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IMPACT OF ACIDIC DRINKS ON GINGIVAL MARGINAL INTEGRITY OF DIFFERENT CERVICAL GLASS IONOMER RESTORATIONS

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ABSTRACT

Background: the aim of the present study was to evaluate and compare microleakage and marginal gaps of five different types of glass-ionomer restorations after aging in apple and lemon juices.

Materials and Methods: One hundred and fifty sound teeth prepared with standardized Class V preparations on buccal and lingual aspects with dentin/cementum gingival margins. They were divided into five groups and restored using; Fuji IX GP FAST, riva HV, EQUIA fill, Fuji II LC, Micron bioactive. Every group was further distributed into three subgroups: subgroup 1 was immersed in distilled water (DW) as control, subgroup 2 was immersed in apple juice (AJ), and subgroup 3 was immersed in lemon juice (LJ). Each subgroup was distributed equally for marginal adaptation and microleakage testing (n=10). The interfaces of restoration/gingival dentin were detected by scanning electron microscopy (SEM) to measure gaps for marginal adaptation assessment. For microleakage, samples were submerged in 2% methylene blue dye solution. Then, they sectioned labio-lingually at the middle of the teeth. The dye penetration alongside the gingival margins was assessed on buccal and lingual surfaces under a stereomicroscope.

Results: One way ANOVA test showed statistical significance among all tested GIs for marginal adaptation and microleakage and paired-t test showed significant differences for AJ and LJ.

Conclusions: The marginal integrity of glass-ionomers was negatively affected by popular acidic fruit juices. Riva HV, EQUIA Fil and RMGI Fuji II LC are considered less affected by these acidic juices.

KEYWORDS: Acidic Drinks, Gingival Marginal Integrity, Cervical, Glass ionomers.

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INTRODUCTION

Caries, abrasion, and erosion are the main causes of cervical dental tissue loss[1]. Drinking acidic beverages, such as fruit juices, is currently increasing the incidence of dental erosion[2]. Similarly, low pH levels in the oral cavity cause the restorative materials to degrade, so when choosing any restorative material, it is important to take into account how resistant and viable they are in acidic environments[3]. The creation of durable, biocompatible restorative materials that can tolerate the circumstances of the oral environment has been a major issue for decades[4]. The complicated shape of Class V faults with borders in dentin makes it difficult for the restorative material to seal[5]. Because of their chemical ion exchange adherence to dentin, high fluoride release that inhibits cavities, thermal compatibility with enamel and dentin, and minimal setting shrinkage, glass ionomers (GIs) are smart materials that are thought to be the best selection for cervical lesions restorations[2]. Despite their well-known lack of strength, susceptibility to solubility in low pH due to their inorganic nature, and poor aesthetics, GIs are the most straightforward materials to utilize for cervical lesions as better alternatives to amalgam[6]. Many compositional changes have been made to improve their mechanical and physical qualities. Examples of these include silica-reinforced glass ionomer (SRGI), bioactive glass reinforced glass ionomer (BGRGI), resin modified glass ionomer (RMGI), and nano-hydroxyapatite glass ionomer (NHAGI)[7] .

In order to restrict the creation of calcium polyalkenoate chains for quick setting, Fuji IX GP FAST is a conventional (CGI) modified by washing in acids to remove calcium ions and reduce calcium content[8]. EQUIA Fil is a traditional high viscosity CHVGI that contains glass nano-fillers to reinforce the mechanical qualities for high strength and surface hardness, while Riva Self Cure HV is a conventional high viscous CHVGI that uses patented ion glass fillers[9]. Compared to CGI, Fuji II LC RMGI has better strength, reduced solubility, longer working and shorter setting times, enhanced aesthetics, and translucency thanks to the addition of a second resin polymerization step[10]. Nano-sized hydroxylappetite particles combined with micron bioactivity for enhanced physical properties and bioactivity[11].

