Research Article

Color stability of nano resin-modified glass Ionomer restorative cement after acidic and basic medications challenge

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Abstract: Background: Color stability of glass ionomers (GIs) could be affected by many factors such as pH and consumption of liquid medications like antibiotics. Most common antibiotics used during childhood are amoxicillin suspension (AM.S) and azithromycin suspension (AZ.S) which have acidic and basic pH respectively. Aim: to evaluate and compare the effect of AM.S and AZ.S on color stability of nano resin-modified GI. Methods: Thirty disc of nano resin-modified glass ionomer (2mm height x 4mm diameter) were divided into three groups (n=10 for each) and independently exposed to AM.S, AZ.S, and artificial saliva (A.S.). Color stability was evaluated in triplicate by VITA Easyshade® before and after three immersion protocols, repeated over a three-week duration with two-days intervals. In each protocol, samples were exposed for two minutes, three times daily for AM.S, once daily for AZ.S, and A.S. full day. GI discs rinsed off after each immersion and kept in artificial saliva until next immersion period. Results: One way ANOVA test and Post-hoc analysis of the changes in color space compartments of nano-resin modified GI samples demonstrated just a significant change (p<0.05) in yellow-blue axis (Δb^*) value after immersion in AM.S in comparison with A.S. Total Color change values (ΔE) of nano resin-modified glass ionomer samples also illustrated a significant effect (p<0.05) between AM.S and A.S. only. The highest (ΔE) value was recorded for samples immersed in AM.S (ΔE =12.5) followed by AZ.S (ΔE=6.5) while the lowest was recorded for A.S. (ΔE=1.1). Conclusion: AM.S (the acidic medication) exhibited a higher staining effect to nano-resin modified GI samples when compared with AZ.S (the basic medication). Several factors such as low pH, more exposure time and coloring material of the immersion media added critical roles in coloring instability.

Keywords: Amoxicillin suspension (acidic medium), Azithromycin suspension (basic medium), VITA Easyshade®, Nano resin modified glass ionomer, Color Stability, Child complications.

Introduction

Dental caries is the most common dental problem during childhood and the major reason for tooth lost [1, 2]. Accordingly, restoring carious primary teeth can be one of the major treatment goals for children by using different types of restorative materials [3]. One of the most frequently used restorative materials in a wide range of clinical applications in pediatric dentistry is the glass ionomers (GIs). This can be attributed to their advantages such as their ability to bond chemically to dentin and enamel, biocompatibility, favorable thermal expansion, decreased moisture sensitivity, and the ability to release fluoride [4]. On the other side, GIs have a number of disadvantages such as: dehydration, early moisture sensitivity, a long setting reaction time, and a rough surface texture. These disadvantages might reduce their mechanical properties of the restoration and lead to clinical failure [5]. To overcome these issues, many researches were conducted to modify the GIs properties using different approaches [6,7,8]. One of these approaches was the use of nanotechnology that produced the nano-resin based GIs [8,9]. Incorporation of nano-filler particles led to getting GIs with higher physical and chemical properties, mechanical properties, wear resistance, color stability, and biomechanical degradation resistance of GIs [5,10].

Despite the marked improvement in the properties of the GIs due to the use of nanotechnology, the critical oral environmental conditions (such as pH changes and humidity, consumption of beverage and pediatric oral liquid medications) still may increase the GIs bio- degradation and effect on color stability over time [11,12,13,14]. Consumption of pediatric liquid medications is unavoidable and so are their harmful effects on the oro-dental structure [15]. There are several categories of medications can be prescribed by physicians and dentists during the childhood to manage a variety of oral diseases and conditions like microbial infections and pain management. One of the most commonly used antimicrobial drugs is the amoxicillin suspension (AM.S); however, azithromycin suspension can be a good alternative for patients who experienced an allergic reaction to AM.S [16,17,18,19] .

