Original Article

Surface Roughness Examination of Glass Ionomer Restorative Cements Treated with Acidic and Basic Pediatric Medications: An *In Vitro* Study

Zainab R. Hasan[1], Noor R. Al-Hasani[2], Ali I. Ibrahim[3,4]

[1]Pedodontics Department, College of Dentistry, University of Baghdad, Baghdad, Iraq, [2]Department of Basic Sciences, College of Dentistry, University of Baghdad, Baghdad, Iraq, [3]Department of Orthodontics, College of Dentistry, University of Baghdad, Baghdad, Iraq, [4]Centre for Oral, Clinical and Translational Sciences, Faculty of Dentistry, Oral & Craniofacial Sciences, King's College London, London, UK

Received : 31-Dec-2023
Revised : 15-Mar-2024
Accepted : 27-Mar-2024
Published : 27-Aug-2024

Abstract

Background: Consumption of different types of beverages and liquid drugs can affect of the surface properties of restorative material. This may lead to an increased probability of dental caries and periodontal inflammation. **Aim:** This study evaluated and compared the effect of amoxicillin suspension (AMS) and azithromycin suspension (AZS) on the surface roughness (SR) of silver-reinforced glass ionomer (SGI) and nano resin-modified glass ionomer (NGI). **Material and Methods:** Thirty disks (2 mm height × 4 mm diameter) of each glass ionomer (GI) type were prepared and subdivided into three groups (n = 10), which were separately exposed to AMS, AZS, and artificial saliva (AS). SR was evaluated by atomic force microscopy before and after three-immersion protocols repeated over a 3-week duration with 2-day intervals. In each protocol, the GI samples were exposed weekly to AMS three times daily, AZS once daily, and a full day to AS. **Results:** This study demonstrated, for the first time, the effect of a basic drug (AZS) on the SR of GIs. Intra- and inter-group comparisons showed significant changes ($P < 0.05$) in the SR pattern of the GIs after immersion cycles in AZS, AMS, and AS. However, the acidic medication (AMS) exhibited significantly higher changes in SGI than in NGI. **Conclusions:**The SR of NGIs and SGIs can be significantly affected by the use of AMS and AZS suspensions. SGI demonstrated higher SR deterioration than NGI after immersion cycles in AMS.

Keywords: *Amoxicillin suspensions, antibiotic, azithromycin suspension, medicines, nano resin-modified glass ionomer, silver-reinforced glass ionomer, surface roughness*

Introduction

The use of liquid medications to treat conditions such as microbial infections and pain during childhood can have adverse effects on the restoration/prosthesis present inside the oral cavity.[1] Among these medications is the amoxicillin suspension (AMS), a type of penicillin (B-lactam) antibiotics[2] that is widely prescribed in dental practice for its effectiveness in treating various kinds of oral infections.[3] In cases of possible allergic reactions to AMS, azithromycin suspension (AZS) is indicated as an alternative. In comparison to AMS, AZS has the same antibacterial spectrum, however, the latter can be administered once daily in comparison with thrice per day use of AMS.[4-6] In pedodontics, glass ionomers (GIs) have wide and frequent clinical implementations due to the possibility of modifying and improving their physical properties.[7] Attempts were conducted to enhance the mechanical properties of GIs via incorporating silver particles.[8]

Access this article online
Quick Response Code:
Website: https://journals.lww.com/jpcd
DOI: 10.4103/jispcd.jispcd_212_23

Address for correspondence: Dr. Noor R. Al-Hasani, Department of Basic Sciences, College of Dentistry, University of Baghdad, Baghdad 1417, Iraq.
E-mail: noor.raouf@codental.uobaghdad.edu.iq

How to cite this article: Hasan ZR, Al-Hasani NR, Ibrahim AI. Surface roughness examination of glass Ionomer restorative cements treated with acidic and basic pediatric medications: An *in vitro* study. J Int Soc Prevent Communit Dent 2024;14:287-94.

However, the strength properties of silver-reinforced GI (SGIs) are still insufficient to withstand occlusal loads unless they are well supported by the surrounding tooth structure.[7]

On the other hand, the incorporation of nanoparticles into micro-sized GI powder led to widened particle-size distributions, resulting in higher mechanical values than conventional GIs.[9] Hence, nano resin-modified GI (NGI) could be a superior restorative material for dental applications.[9]

Critical intraoral factors such as pH variation, humidity levels, as well as the intake of pediatric liquid medications could aggravate the biodegradation of restorative materials over time, leading to changes in their physical properties.[10-12] A previous study reported that some liquid medications such as amoxiclav, metronidazole, cephalexin, ibuprofen and paracetamol affected the surface roughness (SR) of zirconomer, composite and GIs, in which the GIs demonstrated lower durability and higher SR changes in the immersion media as compared with other restorative materials.[13] Moreover, a recent work studied the effect of multivitamin syrups on the SR and hardness of conventional GIs in comparison with resin-modified GIs. They demonstrated that the long term use of multivitamin solutions can adversely impact the physical characteristics of restorative materials.[11] Thus far, no previous study has examined the effect of amoxicillin nor azithromycin suspensions (the regularly prescribed antibiotics for children) on the SR of NGI and SGI.

