-shaped molds 2 mm tall x 5 mm in diameter (ISO 4049: 2019-05). The specimens were grouped according to type of giomer: Beautifil II (BII) or Beautifil II LS (BIILS), and according to the type of Mylar strip: conventional, blue, or control group without strip. They were subsequently subjected to the Knoop (KHN) microhardness test. The database was analyzed with Stata SE v18 statistical software, and two-way ANOVA was performed.* ***Results:*** *Interaction was found between the type of giomer and Mylar strip (p=0.039). Significant differences were found between surface microhardness values according to the type of giomer (0.001) and the type of Mylar strip (0.001). Beautifil II LS presented significant differences between conventional Mylar strip vs. without Mylar strip (43.58 ± 1.65 vs. 40.44 ± 2.12) and between blue Mylar strip and without Mylar strip (44.69 ± 1.75 vs. 40.44 ± 2.12). In the Bonferroni Post hoc test, a significant difference was found between Conventional Mylar Strip and without Mylar Strip (p=0.001) and Blue Mylar Strip and without Mylar Strip (p=0.001).* ***Conclusion:*** *The use of blue and conventional Mylar strips inhibits the oxygen layer on the Beautifil II and Beautifil II LS giomers, endowing them with high values of surface microhardness.*

Keywords: *dental materials - glass ionomer cements - hardness*

Efecto de dos agentes inhibidores de oxígeno sobre la microdureza superficial de materiales restauradores giomeros

RESUMEN

Los giomeros son materiales restauradores híbridos bioactivos, constituidos por resina compuesta y relleno de ionómero de vidrio pre-reaccionado en superficie, mantienen cualidades clínicas aceptables en el tiempo; un factor principal para ello es la dureza superficial que se logra inhibiendo la capa de oxígeno. ***Objetivo:*** *Comparar el efecto entre la Tira Mylar azul y convencional al ser utilizados como agentes inhibidores de oxígeno sobre la microdureza superficial de los materiales restauradores Giomeros.* ***Material y Método:*** *Se confeccionaron un total de 96 muestras de giomeros en una matriz en forma de disco, de 2 x 5 mm de diámetro (ISO 4049: 2019-05). Se agruparon las muestras según el tipo de giomero: Beautifil II (BII) y Beautifil II LS (BIILS), y según el tipo de tira mylar: convencional, azul y el grupo control sin tira. Posteriormente fueron sometidas a prueba de microdureza Knoop (KHN). La base de datos fue analizada con el software estadístico Stata SE v18, se realizó la prueba ANOVA de dos factores.* ***Resultados:*** *Se encontró interacción entre el tipo de giomero y de tira mylar (p=0.039), y también diferencias significativas entre los valores de microdureza superficial según el tipo de giomero (0.001) y según el tipo de tira mylar (0.001). Beautifil II LS presentó diferencias significativas entre Tira Mylar Convencional vs sin Tira Mylar (43.58 ± 1.65 vs 40.44 ± 2.12) y entre Tira Mylar Azul y sin Tira Mylar (44.69 ± 1.75 vs 40.44 ± 2.12). En la prueba Post hoc de Bonferroni se encontró diferencia significativa entre Tira Mylar Convencional y sin Tira Mylar (p=0.001) y Tira Mylar Azul y sin Tira Mylar (p=0.001).* ***Conclusión:*** *El uso de las tiras mylar azul y convencional inhiben la capa de oxígeno sobre los giomeros Beautifil II y Beautifil II LS, confiriéndoles valores altos de microdureza superficial.*

Palabras clave: *materiales dentales - cementos de ionómero vítreo - dureza*

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INTRODUCTION

Giomers are hybrid restorative materials with bioactive features: they can release and recharge fluoride from the glass ionomer, and have the physical, mechanical and optical properties of resin[1]. Giomers are a special class of dental composites[2] because they contain pre-reacted glass-ionomer (PRG) filler particles in a resin matrix[3]. The PRG filler is formed by an acid-base reaction between polyalkenoic acid and particles of fluoro-boro-aluminosilicate glass, in presence of water, before being added to the resin. S-PRG filler is surface pre-reacted glass-ionomer. Its particles have a three-layered structure[4], consisting of a glass core enveloped by a stable glass-ionomer hydrogel[3], in turn surrounded by the reformed phase or modified surface layer which provides structural protection for the hydrogel[4].