Color stability was considered the main indicator of successful restoration [20]. So, factors that might affect the color stability should be considered and one of these factors that was recorded in the literature was the pediatric liquid medications uses [15,20,21]. This was approved by Faghihi et al (2021) and Almutairi et al (2022) who studied the effect of some pediatric liquid drugs on color stability of some esthetic restorative materials. Both studies concluded that color stability of the restorative materials used in pediatric dentistry could be influenced by using different types of liquid pediatric medications [12, 21].

In spite of studying the effect of different liquid medications on the restorative materials, to our knowledge, none of the studies investigated the effect of amoxicillin nor the azithromycin suspensions (which are the most frequently prescribed antibiotic for children) on the physical properties of nano resin modified glass ionomer. So, this study was designed to investigate the effect of amoxicillin and azithromycin suspensions on color stability of nano resin-modified glass ionomer.

Methods

The present study was approved by the Ethics Committee of college of Dentistry /University of Baghdad (Reference number: 573) and conducted at the Department of Pedodontics & Preventive Dentistry.

pH measurements

A calibrated pH meter (Singapore -Serial Number 1036780) was used to measure the AZ.S and AM.S pH. In addition, it was used to measure the adjusted pH value of artificial saliva (A.S.) to be 7.0.

Specimen preparation and grouping

Nano resin modified GI discs (n=30) were prepared with a cylinder teflon split mold measuring 2 mm in diameter and 4 mm in height [22] {Ketac N100 3M-ESPE, St. paul, USA, average size of nano fillers (5-25 nm ,composition, Nonomers nanocluster, methacrylate modified polyalkenoic, hydroxyethylmethacrylate (HEMA) ,fluoro- aluminosilicate (FAS), deionized water). Then, the mold was applied on a transparent celluloid strip and fixed on a glass cement slab. After that, the GI sample was placed and covered with another matrix strip and glass cement slide. To remove the surplus material from the mold, a pressure of 200 g was applied [23]. Light curing was conducted for the specimen (Germany's eighth model curing; LOT# G2108030) and polymerized as directed by the manufacturer [24]. Another exposure of light curing (for 40 sec) was applied to the bottom of the disc to ensure a full polymerization of the sample [25]. For standardizing purposes, the polishing procedure was taken into account. This was accomplished via a sequential polishing approach for the GIs discs that was based on Ibrahim et al (2019) method [26].

In 30 coded glass vials that were grouped according to the immersion solvent, the prepared nano resin modified GI samples were inserted (Figure 1). Each group (n=10) had samples that were individually and independently immersed in a certain immersion medium; i.e, the first group (n=10) had samples that were

immersed in AM.S, while the second and third groups had samples that were immersed in AZ.S and artificial saliva (A.S.) respectively (Figure 1).

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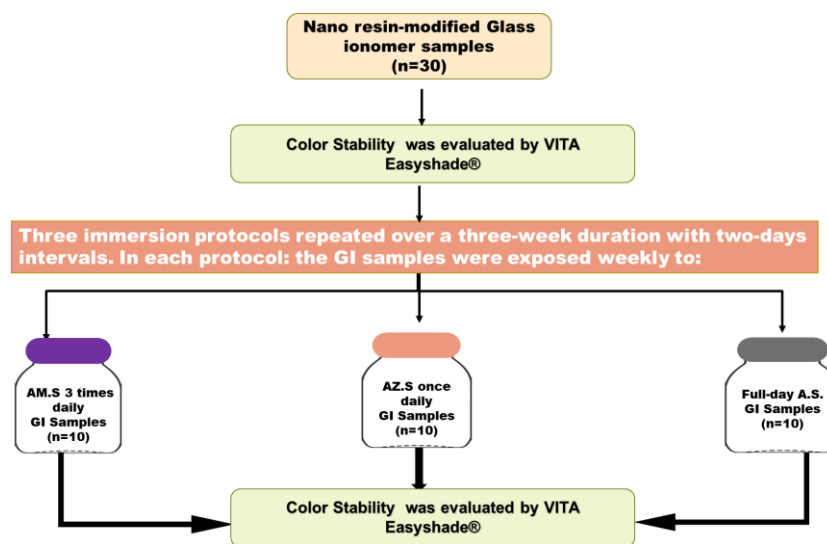

