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Original Article

COMPARATIVE ANALYSIS OF THE EFFECT OF MODELING AGENTS ON THE SURFACE PROPERTIES OF AESTHETIC NANO-HYBRID

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ABSTRACT

Objective: *Resin-Based Composite is one of the most widely used direct restorations in modern dentistry. However, it has its own drawbacks as its stickiness to the dental instrument upon packing which results in some difficulties when handling, therefore some clinicians resort to the use of some agents to ease the handling of the composite. However, this practice raises the question of how such agents can affect the restoration's physical properties.*

Aim: *This in vitro study aims to assess the effect of different modeling agents on the Nano-hybrid Resin Composite, specifically the restoration's color change and microhardness.*

Materials and Methods: *The study involved 45 Nanohybrid Resin-based Composite blocks divided into 3 groups with 15 blocks in each. First group was a control group consisting of only composite, meanwhile the second and third groups were subjected to a Modeling Liquid and a Universal adhesive respectively, then all three groups were light cured, immersed in colored media and kept in a container for 1 week. Color change and Microhardness of the cured blocks were measured before and after there immersion into the colored media.*

Results: *Results have shown statistically significant difference among the values of color change and microhardness within the three groups.*

Conclusion: *Modeling agent use might negatively affect the microhardness and color stability of the Nano-hybrid Resin-Based Composite depending on the type of the modeling agent itself.*

Clinical implications:

Based on our findings, it is advised for the clinicians to be more cautious about the use of different agents on Composite, with extra care to be taken when selecting the type of the modeling agent to be used.

Keywords: *Nano-hybrid composite, modeling agent, microhardness, color change*

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INTRODUCTION

Resin-based composite had its breakthrough in dentistry as a direct restoration due to the Bis-GMA development in 1962 by Bowen. Subsequently, Resin has undergone different stages of modifications in filler types, shape, and salinization to improve its physical properties as well its ability to withstand color change and wearing process until it became one of the most widely used dental restorations.[1] Furthermore, aesthetic nano-hybrid composites have emerged as a popular choice in restorative dentistry due to their superior mechanical properties and ability to mimic the natural appearance of teeth. These composites are characterized by a blend of nano-sized filler particles within a resin matrix, offering enhanced polishability, wear resistance, and color stability.[2] Recently, clinicians have faced difficulties in handling the Resin-Based Composite with such difficulty caused by the stickiness of this material to the dental instruments. Many solutions have been introduced to solve this problem such as: introducing dental instruments coated by titanium/aluminum, composite brushes, and rubber tips. Dentists have also resorted to using adhesive agents to overcome said stickiness.[3] However, based on the type of the adhesive agent used, it may pose a risk when applied on the top of the Resin-based Composite restoration leading to poor optical properties and discoloration of the restoration.[4]

Moreover, modeling agents were introduced into the market by manufacturers, which are considered to have better manipulation and better physical properties for the restoration.[5] The choice of modeling agent can have a profound impact on the surface characteristics of the final restoration, influencing factors such as surface roughness, gloss, and susceptibility to staining, filling the voids in the restoration by diffusing through any pores created during the application of the restorative material, as well, inhibiting the stickiness of Resin-Based Composite materials thus resulting in better handling properties.[6] In addition, the interaction between the modeling agent and the nano-hybrid composite matrix can affect the bond strength, potentially impacting the overall durability of the restoration.[7]

Sedrez-Porto et al. (2016) studied [Adper™ Scotchbond™ Multi-Purpose Adhesive (3M ESPE)], evaluating how it affects resin-based composite which when used as the modeling liquid between the layers of the composite, also effect the finishing/polishing of the material on color change in specimens exposed to a colored drink staining over time was studied. The results that were found that staining was reduced or delayed and the stability of the Resin-Based Composite restoration color can be enhanced substantially by polishing the material.[8] Additionally, Kutuk et al. (2020) assessed how nano-hybrid composite microhardness, roughness, and color change are influenced by various modeling agents with or without exposure to the discoloring agent and concluded that it's possible to use modeling liquid and a Universal Adhesive to sculpt the external layer of a nano-hybrid composite while relatively maintaining the composite's important physical properties.[9] On the other hand, Bayraktar et al. (2021) investigated six brands of resin-based composite (Charisma Smart, Estellite Asteria, CeramX-One SphereTEC, Admira Fusion, Filtek Ultimate, and Clearfil Majesty Es-2) and three modeling agents (Modeling Liquid, Composite Primer, and Modeling Resin) and concluded that all tested modeling resins showed decreased microhardness with varying amounts among the test specimens. Moreover, it might be safer to avoid the use of modeling agents unless they are necessary.[3]

Lately, there are concerns regarding the impact of modeling agents on the microhardness properties of a nanohybrid composite. The exact effect is still not determined since previous literature studies showed diversity on the effect of modeling agents on the final surface properties of the restoration if these agents were present in the composite structure, such ambiguity includes the long-term effects of various agents on the microhardness of the Composite restoration. Thus, the aim of this in vitro study is to investigate the effect of using multiple modeling agents on the surface microhardness and color change of the nano-hybrid composite. Null Hypothesis of the study: The use of modeling agents does not significantly affect nano-hybrid composite in terms of color change and surface microhardness.