The rational of this study is that the difference in pH and chemical composition of AMS and AZS might exhibit different interactions with the chemical composition of NGI and SGI in terms of SR. So, the null hypothesis stated that there are no differences between the effect of AMS and AZS on SR of NGI and SGI; Therefore, this study aimed to assess the effect (and find the difference if any) of amoxicillin and azithromycin suspensions on the surface roughness of NGI and SGI samples.

Materials and Methods

Study design

In *in vitro* study.

Sample size estimation

Sample size was estimated by G Power 3.1.9.7 (developed by Franz Faul, University of Kiel, Germany) with a statistical power of 80%, an alpha error probability (Type I error) of 0.05%, In addition, an effect size of F equaled to 0.40 (representing a large effect size) among 6 groups. The minimum required sample size was 60 (10 samples per group). Effect size F is accounted as: Small =0.1, medium=0.25, large=0.4.[12,14,15].

Blinding

The samples were randomly coded and blindly analyzed.

Methods

This study was ethically approved by The Ethical Committee at the University of Baghdad College of Dentistry, Department of Basic Sciences (Reference number:573).

The mold was set on a transparent celluloid strip and secured on a glass cement slab. Afterwards, the GIs were applied and overladed with another matrix strip and glass cement slide, and 200 g pressure was used to remove surplus materials from the mold.[16,17] Then, the specimen was directly applied to the top of a glass slide, light-cured (Germany's Eighteeth model curing; LOT# G2108030) and polymerized as directed by the manufacturer.[18] Another round of light curing (for 40 sec) was applied to ensure the polymerization of the bottom of the GI discs.[19] For standardization purposes, the GI discs were polished following a sequential polishing protocol used by Ibrahim *et al.* (2019).[20] In 60 coded glass vials, 30 samples of each type of restorative material, NGI and SGI (Table 1) placed individually and coded depending on the type of GIs and the used medications [Figure 1]. For each kind of GI, the samples were subclassified into three groups (n = 10) and individually subjected to AMS, AZS, and artificial saliva (A.S).

Artificial saliva was prepared according to Björklund *et al*. The following materials were used to prepare one liter of artificial saliva: calcium chloride 0.05 g, sodium fluoride 0.0002 g, magnesium chloride 0.05 g, potassium phosphate 0.04 g, potassium thiocyanate

Table 1: Mode of activation, composition, and average particle size of GIs used in this study

Material	Mode of activation	Composition	Average particle size
NGI (3M-ES PE Ketac N100, St. Paul, MN, USA; LOT# NE60328)	Light cure	Monomers nanocluster, methacrylate modified polyalkenoic, HEMA(Hydroxyethyl methacrylate) FAS (fluoroaluminosilicate) and deionized water	Nanofillers 5–25 nm
SGI Riva sliver 8670008	Light cure	Sliver glass powder, acrylic acid, homopolymer, alloy powder, liquid acrylic acid homopolymer, and tartaric acid	8 µm