Figure 1: A flowchart of sample distribution and grouping

Artificial saliva preparation:

A.S. (one litter) prepared using the following materials: sodium fluoride (0.0002 g), calcium chloride (0.05 g), magnesium chloride (0.05 g), potassium phosphate (0.04 g), potassium thiocyanate (0.01 g), one gram of sodium chloride, sorbitol and potassium chloride. All the above substances were dissolved in 900 mL of deionized water. After that, sodium carboxymethyl cellulose (10 g) dissolved in 100 mL of boiling water that cooled down later to the room temperature before mixing with the above mentioned ingredients. pH Measurement was carried out to adjust the artificial saliva pH to 7 [27].

Immersion cycles

The GI discs were individually immersed in the immersion media over a period of 25 days (7 days for 3 successive immersion protocols at 2-day intervals). Each immersion protocol involved: GI Samples (n=10) were immersed in AZ.S (AZi-Once® 200 mg/5 mL, Jamjoom Pharmaceuticals Co., MWT 748508) for 2 minutes once daily, whereas AM.S (Amoxicillin BP (Athlone®), Oral Sugar-Free Suspension 250 mg/5 mL, Ireland, MWT 419.4) for three times daily. GI discs were rinsed off after each sample immersion and kept in artificial saliva (A.S.) until the next immersion period. On a daily basis, A.S., which contained the control samples, was refreshed. The color stability was assessed twice: once before the first immersion cycle and again after the third immersion cycle.

Measurement of color parameters of the specimens:

Color measurement was made by calibrated by electronic shade guide (VITA Easyshade®) Zahnfabrik, Switzerland LOT# C014). The color measurements were conducted before and after immersion cycles of GI discs in azithromycin and amoxicillin suspensions as well as the artificial saliva. For each disc, the color measurement represented the average of the three repetitions; in each, the probe was pointed to the center

of the disc and GI sample color was calculated using the CIE L* a* b* color space system[28] .The L* a* b * represented the lightness (L*), red-green (a*), and yellow-blue (b*) of the color space [29] . The color variation (ΔE) between the baseline measurements and at the end of immersion cycles of the GI samples in the liquid medications was calculated by the following equation[29]:

ΔE (L* a* b*) = [(ΔL*)2+ (Δa*)2+ (Δb*)2]1/2. ……. Equation (1)

Where:

◎ΔL* (L1-L0) is the difference between the L values

◎Δa*(a1-a0) is the difference between the a values

◎Δb* (b1-b0) is the difference between the b values

◎L0, a0, b0: Initial measurements (Baseline readings)

◎L1, a1, b1: Second measurements (post immersion readings))

Statistical analysis

The statistical analysis was carried out utilizing (SPSS version -22). Color changes between groups at each time interval were compared using the one-way ANOVA with Dunnett's T3 post hoc test, while the intragroup changes in color parameters for each sample before and after immersion sessions were evaluated by student- t test. The level of significance for all statistical tests was p<0.05.

Results

Color space (CIE L* a* b* system) changes of the nano-resin modified GI samples before and after exposure to the AM.S, AZ.S and A.S. for 25 days were summarized in table 1.

Table 1: Statistical analysis for the color space parameters of nano resin modified glass ionomer samples before and after immersion in different media (p<0.05).