Giomers have fluoride release and recharge properties, and minimize the onset of caries by providing constant remineralization[5]. They are employed as sealants for pits and fissures, liner or base materials, varnish for exposed hypersensitive areas, and for pediatric use[2]. Beautifil II can be used on occlusal and proximal surfaces of posterior teeth, and in patients with high caries index[2, 5]. A longitudinal study showed that after thirteen years, giomers maintained acceptable clinical qualities[4,6]. The giomer Beautifil II LS is a system based on Beautifil II, with low volumetric contraction, chameleon effect, easy manipulation and sustained fluoride release and recharge[2]. According to Alinda[7], Beautifil II is a better alternative than Fuji IX glass ionomer cement, because it has is significantly higher resistance to compression and superior characteristics in terms of surface morphology.

The main factor that affects the hardness of a dental composite is the polymerization process. Since polymerization occurs in open air, oxygen is able to bond to the free radicals, forming peroxi radicals and thereby disrupting or retarding the process[8-9]. As a result, a gelatinous layer is formed: the oxygen inhibition layer (OIL), which contains unreacted resin monomers and oligomers[10] The OIL affects dental composite prognosis negatively because it reduces surface hardness, and fosters microleaks, plaque formation and secondary caries[9].

In order to minimize OIL formation as much as possible, the use of Mylar strips is recommended during photopolymerization to displace the oxygen present on the surface[10]. Mylar strips are easy to use for proximal and buccolingual cavities and provide very smooth surfaces[11-12]. Blue Mylar strips are known to provide higher surface hardness than white strips because when monochromatic light passes through a clear object of the same color, the intensity of the light increases, providing greater polymerization and hardness in composite resins[13]. Hardness also depends on the distance of the light source because it decreases as the distance from the light source increases. Greatest hardness is achieved with the light source at a distance of 00 mm[14]. Blue Mylar strips are characterized by their color system, which helps control perfect fit to the gingival base of the cavity[15].

Using blue and conventional Mylar strips to inhibit OIL formation increases the surface hardness of restorative materials[13,16]. Surface hardness is a major factor for increasing resistance to masticatory forces, thereby preventing the risk of restoration breakage, which would affect its clinical success[9,17]. Sánchez-Sánchez et al.[16] report that there is no consensus regarding the best technique for eliminating the oxygen inhibition layer. The aim of this study is therefore to compare the effects of blue and conventional Mylar strips used as oxygen inhibiting agents on the surface microhardness of giomer restorative materials.

MATERIALS AND METHOD

This *in vitro* study was approved by the Ethics Committee at Universidad Científica del Sur, Lima, Perú (No. 810-2021-POS53). It employed the giomers Beautifil II (Shofu Inc., Lima, Perú) color A3, Beautifil II LS (Shofu Inc., Houston, USA) color A3; clear Mylar strips (Maquira, Lima, Perú) and Mylar Blue View VariStrip (Garrison Dental, Spring Lake, USA).

Sample size

Sample size was calculated by means of a pilot study and by using the formula for comparing means for independent groups with confidence level 0.95, statistical power 0.80, and precision 3.5. The result indicated 16 specimens for each of the six groups (combining giomer types, Mylar strip types and controls). A total 96 specimens were prepared.