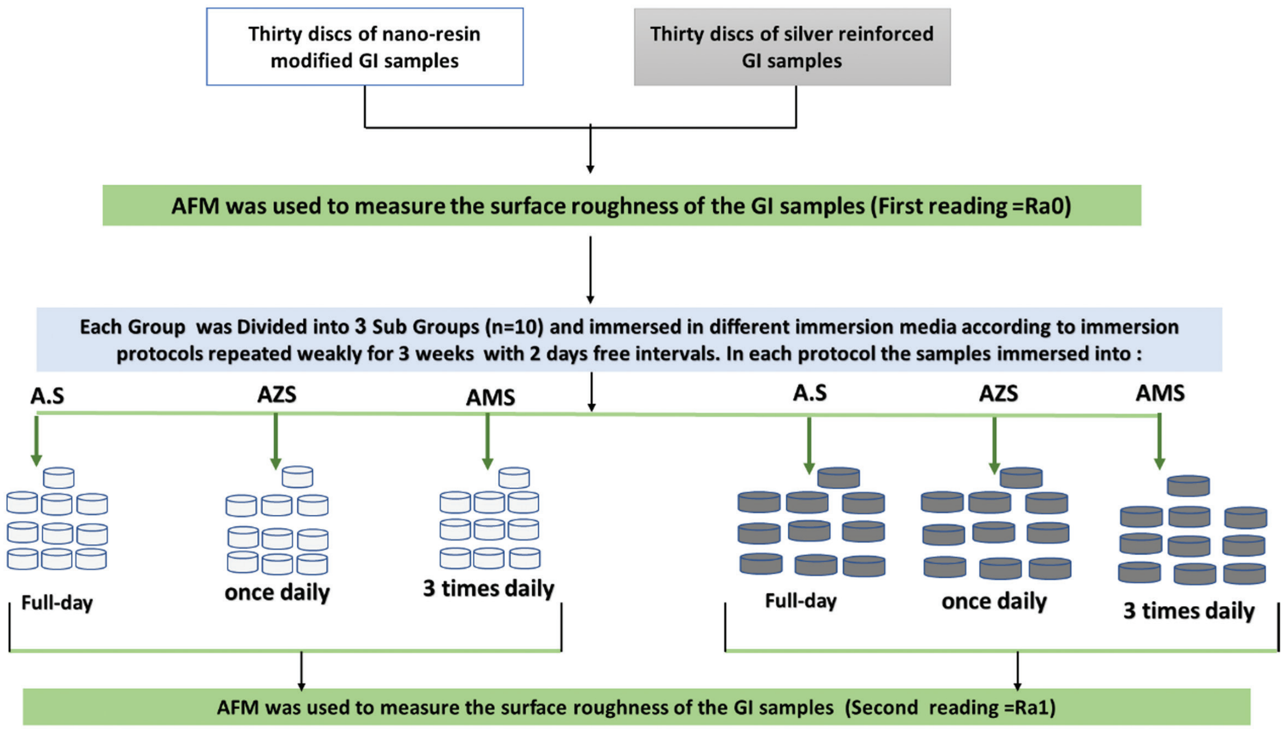

Figure 1: A flowchart of sample distribution and measured parameter

0.01 g, and one gram of sodium chloride, sorbitol and potassium chloride.[21]

Deionized water (900ml) was used to dissolve all of the above substances. After that, boiling water (100 mI) was required to dissolve sodium carboxymethyl cellulose (10 g) and then the solution was left to cool down before its addition to the previous ingredients. After that, the pH of artificial saliva was modulated to 7. A professional benchtop pH meter consisting of a glass electrode and an electronic meter was used for measurements of pH in this study. The glass electrode was firstly calibrated using buffering solutions with known pH level solutions (4.0, 7.0, 9.0).[21]

Two commercial antibiotics were used in this study, the AZi-Once and amoxicillin BP suspensions. Azi-Once (Jamjoom Pharmaceuticals Co., Saudi Arabia, MWT 748508) consists of: Azithromycin oral suspension 200mg/5mL with excipients include: banana flavor, colloidal silicon dioxide, fantasy flavor permaseal, fresh co forte permaseal, hydroxyoropyl cellulose, sucrose trisodium phosphate monohydrate, xanthan gum and purified water. Amoxicillin BP sugar-free suspension (Athlon Laboratories, Ireland, MWT 419.4) consists of: Amoxicillin oral suspension 250mg/5mL, sorbitol solution BP, sodium benzoate, disodium edetate, sodium citrate, orange bramble flavor, quinoline yellow, citric acid, colloidal anhydrous silica, xanthan gum, sorbitol and saccharin sodium.

To conduct pH measurements of antibiotic suspension, the glass electrode of the pH meter was separately immersed into a glass beaker containing 20 mL of each antibiotic suspension at room temperature (25°C). To avoid any potential cross-contamination, the glass electrode of the pH meter was carefully dried with cotton pads after being washed with distilled water before each pH measurement. The recorded pH values were 4.1 for AMS (representing the acidic media), and 9.2 for AZS (representing the basic media). To ensure the precise readings of pH, the pH values of each antibiotic suspension represented a mean of three readings.

Immersion protocols

Immersion cycles were performed by separately immersing the GI discs in the immersion media over a period of 25 days (7 days for three consecutive immersion protocols at 2-day intervals) in accordance with the following sessions: AMS for 2 minutes three times daily and AZS once daily. After every sample immersion period, the GI discs were rinsed and kept in A.S up to the next immersion time. Control samples were kept in A.S, which was refreshed daily. SR was evaluated twice: before the first immersion cycle (baseline or R0) and after the third immersion cycle.

Surface roughness assessment

Atomic force microscopy (AFM, Naio AFM 2022, Nanosurf AG, Switzerland, version 3.10.0)