METHODOLOGY

The study sample consisted of 45 Essentia (GC corp., Tokyo, Japan) nano-hybrid resin composite blocks that were made, standardized and equally distributed into three groups with 15 blocks each. Group 1: No modeling agent was applied (control group), Group 2: a Modeling Liquid (GC corp., Tokyo, Japan) was applied on the external surface of the composite specimens using a humidified sable brush. and Group 3: the composite specimens were subjected to a Universal Adhesive (G-primobond; GC corp. Tokyo, Japan) at their external surfaces by a humidified micro brush applicator. The study's total sample size (N) consisted of 45 blocks, as the number was calculated based on the data from a previous pilot study that had a total number of 6 composite blocks, with 2 blocks assigned for each of the 3 groups, while these blocks were not included in the sample size of the current study. The pilot study's formula for analysis of variance was applied in G*Power statistical software (ver. 3.1.9.7) considering a significance level (α) = 0.05 and statistical power ($1 - \beta$) = 0.90. The subject of investigation and evaluation was the nano-hybrid composite microhardness and color change in each group. Essentia (GC corp., Tokyo, Japan) nano-hybrid composite was used to fabricate a total of 45 specimens for each group. The composite was packed using a composite filling spatula in a custom-made cylindrical mold, the dimensions were 5 mm diameter and 2 mm height. The mold was placed over a thick glass slide, containing the composite that was packed as a single increment. Subsequently, each specimen has been treated at its external surface according to the following procedures after the specimens forementioned distribution. The specimens maintained smooth external surface by the application of mylar strip and glass slide on them, as such measures eliminated the need of further finishing and polishing. Bluephase G2 curing unit (Ivoclar Vivadent, Schaan, Liechtenstein) was used as light-cure for each specimen in accordance to the manufacturer's instructions with 1200 milliWatts per square centimeter irradiance. The curing process maintained a constant distance of 1 mm (The glass slide thickness) between the polymerizing light source and each specimen. To ensure polymerization completion, specimens were placed in a light proof bottle at a temperature of 37°C / 98.600 °F as dry storage that lasts 24 hours. The specimens' microhardness was determined based on Vickers hardness number (VHN) at the top and the bottom surfaces of each specimen using (Shimadzu HMV/2000, Shimadzu Corporation, Kyoto, Japan), the applied load was of 200 grams and the dwell time was of 10 seconds. Three indentations with 1mm as a random distance were taken from the top and bottom surfaces of each disc using a diamond indenter with a pyramidal shape and a square base, then the mean value was calculated. The indentation diameters were measured to assess the microhardness of the specimen. The average bottom/top microhardness ratio equals the VHN of the bottom surface divided into its counterpart at the bottom surface. For color measurements, the staining solution was a colored media, which was coffee (Nescafe classic, Aras, Brazil). All specimens were immersed in the colored media within a container of stainless steel. To simulate the intraoral conditions of a patient mouth, the specimens were kept in a dark environment with a temperature of 37°C / 98.600 °F. (10). As the test progresses, the staining solution (colored media) has been changed frequently at 2 days interval for 1 week as immersion period. After 1 week of exposure to the colored media, each specimen has been washed with water and dried with air spray, then a spectrophotometer (VITA Easy Shade; Vident, Brea, CA, USA) was used to read and measure the color distribution (CIE L*, a*, b*, and ΔE*) of each specimen. Measurements were acquired from middle third area with 3 times repetition of every reading process before getting the mean of the 3 measurements. Prior to each measurement, the spectrophotometer was calibrated with a white reflectance standard according to the manufacturer's instructions. The equation below was used to calculate the overall color change (ΔE)

$\Delta = [(\Delta L)2 + (\Delta a)2 + (\Delta b)2\ ]^{1/2}$.

Data analysis

Data analyzation was aided by IBM SPSS software of statistical analysis over Windows operating system, the software version is 26.0 (IBM Corp., Armonk, N.Y., USA). Descriptive statistics (consisting of mean and standard deviation) were used to describe the color change (Δ E) and hardness values across the three study groups Group1 (No modeling agent), Group2 (with modeling liquid) and Group3 (with Universal Adhesive). The hardness values between the baseline and after 1 week in each group were compared using the student's paired t-test. The one-way analysis of variance followed by a post-hoc test (Tukey's test) was used to compare the mean hardness values and color Δ E values among the 3 study groups. A p-value of <0.05 was used to report the statistical significance of results.