Predicting the long-term viability of restorations requires margin integrity, particularly in cases of cavities involving dentin and cementum margins with worsened clinical issues[12]. The two main techniques for assessing marginal seal in vitro are microleakage measures and marginal adaption[13]. Microleakage is the microscopic entry of ions, chemicals, and microbes within the formed cavity walls and the restorations. Marginal adaption is the boundary space between the tooth structure and the restoration; the more tightly the margins are sealed, the less microleakage there will be[14].

According to the earlier data, this study was designed to quantify and compare microleakage and marginal adaptation of Class V restored with five different types of GI at dentinal gingival margin after aging in apple and lemon juices to analyze the reliability of the results obtained by using two *in vitro* methods. The null hypotheses were: (1) the aging with thermocycling and apple and lemon juices would not affect the microleakage and marginal adaptation of different glass-ionomer restorations, and (2) the type of glass-ionomer would not have an impact on microleakage and marginal adaptation.

MATERIAL AND METHODS

Materials

Five commercially restorative materials were tested in this study: conventional glass ionomer (Fuji IX GP FAST), high viscosity conventional glass ionomer (Riva Self Cure HV), highly viscous conventional glass ionomer (EQUIA Fil), Resin modified glass ionomer (Fuji II LC), and bioactive glass ionomer (Micron bioactive). The detailed description of the materials is demonstrated in Table 1.

TABLE (1) Materials used in the study

Material	Type	Main Components	Manufacturer
Fuji-IX GP Fast	CGI (chemical)	Alumino- fluoro -silicate glass, Poly acrylic acid powder, polybasic carboxylic acid, polyacrylic acid, distilled water	GC Corporation, Tokyo, Japan
Riva HV self-cure	HVGI (chemical)	Polyacrylic acid,Tartaric acid, Fluoro-aluminosilicate glass	SDI, Victoria, Australia
Equia Fil	CHVGI (chemical)	Strontium fluoro-alumino-silicate glass (SFASG), poly acrylic acid, aqueous poly acrylic acid	GC Corporation, Tokyo, Japan
Fuji II LC	RMGI (dual-cure)	SFASG , HEMA, distilled water, polyacrylic acid, tartaric acid, camphorquinone	GC Corporation, Tokyo, Japan
Micron bioactive	CGI (chemical)	FASG, hydroxyappetite powder, polyacrylic acid	Prevest DENPRO, India
Equia Coat	Low-viscosity non-filled resin coat (light-cured)	Methyl methacrylate, colloidal silica, camphorquinone, urethane methacrylate, phosphori ester monomer	GC Corporation, Tokyo, Japan

Sample size calculation:

G*Power software (Ver. 3.0.10; G*Power, Kiel, Germany) was used to compute the sample size for this study in accordance with a prior study; at error prop (α) = 0.01 and power (1-β) = 0.99, the total calculated sample size was 6 specimens for each subgroup. To make up for missing data and boost study power, the sample size was raised to 10 specimens per subgroup[15].

Teeth selection and cavity preparation

One hundred and fifty human upper and lower molars that extracted because of periodontal disease were used in our study. The study procedures were registered and authorized by Zagazig University's Institutional Review Board (IRM# 613/25-8-2024). Caries, cracks, craze lines (found by transillumination), cervical abrasion, cervical repair, and endodontic treatment were all excluded. A hand scaler (Zeffiro; Lascod, Florence, Italy) was then used to remove any remaining soft tissue, and teeth were preserved in a 0.5% chloramine T solution. The teeth were then stored in an incubator (BTC, Model: BT1020, Cairo, Egypt) at 37°C containing distilled water until they were ready to be used[16]. Every sample was made with standardized Class V cavities on the buccal and lingual sides without bevels, measuring 4 mm for mesiodistal width, 3 mm for occlusogingival width, and 2 mm for depth. An inerasable pen was used to sketch the dimensions, and cavities were made inside. The cement-enamel junction (CEJ) was where the gingival edge was found. In a high speed hand piece (Dentsply Sirona, USA) with appropriate air-water cooling, a straight fissure design rotary cutting abrasive (H21 314 012; Komet, Brasseler, Germany) was utilized for preparation. Every four preparations, it was replaced, and the measurements were verified using William's graduated periodontal probe[14].