Grouping

Groups were as follows: 1) BII-Blue Mylar Strip: Beautifil II light-cured with blue Mylar strip, 2) BII-Conventional Mylar Strip: Beautifil II light-cured with conventional Mylar strip, 3) BII-Control: Beautifil II light-cured without Mylar strip, 4) BIILS-Blue Mylar Strip: Beautifil IILS light-cured with blue Mylar strip, 5) BIILS-Conventional Mylar Strip: Beautifil IILS light-cured with conventional Mylar strip, 6) BIILS-Control: Beautifil II LS light-cured without Mylar strip.

Procedure

Specimens were prepared following ISO standard 4049: 2019-05 – Dentistry: polymer-based restorative materials. A stainless-steel mold was used to prepare 96 disk-shaped specimens 2 mm thick and 5 mm in diameter. The giomer was inserted in the mold in a single increment using a 442-443DDES spatula. Then the Mylar strip (conventional or blue, according to experimental group) was applied, and the mold was pressed with a glass slide to remove excess material and homogenize and level the surface. For control group specimens, pressure was applied using only the glass slide.

When all specimen surfaces had been leveled, photopolymerization was performed according to the manufacturer's recommendations, using a LED light-curing unit (Optilight Color, Gnatus, Lima, Perú), and applying the same time (10 seconds) and power (≥ 1000 mW/cm2) to all groups. The distance between the Mylar strip and the light source was 00 mm in all groups. All specimens were stored in distilled water in an electric muffle for 24 hours at 37 °C13. Then, the specimens were placed on a glass plate covered in red wax and pressed with a clamp to achieve a surface parallel to the floor.

Knoop hardness (KHN) Measurement

KHN was measured with a microhardness tester (HV-1000, LG Digital, Korea) with a load of 100 grams-force at 15 seconds dwell time. Before testing, all specimens were polished with 800, 1000, 1500, 2000 and 2500 grit silicon carbide paper[1]. Readings were taken on the surface of each specimen at 3 equidistant indentation points[13]. The results were averaged independently and reported as KHN values.

Statistical analysis

Data were analyzed using the statistical software Stata 18.0 (Stata Corporation, College Station, TX, USA), and reported as measurements of central tendency and dispersion. The assumptions of normality and homogeneity of variances were evaluated by the Shapiro-Wilk test and Bartlett's test, respectively. Two-way analysis of variance (ANOVA) and post-hoc Bonferroni's pairwise multiple comparison test were applied to determine significant differences. All statistical tests were performed at a confidence level of 0.95 and significance level 0.05.

RESULTS

Two-way analysis of variance (ANOVA) showed interaction between giomer type and Mylar strip type (p=0.039), and significant differences between surface microhardness values (KHN) according to type of giomer (p=0.001) and type of Mylar strip employed (p=0.001) (Table 1).

According to the Mylar strip type, surface microhardness (KHN) was significantly higher in the giomer Beautifil II than in the giomer Beautifil II LS. According to giomer type used, surface microhardness (KHN) in the Beautifil II LS group,

Table 1. Two-way ANOVA for surface microhardness (KHN) according to Giomer type and Mylar strip type

Number of observations = 96			R- squared = 0.9579		
Root MSE = 1.99592			Adjusted R-squared = 0.9556		
Source	SS	df	MS	F	P value
Model	8159.4083	5	1631.8817	409.64	0.001
Giomer type	7971.615	1	7971.615	2001.07	0.001*
Mylar strip type	160.88271	2	80.441354	20.19	0.001*
Giomer type # Mylar strip type	26.910625	2	13.455313	3.38	0.039*
Residues	358.53125	90	3.9836806		
Total	8517.9396	95	89.662522		

*p<0.05 significant, two-way ANOVA. SS: Sum of squares. DF: Degrees of freedom. MS: Mean squares. F: Statistical F. #: Interaction between Giomer type and Mylar strip type.

there were statistically significant differences between conventional Mylar strip and without Mylar strip (43.58 ± 1.65 vs 40.44 ± 2.12) and between blue Mylar strip and without Mylar strip (44.69 ± 1.75 vs 40.44 ± 2.12), while no significant differences were found between blue and conventional Mylar strips (44.69 ± 1.75 vs 43.58 ± 1.75); and in the Beautifil II group there were no significant differences (Table 2). Post-hoc Bonferroni's pairwise multiple comparison test was performed to determine significant differences. Because the comparison was pairwise, it found that there was a significant difference in surface microhardness according to Mylar strip type, that were, between Blue Mylar Strip and Without Mylar Strip (p= 0.001), and between Conventional Mylar Strip and Without Strip Mylar (p= 0.001). There was also a significant difference in surface microhardness according to giomer type (p= 0.001) (Table 3).