RESULTS

Color Change:

For the three groups, color change has minimum and maximum values of 2.79-5.74 (Group1); 3.08-5.58 (Group2) and 8.98-19.46 (Group3). The table1 shows the comparison of mean values of Δ E (color change) among the three study groups, where there is highly statistically significant difference in Δ E mean values among the three study groups (F=136.68, p<0.001). That is the mean Δ E value of group3 (with Universal adhesive) is significantly higher than the mean Δ E values of other two groups. According to post-hoc test, there is no statistical significant difference between the two groups (no modelling agent and with modelling liquid) but there is a notable statistically significant difference in the mean values Δ E between group3 and group1 (universal adhesive and no modelling agent) and between group3 and group 2 (universal adhesive and with modelling liquid).

Hardness:

The comparison of mean values of hardness between baseline and after 1 week in group1 (no modeling agent) shows statistically significant difference, where the mean hardness values have significantly reduced from baseline to after 1 week and the difference is statistically significant(p=0.002). In group3 (with Universal Adhesive) the change in mean hardness values from baseline to after 1 week also was statistically significant (p=0.039), that is the mean hardness values has been decreased from baseline to after 1 week. However, in group2 (with Modeling Liquid) the change in mean hardness values from baseline to after 1 week is not statistically significant (p=0.091) (Table 2)

The comparative analysis of hardness mean values within the study groups at baseline showed vast significant difference (F=21016.47, p<0.0001). The post-hoc test shows that there is significant difference between group1 and group2, between group1 and group3 and between group2 and group3 where the mean hardness values of group 1 are significantly higher than the mean hardness values of group2 and group3 (p<0.0001 and p<0.0001) and mean hardness values of group2 are significantly higher than the mean hardness values of group3 (p<0.0001) at baseline.

For comparison of mean values of hardness among the study groups after 1 week, there was still a significant difference present (F=15639.04, p<0.0001). The post-hoc test indicates that there is a significant difference between group1 and group2, between group1 and group3 and between group2 and group3 where the mean hardness values of group 1 are significantly higher than the mean hardness values of goup2 and group3 (p<0.0001 and p<0.0001) and mean hardness values of group2 are significantly higher than the mean hardness values of group3 (p<0.0001) after 1 week.

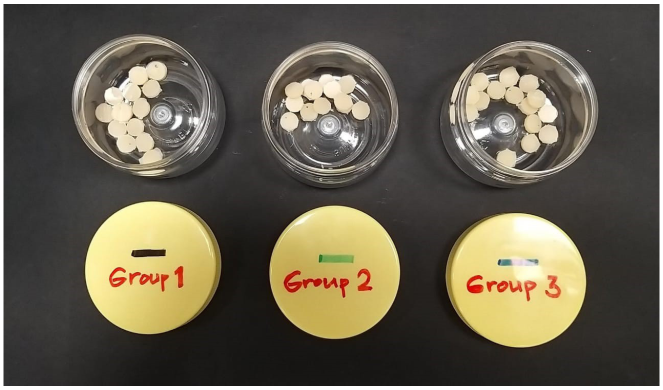

Fig 1: The composite specimens after being distributed intro 3 groups

DISCUSSION

This in vitro lab study aimed to assess how different modeling agents affect aesthetic nano-hybrid composites in terms of surface microhardness and color change (Δ E). Our findings demonstrate significant differences in both microhardness and color change among the groups studied, especially with the universal adhesive group, which corroborates with and extend upon existing literature in the field.

Our results showed that the use of modeling agents has significant influence on nano-hybrid composite in terms of the material's microhardness and color change, therefore color stability. Specifically, the group treated with Universal Adhesive exhibited a notable decrease in hardness and a minimal color change, aligning with the findings of Kutuk et al. (2020), who suggested that modeling agents could sculpt the outer layer of nano-hybrid composites without compromising their essential properties.[9] However, contrary to Bayraktar et al. (2021), who cautioned against the indiscriminate use of modeling agents due to potential reductions in

TABLE 1: COMPARISON OF MEAN Δ E VALUES AMONG THE THREE STUDY GROUPS

Groups	Δ E Mean (Sd.,)	F-value	p-value
Group1(No modelling agent)	4.06(0.75) *	136.68	<0.001
Group2(with modelling liquid)	4.12(0.56) *		
Group3(with Universal Adhesive)	14.28(3.24) **		

By using post-hoc test: * No significant difference between Group1 & Group2;