Restorative procedures

According to the used restorative GI, the prepared teeth were randomly assigned to five groups. The same operator completed every restoration. The Fuji IX GP FAST was used to restore group A. After the cavity was carefully dried, a capsule was made and put into the applicator to extrude the mixture, and a metallic condenser was used to adapt it to the cavity walls. To obtain a smooth surface and prevent moisture or dryness, a plastic celluloid strip is placed over the restoration surface. Using a super-fine diamond point (Mani DIA burs 41EF, Mani INC, Japan) and Al_2O_3 discs (Extra-Thin Sof-Lex discs, 3M ESPE) in a low-speed hand piece under water cooling, excess was removed at the margins after six minutes of setting. The process was completed in three minutes. Similar to group A, group B was restored with Riva Self Cure HV, and following five minutes of setting, it was completed and polished. After a minute of setting, Group C was restored using EQUIA Fil as before, completed, and polished.

Group D was restored using Fuji II LC as previously, and it was cured using a light cure device (Elipar, 3M ESPE, ST Paul, USA) with a wave length of 430–480 nm and a light intensity of 1000Mw/cm2 for 20 seconds. Group E was restored using Micron Bioactive; the ratio of powder to liquid was two scoops to two drops; the mixture was combined for 40 to 60 seconds using a flat and firm spatula; it was then transported by a cement carrier and covered with a plastic celluloid strip. After twenty-four hours, the samples were completed and polished. Lastly, a layer of EQUIA COAT was applied to all restorations using a microbrush, light-cured for 20 seconds, and then kept in DW at 37°C in an incubator (BTC, Model: BT1020, Egypt) for 24 hours.

Artificial thermocycling and chemical aging

According to ISO 11405 requirements, the teeth were thermocyclically treated for 10,000 cycles between 5 and 55 degrees Celsius with a 15-second immersion and 10-second transfer time (using SD Mechatronik Thermocycler, Germany). These cycles are equivalent to almost a year of intraorally[17]. Three subgroups were created from each group: subgroup 1 was kept in DW as a control until the erosive aging process was finished, subgroup 2 was submerged in AJ (Purified water, apple juice concentrate, Almarai company, KSA) and subgroup 3 was submerged in mixed fruit LJ (Purified water, mixed fruit juice concentrates ; apple, pear, grape, lemon juice concentrate with orange cells, pomelo pieces lemon juice concentrate, vitamin C, Almarai company, KSA). The pH was measured using a pH meter (Hanna Instrument, USA).

The aging process involved keeping the material in DW in between erosive cycles and immersing it for 10 minutes three times a day for seven days. Every subgroup was housed in an airtight plastic container that was large enough to completely cover the teeth in the incubator. The immersion media was replaced daily, and the remaining juice bottle contents were thrown away[18]. Each subgroup was finally assigned into two divisions: division (a) was evaluated by marginal adaptation, and division (b) was subjected to the microleakage test.

Marginal Adaptation Evaluation by Scanning electron microscopy (SEM)

To prepare the samples, 10% phosphoric acid was applied to the gingival interfaces of the restorations for five seconds in order to remove any debris. Gold then sputtered in a coating machine after they were dehydrated. Standard half-inch pin-style aluminum stubs were used to fix the samples. The photos were moved to a computer after the stubs were positioned in a specimen chamber mounting table of a SEM (JEOL JSM-6510 LV) at an accelerating voltage of 30 KV for 500X magnifications. The width of the interfacial gaps was measured at three different sites using a software tool, and the mean for each of the three points within the same margin was noted in micrometers (μm) [19].