Measured parameters	AZ.S Mean ± SD	AM.S Mean ± SD	A.S. Mean ± SD	F	*p* value
L0	73.9 ± 1.7^{Aa}	75.7 ± 2^{Aa}	76.2 ± 3^{Aa}	2.7	0.1
L1	74.8 ± 1.3^{Ab}	75.4 ± 1.6^{Aa}	76.3 ± 3.1^{Aa}	1.2	0.3
p value	0.01*	0.7	0.9		
a0	1.2 ± .4^{Aa}	1.1 ± 0.3^{Aa}	1.2 ± 0.4^{Aa}	0.4	0.7
a1	0.2 ± 1.7^{Ab}	0.7± 1.1^{Aa}	1.1±0.5^{Aa}	1.5	0.2
p value	0.0 3*	0.3	0.4		
b0	33.4 ±1.3^{Aa}	34.9 ± 2^{Aa}	37.3 ± 3.1^{Aa}	3.8	0.1
b1	32.7 ± 1.3^{Aa}	32.9±1.5^{Ab}	36.9 ± 2.7^{Ba}	15.2	<0.001*
p value	0.1	0.004*	0.3		

- Dissimilar capital letters indicated a significant difference between immersion media (inter-group comparison- Horizontal line).

- Dissimilar small letters indicated intra-group statistics. Significant differences between baseline and post immersion readings (Vertical line).

- *indicates statistically significant difference between base line and post immersion readings independently

Inter-group comparison:

Statistical comparisons of brightness (L*), red-green axis (a*), and yellow-blue axis (b*) values of the nano-resin modified GI samples before the immersion cycles in different media demonstrated non-significant differences (p > 0.05). After immersion cycles in AM.S, AZ.S and A.S., the nano-resin modified GI samples color space demonstrating a significant change along the yellow -blue axis (b*) only (p<0.05) (Table 1).

Dunnett's T3 post hock test revealed significant difference (p <0.05) in yellow- blue axis of the nano-resin modified GI samples (after immersion cycles) that were exposed to A.S. in comparison with samples that were immersed in AZ.S and AM.S. However, the comparison between the AZ.S and AM.S effects on yellow -blue axis (b* values) of the nano-resin modified GI samples that were immersed in, revealed a non-significant effect (p >0.05). This indicated the equivalent effect of AM.S and AZ.S on the color stability of the nano-resin modified GI samples after separate immersion in these media.

One-way ANOVA and Dunnett's T3 post hoc test investigated the significant differences (p <0.05) for ΔL*, Δa*, and Δb* of the nano-resin modified GI after immersion cycles in different media. It was recorded a non-significant changes (p> 0.05) for ΔL*; however, ΔL* recorded the highest positive non-significant changes for samples immersed in AZ.S and A.S while a negative non-significant (p> 0.05) changes for those immersed in AM.S (Figure 2).

Despite the negative values that were recorded for Δa* in all immersion media, the statistical analysis revealed non-significant differences between them when compared in different immersion media (p >0.05). Yet, the highest negative changes in Δa* was recorded for the GI samples that were immersed in AZ.S (Figure 2).

On the other side, the statistical analysis recorded just a significant negative change in Δb* value of GI samples that were immersed in AM.S in comparison with samples that were immersed in A.S (p <0.05).
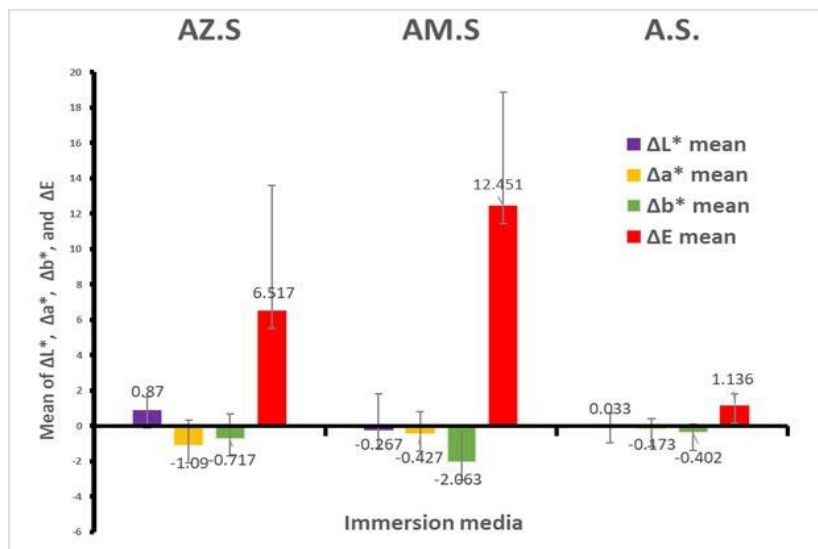