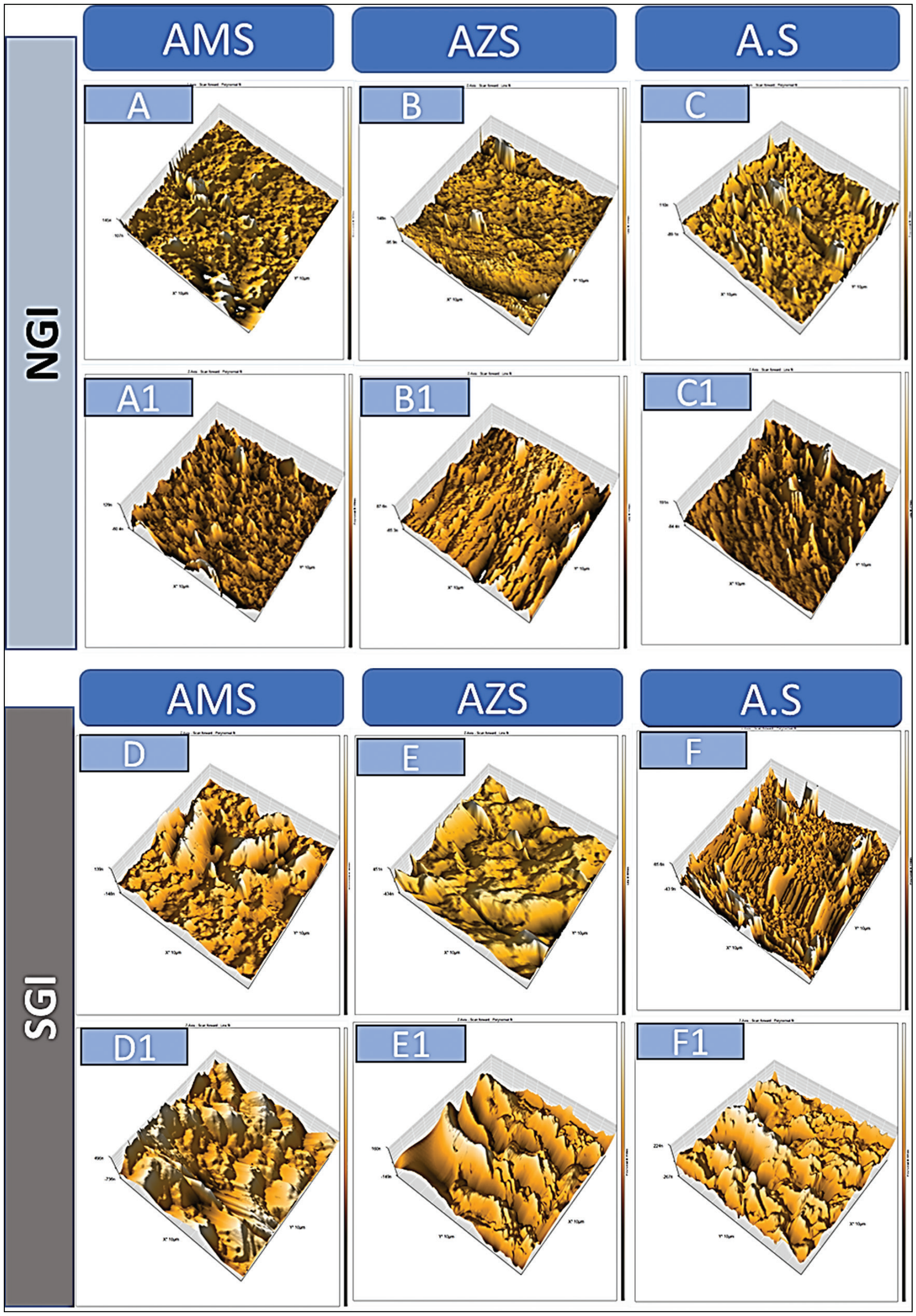

Figure 2: 3D AFM topography of NGI and SGI samples. (A), (B) and (C) represent NGI samples, while (D), (E), and (F) represent SGI samples before immersion in AMS, AZS, and AS, respectively. (A1), (B1), and (C1) refer to the NGI samples, while (D1), (E1), and (F1) refer to the SGI samples, following the third immersion cycle

was utilized to evaluate the SR of the GI samples initially (Ra0) and after day 25 (Ra1). Scanning was performed using a tapping mode on 10 μm × 10 μm areas at 1 Hz scanning speed with a scan at its center.[20] Roughness was measured in nanometers to quantify surface texture and measured using Ra parameters (the arithmetic mean of the peak height and valley depth from the mean line), which depict the total SR of a sample.[21-23] AFM 3D images were acquired at a resolution of 1024 × 1204 pixels.