Microleakage assessment

Utility wax was used to seal the tooth apices, and nail varnish was applied twice to the whole tooth surface, with the exception of the 1 mm area surrounding the restoration. 50 grams of methylene blue (MB) salt were dissolved in 100 milliliters of deionized water to create the MB solution. After drying, all of the teeth were placed in closed bottles away from light and left in the prepared 2% MB dye solution for 24 hours at room temperature. Teeth were then taken out of the dye solution, cleaned, and allowed to dry. A low speed diamond saw machine (Isomet 4000, Buehler, Lake Bluff, IL, USA) was then used to section the teeth labio-lingually in the middle of both restorations at a speed of 2500 rpm while being water cooled. A 40X magnification stereomicroscope (MA 100Nikon, Japan) was used to measure the dye penetration along the cavity walls[20]. A single observer used the scoring criteria in accordance with the scoring method to determine the extent of microleakage, enabling quantitative analysis: (1) Dye penetration not beyond the middle of the cavity depth, (2) Dye penetration surpassing the middle of the cavity depth, (3) Dye penetration reaching the axial wall, and (0) no dye penetration[21].

Statistical analysis

The IBM SPSS Statistics software, Version 2.0 for Windows, was used to process and analyze the gathered data. Following a Shapiro-Wilk test to check for normality, the data were quantitatively displayed as mean and standard deviation (SD). A significant threshold of $P < 0.05$ was established. Tukey's post-hoc test was used for pairwise comparisons after One Way ANOVA was used for multiple comparisons among research subgroups.

RESULTS

Marginal adaptation evaluation results

As shown in Table 2, One Way ANOVA test revealed significance between acidic juices for all the tested GI restorations. Also, the marginal gaping increased significantly in subgroups (LJ and AJ) compared to DW subgroup. The widest gap was recorded for EQUIA Fil by aging in LJ and the narrowest gap was recorded for Riva HV self-cure in AJ. According to the effect of GI type, there was significance between all the tested five materials when were immersed in DW or AJ or LJ. Also, it was noticed that there is a significance between Fuji IX GP FAST and Riva HV self-cure, when were immersed in DW or AJ or LJ. Also, the marginal adaptation increased significantly in the main groups (EQUIA Fil, Fuji II LC, and Micron bioactive) compared to Riva HV self-cure when immersed in DW or AJ or LJ as presented in Table 3 and Figure 1.

Microleakage test results

Regarding Table 4, there was significance in microleakage scores between DW, AJ, and LJ in all the 5 main groups (Fuji IX GP FAST, Riva HV self-cure, EQUIA Fil, Fuji II LC, and Micron bioactive). Also, the microleakage score increased significantly in subgroups (LJ and AJ) compared to DW subgroup for each GI type. The highest score was for Fuji IX GP FAST in LJ, and the lowest for EQUIA Fil in AJ. There was only significance between all GIs when were immersed in AJ. Also, there was significance between Fuji II LC group and Micron bioactive when immersed in DW or AJ or LJ (Figures 2, 3).

TABLE (2) The effect of juice type on the marginal adaptation.

Material	Juice type			P value
	DW	AJ	LJ	
Fuji IX GP FAST	16.5±2.7	40±3*	40.6±5.6*	<0.0001
Riva HV self-cure	12±2.1	21.9±4*	28.5±3.3*#	<0.0001
EQUIA Fil	14.9±2.5	40.5±1.8*	43.5±1.4*#	<0.0001
Fuji II LC	17±2.5	35.9±7*	36.5±3.5*	<0.0001
Micron bioactive	20.1±4.5	41.1±3.9*	42.6±2.3*	<0.0001

Significant p <0.05, *significant with DW, #significant with AJ.

TABLE (3) The effect of GI type on the marginal adaptation.