Table 2. Mean, standard deviation and confidence intervals for surface microhardness (KHN) according to Giomer type and Mylar strip type

	Mylar strip type		
Giomer type	**Blue Mylar strip Mean (± SD)**	**Conventional Mylar strip Mean (± SD)**	**Without Mylar strip Mean (± SD)**
Beautifil II	61.61 ± 2.38 Ba CI 95% (60.35; 62.88)	61.81 ± 1.81 Ba CI 95% (60.84; 62.77)	59.96 ± 2.17 Ba CI 95% (58.81; 61.12)
Beautifil II LS	44.69 ± 1.75 Ab CI 95% (43.76; 45.62)	43.58 ± 1.65 Ab CI 95% (42.69; 44.46)	40.44 ± 2.12 Aa CI 95% (39.32; 41.57)

X: Medium. SD: Standard deviation. CI: Confidence interval. Two-way ANOVA. Consider each response variable: A, B, a, b separately; capital letters "A" and "B" indicate comparisons within each column (Mylar Strip Type), while lowercase letters "a" and "b" indicate comparisons within each row (Giomer Type). The different letters differ significantly from each other, that is, for the columns: Blue Mylar Strip (BII vs BIILS: p = 0.001); Conventional Mylar Strip (BII vs BIILS: p = 0.001); Without Mylar strip (BII vs BIILS: p = 0.001); and for the rows: Beautifil IILS (BMS vs WMS: p = 0.001) and (CMS vs WMS: p = 0.001).

Tabla 3. Post-hoc Bonferroni's pairwise multiple comparison test for surface microhardness (KHN) according to Giomer type and Mylar strip type

Comparison of surface microhardness	
Mylar strip type	**P value**
Conventional Mylar strip vs Blue Mylar strip	1.000
Without Mylar strip vs Blue Mylar strip	0.001*
Without Mylar strip vs Conventional Mylar strip	0.001*
Giomer type	**P value**
Beautifil II vs Beautifil II LS	0.001*

*p<0.05 significant, Bonferroni Post-hoc Test.

DISCUSSION

In the long term, the oxygen inhibition layer produces a negative effect on the giomer surface by reducing hardness, as a result of which the useful life of the restorative material decreases[9]. Mylar strips displace oxygen from the surface, providing a smooth area, whose hardness depends on the type of Mylar strip used, with blue strips providing better outcomes[13]. The aim of the current study was to identify any differences in giomer surface hardness, thereby providing important information to clinicians regarding oxygen inhibition elements.

A review of the literature revealed studies showing that the oxygen inhibition layer is closely related to composite hardness[9]. Surface hardness represents the material's mechanical resistance to plastic deformation[18] and may be affected by the formation of an oxygen-inhibited layer that fosters the development of plaque, secondary caries and microleaks[9].

The current study showed that using a different Mylar strip color had a positive effect of on the oxygen inhibition layer, and in turn on hardness. Because this was an *in vitro* experimental study, it has certain limitations such as not exactly replicating the clinical conditions in the oral environment, therefore the results may be controversial. Moreover, the results cannot be generalized because only one type of oxygen inhibition agent was used: blue Mylar strip.