Statistical analysis

Statistical analysis was carried out on SPSS version 22. Description statistics were represented by the mean and standard deviation. Paired *t* test and independent *t* test were used for intra- and inter-group comparisons at a significant

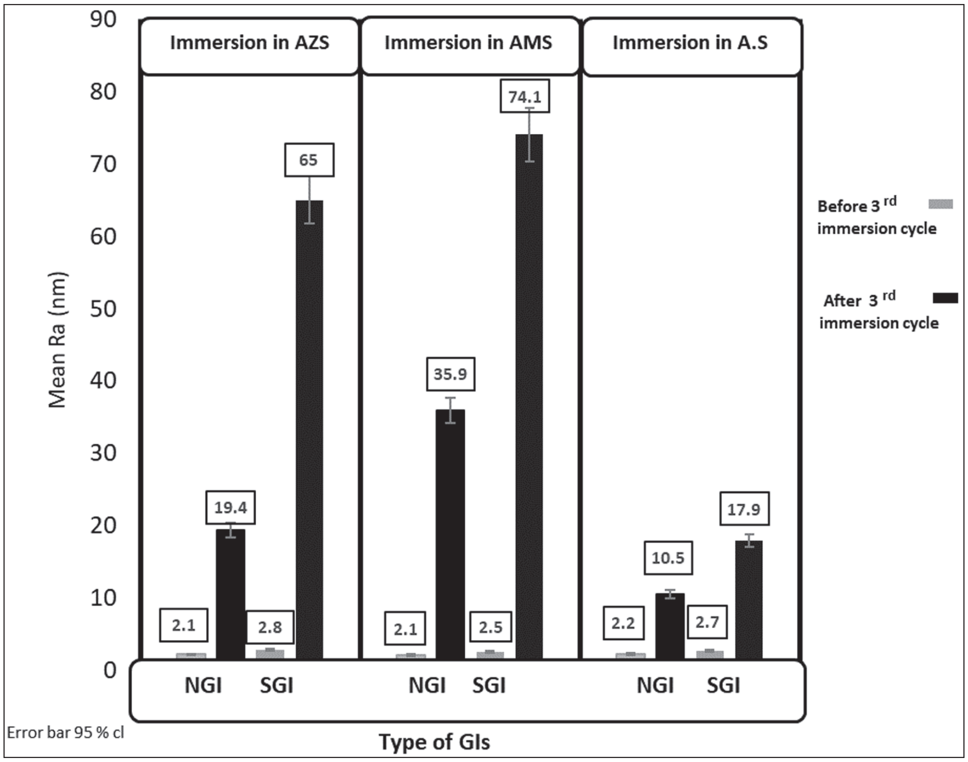

Figure 3: Mean values of SR measurements (Ra) of the GI samples before and after immersion cycles. NGI represents the nano resin-modified glass ionomer, while the SGI represents the SGI

Table 2: Statistical comparisons of the SR values of restorative materials before and after immersion in different media

Immersion media	Ra0 mean ± SD (nm)			Ra1 mean ± SD (nm)		
	Nano resin-modified glass ionomer	SGI	*P* value	Nano resin-modified glass ionomer	SGI	*P* value
AZS	2.2±1.2 Aa	2.7±1.2 Aa	0.11	19.3±3.9 Ba	65.0±6.3 Ba	˂0.001*
AMS	2.1±0.5 Aa	2.5±0.3 Aa	0.23	35.9±6.6 Bb	74.1±10.1 Bb	˂0.001*
AS	2.2±0.7 Aa	2.7±0.6 Aa	0.12	10.5±0.2 BC	17.9±2.8 BC	˂0.001*
ANOVA	*F* 0.04	0.34		48.2	263.3	
	P value 1.0	0.7		˂0.001*	˂0.001*	

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

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

*Indicates statistically significant difference between the two groups (nano resin-modified GI vs. SGI) for the base line and post-immersion readings independently

level of $P < 0.05$. Two-way repeated measure analysis of variance (ANOVA) was utilized to study the SR changes in the GIs between the immersion media. The Bonferroni *post-hoc* test was applied to determine the significant differences between groups at a significant level of $P < 0.05$.

Results

1. **pH measurements**: The recorded pH of AZS was 9.2 (basic medium). The acidic medium was AMS with a pH of 4.1. The AS was a neutral medium with a pH of 7.0.
2. **AFM topography and SR analysis**:

   a. **AFM topography:** The AFM topography demonstrated the comparisons of SR between NGI and SGI samples before and after immersion in different media. Initially, the SR of these GIs exhibited differences in filler shape and size. The SGI samples had a higher number of peaks and valleys and prominent protrusions than the NGI samples, creating a more heterogeneous appearance for the former. These findings were numerically supported by the SGI samples exhibiting higher Ra values than the NGI sample [Figure 2].

A normality test was conducted on the surface roughness data using Shapiro Wilk test with a significance level set at $p<0.05$. This test illustrated that the data were normally distributed across various parameters, involving interval of time measurements, kinds of GI ,and the immersive media that were used.

Considering the difference in GI type, SGI showed higher SR values before and after immersion in liquid medications than NGI [Figure 3].