Figure 2: Average of color changes (ΔE, ΔL*, Δa *, Δb*) of nano-resin modified GI samples.

after separate immersion in AZ.S , AM.S, and A.S. for 25 days.

Intragroup comparisons

The paired t-test was used to statistically analyse the effect of the immersion media on the color space components when they were compared before and after immersion cycles. AZ.S recorded a significant effect ($p<0.05$) on the brightness (L*) and the red-green axis (a*) values, while it did not exhibit any effect on the yellow- blue axis of the nano resin modified GIs samples when compared before and after immersion (Table 1). Amoxicillin suspension followed a different pattern as it merely made a significant effect ($p<0.05$) on the yellow-blue axis of the GI samples (Table 1).

On the other side, the A.S. demonstrated a non-significant effect ($p >0.05$) on the color space components of the tested samples at all (Table 1).

Color changes value (∆E)

The mean color changes varied within a range of 1.1- 12.5 for nano-resin modified GI samples after exposure to AM.S, AZ.S and A.S. for 25 days (according to the above mentioned immersion protocols). The maximum color change value (∆E) was observed for GI samples immersed in AM.S (∆E=12 .5) followed by AZ.S (∆E= 6.5) while the minimum color change was recorded for samples immersed in A.S. (∆E= 1.1) (Figure 2). One-way ANOVA with Dunnett's T3 post hoc test illustrated a non-significant effect in (∆E) for GI samples immersed in AZ.S in comparison to that of A.S. and AM.S respectively. On contrary, a significant effect in ∆E was just recorded when the effect of AM.S on the color stability of GI samples was compared with effect of A.S.

Discussion

Gls (as restorative materials) are persistently exposed to multiple oral environment challenges such as pH variation and consumption of staining materials such as beverages and medications that may affect the color stability of the GIs [30, 31] .Hence, studying the effect of basic drug (which was conducted for the first time in this study) and comparing with the effect of acidic drug   on color stability of GIs would have a special importance. Because it can help in maintaining the color stability of the GIs and reducing the frequency of replacement the discolored restoration especially in pediatric patients which could be costly and time-consuming procedure [30].

In the present study, the color measurement was conducted by VITA Easyshade® because it has been considered as a repeatable and sensitive method for small color changes based on the human eye's capability for different colors [12,32,33] Accordingly, this method helped in preventing the subjective bias associated with color sensitivity in human investigator [33]. The evaluation of color stability in the restoration was conducted utilizing the CIE (Commission International de l'Eclairage) L* a* b* system. The CIELAB system is derived by transforming the x, y, and z values of the coordinate system into the variables L*, a*, and b* [33]. This transformation allows for the measurement and documentation of color variation in three-dimensional color space [33]. These color system exhibits a high degree of applicability and is frequently employed in scientific investigations due to its numerical description of color components [33].

Despite the advantages of GIs such as the anticariogenic properties, GIs lack color stability. This can be attributed to many factors: Firstly, the material's polyacid content, which may be explained by the degradation of metal polyacrylate compounds. Secondly, the process of adsorption or/and absorption of stains, which may be influenced by the glass particles' porosity, dehydration after setting and curing, and micro cracks. In addition, GIs have a spontaneous ability of releasing fluoride with a high ionic exchanging rate, making it more susceptible for discoloration [4, 34]. Hydrophilicity of the matrix of the restorative material may strongly influence its color as a result of its ability to absorb water content of the immersion media. This can lead to rapid GIs staining and surface degradation over time [5,35,36,37] The nano resin

modified GI samples in this study contain a hydrophilic material (the Hydroxyethyl methacrylate (HEMA)), which can absorb water up to 80% of their weight [12]. So, the presence of HEMA can support the hydration and water absorption by the GI samples that leading to samples discoloration after immersion cycles. This concept was adopted by Hotwani et al in 2014 as well. They approved that hydrophobic substances have superior color stability and stain resistance than hydrophilic substances [20]. More recently, Saves et al. (2019) agreed on the high staining susceptibility of GIs can be due to the materials' high water absorption rate [5].