Juice type	Material					P value
	Fuji IX GP FAST	**Riva HV self-cure**	**EQUIA Fil**	**Fuji II LC**	**Micron bioactive**	
DW	16.5±2.7	12±2.1[a]	14.9±2.5[b]	17±2.5[b]	20.1±4.5[abc]	<0.0001
AJ	40±3	21.9±4[a]	40.5±1.8[b]	35.9±7[b]	41.1±3.9[b]	<0.0001
LJ	40.6±5.6	28.5±3.3[a]	43.5±1.4[b]	36.5±3.5[bc]	42.6±2.3[bd]	<0.0001

Significant $p<0.05$***, [a] significant with Fuji IX GP FAST, [b] significant with Riva HV self-cure, [c] significant with EQUIA Fil, [d] significant with Fuji II LC.***

TABLE (4) The effect of juice type on the microleakage scoring.

Material	Juice type			P value
	DW	**AJ**	**LJ**	
Fuji IX GP FAST	0.8±0.8	2±0.8*	2.9±0.7*#	<0.0001
Riva HV self-cure	0.9±0.9	2.2±1*	2.6±1.2*	0.003
EQUIA Fil	0.4±0.5	1.2±0.6*	2.7±0.5*#	<0.0001
Fuji II LC	0.6±0.5	1.6±0.5*	2.2±0.6*#	<0.0001
Micron bioactive	1.2±0.4	2.4±0.5*	2.2±0.6*#	<0.0001