Table 2 illustrates the average SR values of the GIs before and after immersion cycles in different media and the intra-group pairwise comparison results. The intragroup comparisons of the SR of each GI type demonstrated significant differences when analogized before and after the immersion cycles ($p < 0.05$). ANOVA revealed that the intragroup comparisons of the SR of the GIs samples before immersion cycles did not significantly differ ($p > 0.05$), whereas significant changes in the SR were illustrated after immersion in AZS, AMS, and A.S ($p < 0.05$). Besides, the AMS suspension massively roughened the surface of the GIs and demonstrated higher variations in the SR values of GI samples than the AZS and A.S [Table 2]. The latter demonstrated the lowest roughened effect as minimal changes in the Ra values were observed in the GI samples. A multiple pairwise comparison test (Bonferroni post-hoc test) was used to specify the significance of different immersion media on the SR of GIs. The results revealed that all the three-immersion media exhibited significant roughened ($p < 0.05$) in the SR of NGI and SGI when compared with one another. Meanwhile, the intergroup comparisons demonstrated no significant differences ($p > 0.05$) when the initial SR values (Ra0) of the NGI samples were compared with those of the SGI samples. However, significant differences were reported between the Ra1 values of the NGI and SGI samples after separate immersion in AZS, AMS, and A.S ($p < 0.05$).

Discussion

Considering the use of GIs and liquid antibiotics may be unavoidable during childhood.[24] The present research was designed to assess the detrimental impacts, if any, on the SR of GIs induced by AZS and AMS antibiotic suspensions that are frequently used to treat pediatric bacterial infections. The main focus was on roughness changes, because SR plays a crucial role in retaining the intraoral microorganisms, and it induces swifter colonization.[25] So, an increase in SR could increase the likelihood of dental cavities and periodontal infections.[25] Accordingly, a smoother surface of restorative materials could reduce the ability of surface bacterial attachment, reduce bacterial colonization, and subsequently prevent biofilm formation.[25] SR was evaluated using AFM because it provides high-resolution images, 3D imaging, and overall information about surface heterogeneity and particle distribution.[26] NGI exhibited lower SR value and more resistance to environmental changes than SGI, which may be due to the nature of NGI's physical characteristics in comparison to that of SGI. These differences can be assigned to the shape, number, and distribution of the particles and the differences in inter-facial bonding between particles.[27] Incorporating nano-filler particles can fill up the spaces between GI particles, leading to improvement in GI composition, thereby reinforcing the material and supporting higher micro-mechanical interlocking that could enhance the chemical energy stored in the covalent bond of NGI. Hence, the addition of nano-filler particles could render NGI more resistant to environmental changes with a smoother surface than other types of GI cements.[9,25] Meanwhile, the SGI structure was more porous than the NGI structure, leading to increased porosity that can increase water absorption and uptake through polymer chains. This process could modify and decrease the physical and mechanical features of restoration because the loss of chemical bond between filler particles, which ultimately may cause increased SR. [28] Higher SR changes were obtained in acidic media (AMS) compared to basic and neutral ones, mainly due to their abrasive and erosive nature. This detrimental effect can be attributed to the dissolution of particles in the surface of the restorative materials, inducing a rise in the SR values of GI.[29]

Many studies approved the negative outcome of low pH media on the restorative materials and came in a line with what was found in the present study.[1,29-31] For example, De Paula *et al*. (2014) showed that the degradation of nano-filler GIs by orange juice and Coca-Cola caused a significant increase in SR.[30] In an interesting study conducted by Perera *et al.* (2020), the acidic materials used (citric acid, phosphoric acid and lactic acid) exhibited significant destructive impacts on different types of GIs, after 14-day immersion period distinguishing the citric acid as the most erosive material.[32] Daily consumption of acidic beverages can exacerbate the influence of acidic materials on the SR of GIs as demonstrated by Colombo *et al*. (2021), who attributed this finding to the solubilizing effect of the acidic media.[29] More aggressive conditions were applied by Tărăboanță *et al*. (2022) who exposed the resin-modified glass-ionomer cements to gastric juice with brushing effect for 30 min post the acidic attack for one year, and found a significant increment in SR of the tested materials.[33] In addition to the current study, all the abovementioned studies adopted the same concept in explaining the main cause behind the acidic effect on the SR of the restorative materials, specifically the GIs, which can be underpinned by the hydrolysis of the GI surfaces. As the restorative materials are considered as ion releasing materials,[33-35] the detrimental effect of the low pH solutions on the SR of the GIs can be traced back to the aggressive attack and exchange of the surface ions with the H+ ions of the acidic media.[36] In addition to the ability of acidic materials to strongly chelate with the surface ions leading to a marked dissolution and increment in surface roughness.[36] Zaki *et al.* (2012) also mentioned that after immersing the GI in an acidic media, the solution infiltrates inside the cement and expands the gel matrix.[37] Furthermore, diffusion of the hydrogen ions (H+) into the matrix inducing changes in metal cations, which disseminate into the solution when the concentration gradient decreases.[36-39] As a result of the metal cations dissemination, the free oxygen concentration increases, leading to dissolution of the GI surface and an increase in its surface roughness.[36,40,41].