Once the grouping variables were established: type of giomer and type of Mylar strip, the Two-way ANOVA was applied, there was interaction between Mylar strip type and giomer type. Then we proceeded to evaluate the standardized residuals of the Anova mathematical model, finding that these residuals do meet the assumptions of normality (p=0.120) and homogeneity of variances (p=0.406). In both groups, microhardness was lowest without Mylar strips. Thus, it is recommendable to employ either of the Mylar strip types – conventional or blue – to achieve better restorations.

The results would be more relevant if a larger sample had been used or if a longitudinal study had been performed. Another important point to consider is polymerization time. If all the giomer specimens had been polymerized simultaneously, the ongoing curing reaction would have been the same for all of them, instead of being shorter for the last specimens prepared[19].

Mousavinasab et al.[13] evaluated the effect of the photopolymerization distance and the color of the transparent Mylar strips on the surface hardness of composite resins. They concluded that blue Mylar strips provided greater hardness than clear strips when the light source was at a distance of 0 mm, and that hardness decreased as distance from the light source increased. In this regard, the current study found the highest value with blue Mylar strips in the giomer Beautifil II LS group, in agreement with the aforementioned study, with the light source at 0 mm. This may be because when a monochromatic light passes through a clear object of the same color (in this case, blue, the intensity of the light increases, causing an increase in polymerization and hardness in the restorative materials.

In the current study, the distance from the light source to the Mylar strip was 00 mm, which may have generated a positive effect on the microhardness values of both giomers. These results contradict Al-Zain [20], who found better behavior of two resin-based composites when the light source was placed at 2 and 8 mm from the conventional Mylar strip than when it was placed at 00 mm.

Gonulol et al.[21] report that the composition of the giomer Beautifil II does not include urethane dimethacrylate (UDMA), which is more hydrophobic than bisphenol A-glycidyl methacrylate (Bis-GMA) and Triethylene glycol dimethacrylate (TEGDMA). Restorative materials with UDMA matrices such as the giomer Beautifil II LS therefore have less water absorption, and in turn, less filler dissolution, thereby increasing surface hardness. This may explain why, in the current study, in which all samples were submerged in distilled water and placed in a muffle at 37 °C for 24 hours to replicate oral conditions, microhardness was higher in the giomer Beautifil II LS group, with both blue and the conventional Mylar strips. Nevertheless, the highest microhardness values were found for the Beautifil II group with conventional Mylar strip, which may contradict the aforementioned. It would therefore be interesting to conduct the same study on a larger sample size.

Sánchez-Sánchez et al.[16] used conventional Mylar strips to eliminate the oxygen inhibition layer on a Coltene brand resin composite before photopolymerization and achieved better stability in the composite. For greater credibility, they suggest further studies. All the aforementioned studies recommend the use of Mylar strips before photopolymerization because of the improvement observed in composite surface hardness. The current study also found favorable results with the use of conventional and blue Mylar strips, in agreement with the study by Barkatin[22] evaluating the degree of conversion of two composites, one methacrylate-based and another silorane-based, using blue and conventional Mylar strips, and achieving positive effects in both materials, which were greatest when conventional Mylar was used on silorane.

Inhibition of the oxygen layer increases giomer surface microhardness, ensuring better treatment outcome as a result of the improved dimensional stability and resistance to wear of restorations. It is therefore considered to be a contribution to clinical application. Moreover, it should be considered that the color of the Mylar strip may foster greater surface microhardness of the giomer restorative materials evaluated. This provides a basis for results to be extrapolated to longitudinal *in vivo* studies.

CONCLUSION

The study concludes that blue and conventional Mylar strips inhibit the oxygen layer on the giomer restorative composites Beautifil II and Beautifil II LS, providing higher surface microhardness. The best results were found in the giomer Beautifil II LS, microhardness differed significantly between blue Mylar and without Mylar strip, and between conventional Mylar and without Mylar strips. The microhardness of giomer Beautifil II LS was higher when blue Mylar strip was used, possibly due to the light passing through the Mylar strip better because they were both the same color.

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DECLARATION OF CONFLICTING INTERESTS
The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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