Significant $p<0.05$***, * significant with DW, # significant with AJ.***

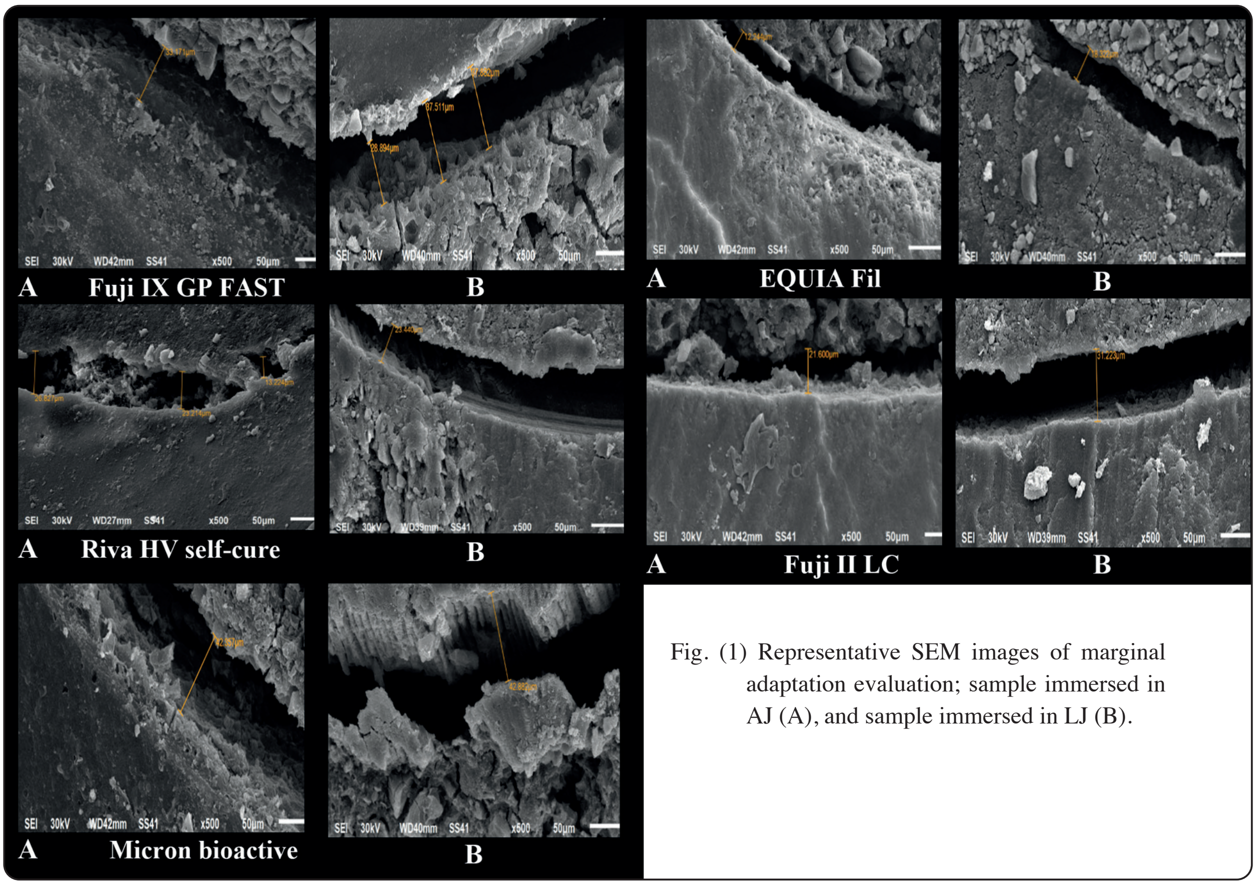

Fig. (1) Representative SEM images of marginal adaptation evaluation; sample immersed in AJ (A), and sample immersed in LJ (B).

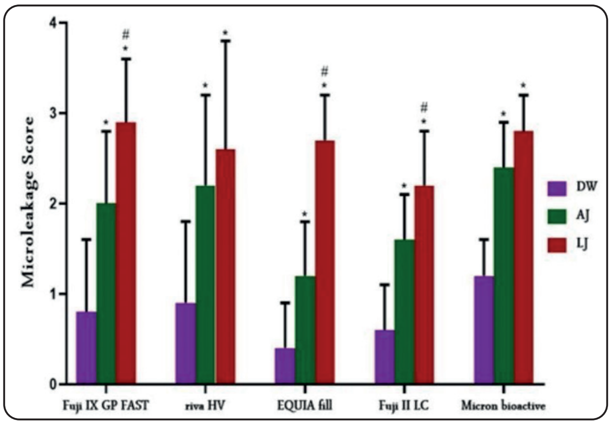

Fig. (2) Microleakage scores among the main studied groups

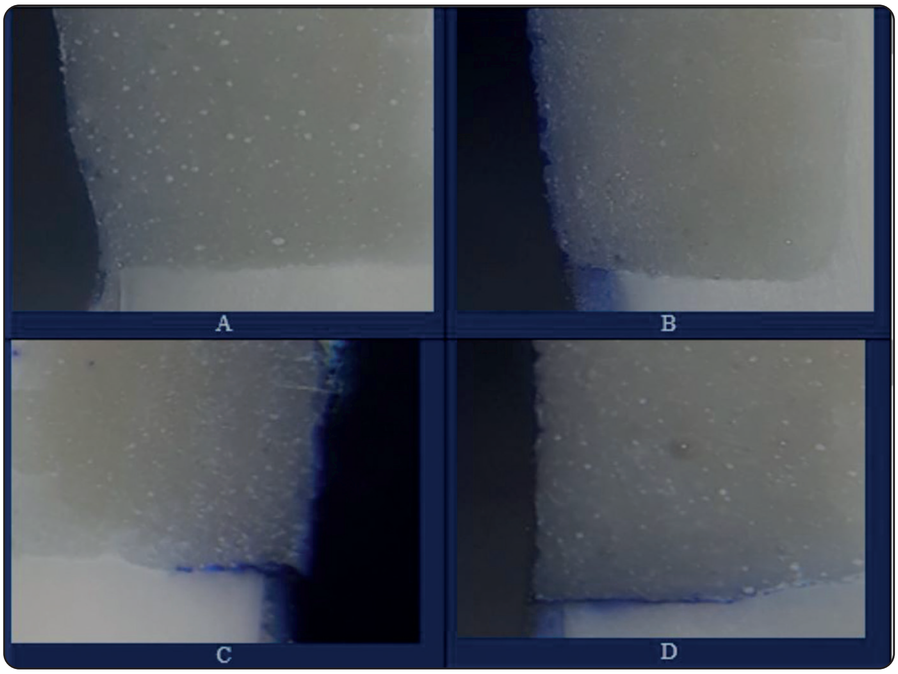

Fig. (3) Representative images of stereomicroscope evaluation of microleakage scores; A. score o for Fuji IX GP FAST immersed in DW, B. score 1 for Riva HV self-cure immersed in AJ, C. score 2 for Fuji II LC immersed in LJ, D. score 3 for Micron bioactive immersed in LJ