Conclusion

AMS, AZS, and AS (acid, alkaline, and natural pH media, respectively) significantly altered and increased the SR of both NGI and SGI. However, NGI exhibited smoother surfaces and higher resistance to alterations caused by oral liquid medications, particularly AMS (acidic medium), compared to SGI. Notably, this study is the first to report that alkaline drugs (AZS) could significantly impact the SR of GIs. Parents are strongly recommended to be educated and advised to brush their child's teeth or at least teach them to use the "swish and spit" method after consumption of pediatric liquid medications. This practice could help avoid the harmful effects of these drugs on restorative materials. Due to the limitations of an *in vitro* study, clinical studies should be conducted to evaluate the intraoral durability of SGIs and NGIs.

Acknowledgement

Not available.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Authors contributions

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

Ethical policy and Institutional Review board statement

The Research Ethical Committee at the University of Baghdad College of Dentistry, Department of Basic Sciences, has reviewed the submitted research project outline below for ethical approval on February 6, 2022, Reference No. 573.

Patient declaration of consent

Not available.

Data availability statement

Not available.

References

1. Jamal DY, Farsi NM, El-Housseiny AA, Felemban OM. Effects of pediatric liquid medications on surface properties of dental restorations. Med Sci 2022;26:ms57e2000.
2. Al-Rufaie EM, AL-Zahra AA. Physical properties and chemical kinetics for the interaction of albumin with amoxicillin. Iraqi J Sci 2015;56:3015-24.
3. Agarwal A, Panat S, Anshul GA, Aggarwal A. Antibiotic usage in pediatric dentistry: A comprehensive review. J Dent Sci Oral Rehabil 2014;5:125-32.
4. Cardinale F, Ciprandi G, Barberi S, Bernardini R, Caffarelli C, Calvani M, *et al*. Consensus statement of the Italian Society of Pediatric Allergy and Immunology for the pragmatic management of children and adolescents with allergic or immunological diseases during the COVID-19 pandemic. Ital J Pediatr 2020;46:1-14.
5. Ahmadi H, Ebrahimi A, Ahmadi F. Antibiotic therapy in dentistry. Int J Dent 2021;2021:6667624.
6. Schwartz DJ, Langdon AE, Dantas G. Understanding the impact of antibiotic perturbation on the human microbiome. Genome Med 2020;12:1-12.
7. Park EY, Kang S. Current aspects and prospects of glass ionomer cements for clinical dentistry. Yeungnam Univ J Med 2020;37:169-78.
8. Almuhaiza M. Glass-ionomer cements in restorative dentistry: A critical appraisal. J Contemp Dent Pract 2016;17:331-6.
9. Lyapina MG, Tzekova M, Dencheva M, Krasteva A, Yaneva-Deliverska M, Kisselova A. Nano-glass-ionomer cements in modern restorative dentistry. J IMAB Ann Proc Sci Pap 2016;22:1160-5.
10. Faghihi T, Heidarzadeh Z, Jafari K, Farhoudi I, Hekmatfar S. An experimental study on the effect of four pediatric drug types on color stability in different tooth-colored restorative materials. Dent Res J. 2021;2021:18.
11. Guler EBG, Bayrak GD, Unsal M, Kuvvetli SS. Effect of pediatric multivitamin syrups and effervescent tablets on the surface microhardness and roughness of restorative materials. J Dent Sci 2021;16:311-7.