**Significantly higher than Group1 & Group2

TABLE 2: COMPARISON OF MEAN HARDNESS VALUES BETWEEN THE BASELINE AND AFTER 1 WEEK IN EACH OF THE THREE STUDY GROUPS

Groups	Hardness Mean (Sd.,)	Difference of mean Hardness	t-value	p-value	95% Confidence intervals for difference of hardness
Group1 (No modelling agent)					
Baseline	61.55(0.62)	0.42	3.280	0.002	(0.16,0.68)
After 1 week	61.13(0.67)				
Group2 (with modelling liquid)					
Baseline	34.09(0.94)	0.36	1.729	0.091	(-0.06,0.78)
After 1 week	33.73(1.25)				
Group3 (with Universal Adhesive)					
Baseline	24.79(1.03)	0.51	2.126	0.039	(0.03,0.99)
After 1 week	24.28(1.07)				

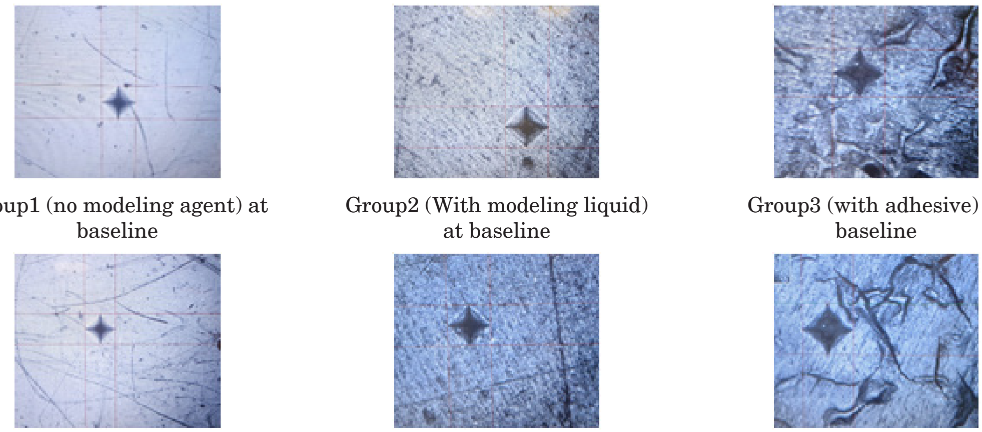

Fig 2: Comparison of microhardness between baseline and after one week for the three groups

microhardness,[3] our study found that the impact on microhardness varied significantly depending on the type of modeling agent used.

The observed changes in microhardness and color stability can be attributed to the chemical interactions between the modeling agents and the composite matrix, with such interactions depending on both type and composition of the modeling agent itself. According to our findings in this study, it can be interpreted that modeling agents, particularly those with adhesive properties, adversely affect the physical properties of the composite. The significant reduction in hardness in the Universal Adhesive group suggests that while this agent improves handling and application, it may compromise the composite's resistance to occlusal forces, potentially affecting the longevity of restorations.

The color stability observed across different groups underscores the importance of selecting modeling agents that do not predispose the composite to staining. This is particularly relevant in aesthetic dentistry, where the longevity of color is paramount. Our findings suggest that while some agents may offer improved handling characteristics, their impact on color stability must also be considered to ensure optimal aesthetic outcomes. The nature and severity of the impact depend on the composition of modeling agent used, as the Adhesive Resin demonstrated more adverse effects than the Modeling liquid on the composite specimens.

From a clinical perspective, these findings emphasize the need for a judicious selection of modeling agents based on the desired balance between workability and the physical properties of the composite. Clinicians must weigh the benefits of improved handling against potential changes in mechanical and aesthetic properties. Furthermore, our study acknowledges that it's important to consider the interactions between composites and modeling agents in the context of the oral environment, where factors such as temperature and moisture can further influence material properties.

Although this study had useful information that aids in the perception of materials usage, it has its own limitations. Since it's a lab study, the circumstances somewhat differ than the oral cavity environment where more factors that provide further complexity exist. Future research should include long-term clinical trials to validate these findings in vivo. Additionally, exploring a wider range of modeling agents and composite materials could offer a more comprehensive understanding of their interactions and effects.

CONCLUSION

In conclusion, our study affirms that modeling agents can significantly affect the nano-hybrid composites in terms of their color stability and microhardness. Therefore, our Null hypothesis has been rejected. These findings contribute to a better understanding of how such agents can be optimally used in clinical practice to enhance the performance and aesthetic outcomes of composite restorations. Ultimately, the selection of modeling agents should be according to both their handling advantages and their impact on the material properties of composites, ensuring that the longevity and aesthetic integrity of restorations are not compromised.

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