DISCUSSION

In the restorative era of dentistry, maintaining long-lasting intraoral restorations is just as important as minimizing the removal of injured tooth tissues. Similar to the oral environment, the restorations are subjected to a variety of circumstances, including temperature and pH variations that alter their structure and acidic meals that can break down restorative materials, which inevitably leads to biodegradation[22]. The silicate-glass hydrogel network around unreacted glass particles dissolves in erosive environments, making GI materials unstable. In order to achieve therapeutic benefits, bioactive-based restorative materials have recently been launched to the dentistry market[23].

Class V cavities were created on the buccal and lingual surfaces with the cervical dentin edge at CEJ because of the bonding challenge to dentin substrates[24]. It is a suitable method for restoration's seal ability assessment, and it is regularly designated for restoration with glass-ionomer materials as there is no need for application of an adhesive to the tooth[25].

In order to replicate the temperature variations in the mouth cavity, thermocycling was also carried out. Both teeth and restorative material contract and expand as a result of these changes in oral temperature, which may have an impact on adhesion at tooth/restoration interfaces because of variations in coefficient of thermal expansion (CTE) [26].

Hengtrakool et al.[18] employed the dynamic pH cycle model in an immersion pattern to mimic clinical situations, when the consumed liquids come into direct contact with the tooth for a few minutes before being washed away by saliva used in our study . To prevent long-term damage to the materials, the specimens were kept in distilled water both before and after each immersion to stop the effect juices. Long-term exposure can occur when chemical substances from fluids are absorbed by the calculus and food debris at the restoration edge intraorally. The current study was therefore created for the seven days of aging.

Because the direct method of SEM is straightforward and representative, it was used in the current investigation to evaluate and record marginal gap values in micrometers; the smaller the marginal gap, the better the marginal adaption[27]. Furthermore, in this study, microleakage is taken into account as a metric for assessing the performance of restorations utilizing the dye penetration approach. It is straightforward, offers a quick and simple screening technique that is frequently used in preclinical examination, and does not react with dentin[28]. Because its particles have a molecular size smaller than bacteria's and can penetrate deeper than any other dye, methylene blue dye was chosen for its superior penetration[29]. The marginal adaptation and microleakage assessments were chosen for this study in order to make sure the materials are suitable for clinical dentistry. This is because a proper marginal adaptation shouldn't result in microleakage[14].

This research has the potential to be clinically useful and assist clinicians in appropriately choosing restorative materials based on patients' dietary preferences. The first hypothesis, according to the findings of this investigation, that the marginal adaptation and microleakage of evaluated glass-ionomer restorations were unaffected by aging with thermocycling and apple and lemon juices, was disproved as there were significant differences (P <0.0001 and 0.003). Also, the second hypothesis that there was no difference in marginal gaps and microleakage among the tested materials was rejected, as significant differences were observed. Juices' effects on the materials may also be directly correlated with pH, the amount and frequency of ingestion, and each GI's chemical makeup. Because lemon juice includes ascorbic and citric organic acids, which may dissolve GIs and cause them to connect with dentin, its pH was 2.6[30]. Ionic components in GIs are chelated by citric acid with a notable degree of solubility. GI restoration's solubility depends on pH, and when salivary H+ levels rise, so does the rate of dissolution[31]. Metal cations in the matrix are replaced by H+ ions that infiltrate into GI components in an acidic environment. The repair surfaces and margins release these free cations as they diffuse outward. More cations are drawn out of the nearby glass particles when these metal cations decline. Furthermore, the glass component's Si–O–Si connection might be harmed by hydrogen ions, creating micro-gaps[32]. According to Al-Taee et al. and Nica et al., exposure to a low pH environment tends to remove filler particles from the material and cause the matrix component to breakdown[33].