In this study, Δa* and Δb* of the nano-resin modified GI samples shifted toward green and blue colors in all immersion media since the negative changes in values of the red-green axis (a*) indicated the shifting to the green area while the negative yellow - blue axis (b*) changes would shift the GI samples color towards the blue side. This explanation was adopted because in the literature was reported that the red-green axis (a*) measure red for positive values at one end, green for negative values at the other and grey in the middle [33,35,36]. In addition, it was mentioned that the yellow - blue axis (b*) changes could reflect yellow color when a positive value was recorded at the one end, blue color for negative values at the other end and grey color could be reported in the middle [33,35,36]. The negative Δ L* value observed in AM.S indicated a decrease and loss of luminosity, whereas the positive Δ L* value observed in AZ.S and A.S. indicated an increase in luminance of the GI samples. So, AM.S shifted down the luminosity of the GI samples toward black area while the AZ.S and A.S. towards the white area. This explanation was considered because the range of luminosity is from 0 (representing black) to 100 (representing white) [33,35,36]. This indicated that amoxicillin suspension changed the color of GI samples to be more bluish and darker.

All the above color changes due to the use of AM.S may be attributed to the surface hydrolysis and degradation, in addition to the adsorption and/or absorption of the yellowish coloring material that is found in the AM.S [38, 39]. So, the suggested adsorption and /or absorption of the colored material of the amoxicillin suspension led to the significant color changes of the GI samples mainly in the yellow- blue axis. This finding came in a line with what was reported by Culina et al in 2022 [33]. They found that the glass material especially that containing nanoparticles could exhibit higher changes in yellow- blue axis (b*) due to the surface degradation of GIs making the nano resin modified glass ionomer material highly adsorbable and/or absorbable for the staining material [33].

Color changes (ΔE) of GI samples after immersion in AM.S and AZ.S were considered clinically unaccepted because ΔE values of GI samples after separate immersion in these media were more than 3.3 [20,29,33]. This finding agreed with what was reported by Ayaz et al (2013) as they reported a significant effect of salbutamol sulphate inhaler on the color of the glass ionomer materials and considered clinically unacceptable because the ΔE was 6.8[40]. In another study, Hotwan et al (2014) investigated the impact of children beverages on the color stability of restorative materials. They revealed that glass ionomer exhibited a significantly unacceptable color changes, with a ΔE value of 7.2, when exposed to orange juice [20]. Recently, Faghihi et al. (2021) observed that glass ionomer composite materials exhibited a wide range of unacceptable color changes after using different medications such as acetaminophen, amoxicillin, and ibuprofen with ΔE values ranging from 3.9 to 9.7 [12]. All the previous evidence supports our findings with regards the instability of the GIs when they exposed to different children medications and beverages.

In addition to the forementioned parameters that can affect the color stability, the low pH values of the immersion media can play a key role in increasing the color instability and discoloration of GI samples [12,13,21,33]. This can explain why the AM.S (pH=4.1) exhibited higher color changes in comparison with AZ.S (pH=9.2). Moreover, lack of AZ.S for coloring material and the less exposure time to the immersion media helped in reducing the discoloration effect on the GI samples by this medium.

Conclusion

The Acidic medication (AM.S) stained the nano-resin modified samples for a wider extent than the basic medication (AZ.S). So, when it is required to use one of these medications, it is suggested to use AZ.S instead of AM.S. In addition, it is advisable to encourage parents to brush or at least wash the children teeth after any use of these antibiotics.

Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

ZH ,NA study conception and design. ZH data collection. ZH, NA Methodology. ZH, NA and OM statistical analysis and interpretation of results. ZH, NA and OM original draft manuscript preparation. ZH, NA and OM writing - review & editing.   Supervision NA; All authors reviewed the results and approved the final version of the manuscript to be published.

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قياس ثباتيه لون الأسمنت الترميمي للشارده الزجاجية المعدله بالراتنج النانوي بعد اختبارها بادويه حامضية وقاعدية.

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المستخلص:

الخلفية: يمكن أن يتأثر استقرارلون للشارده الزجاجية المعدله بالراتنج النانوي للعديد من العوامل داخل الفم ، مثل درجه حموضه واستهلاك الأدوية الفموية السائلة مثل المضادات الحيوية ومن أكثر المضادات الحيوية استخدامًا في مرحله الطفولة هو معلق أموكسيسيلين ومعلق أزيثرومايسين اللذان يحتويان على درجة الحموضة الحمضية والقاعدية على التوالي

الهدف: تقييم ومقارنة تأثير معلقات الاموكسسيلين والازثرومايسين على استقرار لون الشارده الزجاجيه المعدله بالراتنج النانوي.الطريقة:تم تحضير ثلاثين قرصًا (ارتفاع 2 ملم × قطر 4 ملم) من الشارده الزجاجية المعدله بالراتنج النانوي وتخزينه في مياه مقطرة عند 37 درجة مئوية لمدة 24 ساعة. بعد ذلك تم تقسيمها إلى ثلاث مجموعات (ن= 10)، والتي تعرضت بشكل مستقل للمعلقين الأموكسيسيلين والازثرومايسن واللعاب الصناعي . تم تقييم استقرار اللون بواسطة جهاز قياس ثباتيه اللون قبل وبعد ثلاثة بروتوكولات غمر (تم الحصول على ثلاث قراءات لكل عينة) تم تكرارها على مدى ثلاثة أسابيع مع فترات يومين. في كل بروتوكول، تم غمر عينات لمدة دقيقتين، ثلاث مرات يوميًا لـ معلق أموكسيسيلين ، ومرة يوميًا للا زثرومايسين ، و اللعاب الصناعي ليوم كامل. تم شطف العينات بعد كل غمر وتم الاحتفاظ بها في اللعاب الاصطناعي لحين فترة الغمر التالية.

النتائج:أظهر اختبار ANOVA أحادي الاتجاه لسطوع مقصورات مساحة اللون (L *) والمحور الأحمر والأخضر (a *) والمحور الأصفر والأزرق (b *) لعينات الشارده الزجاجيه المعدله بالراتنج النانوي تأثيرًا كبيرًا (p<0.05) في (Δb *) لمعلق الامكسيسيلين بالمقارنه مع اللعاب الصناعي . كما أوضحت القيم الإجمالية لتغير اللون (ΔE) لعينات الشارده الزجاجية المعدله بالراتنج النانوي تأثيرًا كبيرً(p<0.05) بين معلق الاموكسيسيلين واللعاب الصناعي فقط. تم تسجيل أعلى قيم (ΔE) للعينات المغمورة في معلق الاموكسيسيلينΔE=12.5 متبوعة بـ معلق الازثرومايسين ΔE= 6.5 بينما تم تسجيل أدنى قيم للعاب الصناعي ΔE =1.1

الاستنتاج:أظهرت معلقات ألاموكسيسيلين (الدواء الحمضي) تأثير أعلى في تغير اللون في عينات الشارده الزجاجية المعدله بالراتنج النانوي عند مقارنتها بمعلق أزيثرومايسين (الدواء القاعدي).

يضيف العديد من العوامل مثل درجة الحموضة المنخفضة، وزياده وقت التعرض، ومواد التلوين المضافه ، التي تلعب أدوارًا مهما في زيادة عدم استقرار اللون.