12. Hasan ZR, Al-Hasani NR, Mahmood MA, Ibrahim AI. Effect of amoxicillin and azithromycin suspensions on microhardness of sliver reinforced and nano resin-modified glass ionomers: An in vitro study. Dent Hypotheses 2023;14:32.
13. Apeksha V, Kale Y, Dadpe M, Dahake P, Kendre S. Effect of paediatric liquid medications on surface roughness of dental restorative materials. J Adv Med Dent Sci Res. 2019;7: 123-7.
14. Ferguson CJ. An effect size primer: A guide for clinicians and researchers. Prof Psychol: Res Pract 2009;40:532–538. DOI:10.1037/a0015808
15. Aziz SZ, Jafar ZJ. The efficacy of little lovely dentist and tell show do in alleviating dental anxiety in Iraqi Children: A randomized clinical trial. J Int Soc Prevent Communit Dent 2023;13:388-93.
16. Zuryati A-G, Qian OQ, Dasmawati M. Effects of home bleaching on surface hardness and surface roughness of an experimental nanocomposite. J Conserv Dent 2013;16:356-61.
17. Ciccone-Nogueira JC, Borsatto MC, De Souza-Zaron WC, Ramos RP, Palma-Dibb RG. Microhardness of composite resins at different depths varying the post-irradiation time. J Appl Oral Sci 2007;15:305-9.
18. Bashetty K, Joshi S. The effect of one-step and multi-step polishing systems on surface texture of two different resin composites. J Conserv Dent 2010;13:34-8.
19. Abu-Naila AS, Baban LM. The effect of cyclic immersion in cola drinks on the surface microhardness and surface roughness of different composite filling resin materials. J Baghdad Coll Dent 2010;22:7-11.
20. Ibrahim A, Thompson V, Deb S. A novel etchant system for orthodontic bracket bonding. Sci Rep 2019;9:1-15.
21. Björklund M, Ouwehand AC, Forssten SD. Improved artificial saliva for studying the cariogenic effect of carbohydrates. Curr Microbiol 2011;63:46-9.
22. Candan M, Ünal M. The effect of various asthma medications on surface roughness of pediatric dental restorative materials: An atomic force microscopy and scanning electron microscopy study. Microsc Res Tech 2021;84:271-83.
23. Ajami S, Pakshir HR, Babanouri N. Impact of nanohydroxyapatite on enamel surface roughness and color change after orthodontic debonding. Prog Orthod 2016;17:1-8.
24. Culbertson BM. Glass-ionomer dental restoratives. Prog Polym Sci 2001;26:577-604.
25. Bala O, Arisu DH, Yikilgan I, Arslan S, Gullu A. Evaluation of surface roughness and hardness of different glass ionomer cements. Eur J Dent 2012;6:79-86.
26. Johnson D, Hilal N. Characterisation and quantification of membrane surface properties using atomic force microscopy: A comprehensive review. Desalination 2015;356:149-64.
27. Kadhim AAJ. Effect of mouth rinses on surface roughness of two methacrylate-based and siloraine-based composite resins. J Baghdad Coll Dent 2016;325:1-7.
28. Tanthanuch S, Kukiattrakoon B, Siripornanon C, Ornprasert N, Mettasitthikorn W, Likhitpreeda S, *et al*. The effect of different beverages on surface hardness of nanohybrid resin composite and giomer. J Conserv Dent 2014;17:261-5.
29. Colombo M, Gallo S, Chiesa M, Poggio C, Scribante A, Zampetti P, *et al*. In vitro weight loss of dental composite resins and glass-ionomer cements exposed to A challenge simulating the oral intake of acidic drinks and foods. J Compos Sci 2021;5:298-306.
30. De Paula A, De Fúcio S, Alonso R, Ambrosano G, Puppin-Rontani R. Influence of chemical degradation on the surface properties of nano restorative materials. Oper Dent 2014;39:E109-17.
31. Hafez RM, Elkorashy ME, Sultan MS. Compressive strength and surface roughness of ceramic reinforced glass ionomer subjected to chemical challenge. Egyptian Dent J 2017;63:2709-19. DOI:10.21608/edj.2017.76235.
32. Perera D, Yu SC, Zeng H, Meyers IA, Walsh LJ. Acid resistance of glass ionomer cement restorative materials. Bioengineering 2020;7:150.
33. Tărăboanță I, Buhățel D, Nica I, Stoleriu S, Ghiorghe AC, Pancu G. The impact of simulated gastric acid and toothbrushing on surface characteristics of resin-modified glass-ionomer cements. Medicina 2022;58:1149.
34. Moharramkhani F, Ranjbar Omrani L, Abbasi M, Kharrazifard MJ, Ahmadi E. Effect of fluoride varnish on glass ionomer microhardness changes in endogenous acid erosion challenge. Biomater Investig Dent 2021;8:18-23.
35. Ibrahim H, Aziz AA, Yahya NA, Yap AU. Surface degradation of ion-releasing restorative materials with cariogenic challenge. Opera Dent 2024:49:178-88.
36. Nica I, Stoleriu S, Iovan A, Tărăboanță I, Pancu G, Tofan N, *et al*. Conventional and resin-modified glass ionomer cement surface characteristics after acidic challenges. Biomedicines 2022;10:1755.
37. Zaki D, Hamzawy E, Halim SAE, Amer MA. Effect of simulated gastric juice on surface characteristics of direct esthetic restorations. Aust J Basic Appl Sci 2012;6:686-94.
38. Cilli R, Pereira JC, Prakki A. Properties of dental resins submitted to pH catalysed hydrolysis. J Dent 2012;40:1144-50.
39. Hasan ZR, Al-Hasani NR, Malallah O. Color stability of nano resin-modified glass Ionomer restorative cement after acidic and basic medications challenge. J Baghdad Coll Dent 2023;35:10-19.
40. Khan AA, Siddiqui AZ, Al-Kheraif AA, Zahid A, Divakar DD. Effect of different pH solvents on micro-hardness and surface topography of dental nano-composite: An in vitro analysis. Pak J Med Sci 2015;31:854-9.
41. Carvalho FG, Sampaio CS, Fucio P, Carlo HL, Correr-Sobrinho L, Puppin-Rontani M. Effect of chemical and mechanical degradation on surface roughness of three glass ionomers and a nanofilled resin composite. Oper Dent 2012;37: 509-517.