Good marginal sealing is achieved when the restorative material adheres well to the cavity walls and at the margins. This bond is impacted by pH fluctuations and functional stresses brought on by the tooth and restoration's different linear CTE. With recurrent expansion-contraction at the tooth/restoration contact, this stress may be exacerbated during thermocycling aging, resulting in gap formation and microleakage[34]. Because calcium is necessary for the GIs' bonding mechanism, dentin and cementum margins exhibited poor marginal adaptation, which led to microleakage. The degree of surface energy and dentin margin composition at the gingival area that influence chemical bonding or infiltration to GIs[35]. Material adherence to tooth structure may be delayed as a result of CGI's slow acid-base response process. Additionally, because dehydration induces shrinkage in both restoration and tooth tissues, specimens that are dehydrated during SEM assessment may have more marginal gaps[36].

The study's findings showed that aging caused the marginal gaping in lemon and apple juices to increase, with lemon juice showing the highest significant gaping in Riva HV and EQUIA Fil, which are thought to have high viscosity indexes. The material's ability to adapt well may be hampered by its high viscosity, which would diminish its marginal quality[37]. Notably, there were notable variations among the five materials examined, and the behavior of the materials in acid tests depended on their chemical structure. GI was combined with resin monomers to create RMGI, and the mechanical characteristics were enhanced by adding bioactive apatite, silicon particles, reinforcing fibers, and strontium oxide. Their resistance to these several important impacts from acidic fluids was regulated by the filler content[38]. Because of its stickiness, which made it difficult for the material to properly condense, and the presence of hydrophilic functional groups, which absorb water and act as a plasticizer, RMGI's marginal integrity was impacted, leading to deterioration and a loss of marginal sealing[12]. In addition, the ester radicals in resinous monomers hydrolyze at low pH, reducing the ability of entangled poly-alkanoate and HEMA polymers to form bonds with one another and negatively impacting RMGI's ability to adapt to cavity walls[39]. However, acids continue to erode GIs, impairing their functionality; it is widely established that microleakage has no effect on the frequency of recurrent caries because fluoride levels may slow its advancement[40].

Aging in lemon and apple juices enhanced the microleakage scores in this investigation; as previously stated, lemon juice had a greater effect, with the exception of Micron bioactive, which was more affected by apple juice (pH = 3.35). The loss of hard tissues with the restorative components from these drinks may be the cause of the greater microleakage scores at low pH. The use of capsules enables more accurate proportioning, homogenous mixing, and better administration inside the cavity, which was not possible for this type in the trial, and the addition of bioactive glass to GI may boost resistance to acid challenge[41]. Because of the reinforcing resin matrix, RMGI is less vulnerable to acidic degradation than CGI, which may explain why Fuji II LC got lower microleakage scores[42].

The material may work well in clinical settings even if GI restorations were unable to achieve a marginal seal at the tooth/restorations interface with the evidence of acidic damage in this in-vitro testing. This could be as a result of the bioactive materials' therapeutic ion release, which buffers the acidic solution's low pH to postpone or stop the formation of secondary caries[43]. The incapacity to simulate the intricate oral environment and the buffering effects of saliva is one of the study's drawbacks. Future in vivo research should assess the impact of acidic beverages.

CONCLUSIONS

All the different five brands of GIs restorations margins have been deteriorated with bottled acidic juices and the more acidity the more the effect. The high viscosity; ion releasing; Riva HV and EQUIA Fil, and RMGI Fuji II LC are considered less affected by these acidic juices. GIC restorations done in patient with high frequency of acidic drinks intake will have high risk of restoration failure, and the selection of durable restorative material should consider the patient's dietary habits. This study confirms the erosive potential of acidic beverages which the public should be aware.

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