

Original Article

Evaluation of Surface Roughness and Marginal Microleakage of Zirconia Reinforced Glass Ionomer Versus Resin Modified Glass Ionomer in Class V Restoration in Primary Molars: In Vitro Study

Hala Ahmed Al Tijani Saleh¹, Sherine Ezz El Din Taha¹, Nouran Mamdouh Ahmed¹

¹Department of Pediatric Dentistry and Dental Public Health., Faculty of Dentistry, Cairo University.

Email: hala.altijani@dentistry.cu.edu.eg

Submitted: 20-12-2024

Accepted: 09-02-2025

Abstract

Aim: To evaluate surface roughness and marginal microleakage of Zirconia Reinforced Glass Ionomer (Zirconomer) versus Resin modified Glass Ionomer (Riva Light Cure) in restoring class V cavities in primary molars.

Subjects and methods: Thirty-eight primary molars were divided into two groups, group 1 for Zirconomer and group 2 for Riva LC. Class V cavities were prepared on all molars and restored with their assigned restorative material. For microleakage evaluation, teeth were subjected to thermocycling, immersed in methylene blue dye, and sectioned buccolingually. Assessment of the degree of dye penetration was done under stereomicroscope. For surface roughness; molars were subjected to toothbrushing using an automated brushing simulator. Before and after surface roughness measurements were recorded using an atomic force microscope. An Independent t test was performed for surface roughness, and Chi square test for microleakage evaluation.

Results: Zirconomer showed lower surface roughness values before and after simulated toothbrushing than Riva LC. Both materials showed microleakage with a higher mean score for Zirconomer group than Riva LC group.

Conclusion: Within the limitation of the study, Zirconomer showed lower surface roughness values than Riva LC, but had higher microleakage values.

Keywords: Zirconomer; Resin modified glass ionomer; Riva Light Cure; Surface roughness; Microleakage.

I. Introduction

Dental caries is a multifactorial sugar-driven disease, mediated by a biofilm which results in an alternative phase of demineralization and remineralization of the hard-dental tissues. Risk factors of dental caries includes individual and environmental factors such as genetic predisposition, cariogenic oral flora, salivary composition and flow rate, dietary quality, oral hygiene measures, enamel defects, crowding, parents' neglect and accessibility to health care

(Anthonappa & King 2019; Opydo-Szymaczek et al. 2021).

Early examination and detection of the caries process through a series of clinical and radiographic techniques can prevent further progression of the lesion. Untreated lesions in primary teeth may progress to involve the pulp with subsequent pain, swelling, inability to eat, speak and malnutrition. This could alter growth and development which may lead to deterioration of the child's quality of life (Opydo-Szymaczek et al. 2021).

The introduction of adhesive restorative materials has facilitated conservative caries management, while giving an esthetic appearance of the tooth. One of the earliest adhesive restorations is glass ionomer cements (GIC). It has properties of biocompatibility, chemical bonding to enamel and dentin, thermal expansion resembling the tooth structure, antibacterial properties, and less technique sensitive than other restorations. Furthermore, its fluoride release and uptake make it the restoration of choice in managing pediatric patients (*Sidhu & Nicholson 2016; American Academy of Pediatric Dentistry 2023; Manisha et al. 2023*).

Despite the multiple advantages of glass ionomer cement, it exhibits certain limitations such as poor mechanical properties, sensitivity to moisture during setting and lack of translucency which leads to poor esthetics. Multiple modifications have been made to GIC over the years to improve its properties and overcome its disadvantages (*Alsari et al. 2024; Ge et al. 2024*).

Resin modified glass ionomer has gained popularity in pediatric dentistry and has become a preferred option of treatment in restoration of primary teeth. The incorporation of resin in its structure has led to improvement in mechanical properties; as compared to conventional GIC. It has better handling characteristics, good adhesion, fluoride release, less polymerization shrinkage and preserves the properties of the conventional material (*Alsari et al. 2024*).

Another novel modified version of glass ionomer cement that incorporates zirconia particles into the composition, is zirconia reinforced glass ionomer (Zirconomer and Zirconomer Improved), developed by SHOFU, Japan and introduced as the white amalgam. Zirconomer has been made with the aim of achieving superior compressive and flexure strengths with excellent adaptation to the margins, minimal occlusal wear, superior

antibacterial activity and higher initial fluoride release. This combines both the mechanical strength of amalgam and the fluoride releasing properties of glass ionomer cement. Zirconomer is biocompatible; having a coefficient of thermal expansion similar to the tooth and bonds chemically to the tooth structure (*Shetty et al. 2017; Agarwal 2019; Arefein et al. 2019; Dhivya et al. 2022*).

The durability of a restoration is a crucial parameter to consider when deciding on a restorative material to be used with pediatric patients. Durability can be achieved mainly by having a strong adhesion to the tooth surface to prevent dislodgement and leakage around its margin, which may eventually lead to secondary caries formation. Moreover, the ability to control the restoration surface topography to prevent plaque accumulation, which is one of the primary causes of caries formation, is another important factor. All of the above influence the decision of the appropriate restorative material (*Sharafeddin & Bahrani 2021; Manisha et al. 2023*).

In this context, this study aimed to evaluate surface roughness and marginal microleakage of a novel restorative material (Zirconomer) and compare it to Resin modified glass ionomer (Riva light cure) in laboratory settings, when used to restore class V cavities in primary molars.

II. Subjects and Methods

Table 1 shows all utilized materials in the present study.

A. Sample Size Calculation

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups regarding microleakage and surface roughness. For microleakage, by adopting an alpha level of (0.05) a beta of (0.2) i.e. power=80% and an effect size (d) of (1.21) calculated based on the results of a previous study (*Salman et al. 2019*) and

expert opinion; the predicted total sample size (n) was found to be (24) samples (i.e. 12 samples per group). Sample size calculation was performed using G*Power version 3.1.9.7 (Faul et al. 2007).

For surface roughness, by adopting an alpha level of (0.05) a beta of (0.2) i.e. power=80% and an effect size (d) of (1.76) calculated based on the results of a previous study (Komandla, Acharya & Pentapati 2021) and expert opinion; the predicted total sample size (n) was found to be (14) samples (i.e. 7 samples per group). Sample size calculation was performed using G*Power version 3.1.9.7 (Sapkale et al. 2018).

B. Eligibility Criteria

1. Inclusion criteria:

- Extracted second primary molars with at least the buccal surface intact.

2. Exclusion criteria:

- Extracted primary incisors.
- Extracted primary molars with pulp therapy or restorations.

C. Sample Collection

Extracted second primary molars were collected from dental clinics of Pediatric Dentistry and Dental Public Health Department, Faculty of Dentistry, Cairo University, these molars had been already discarded. Molars were disinfected and stored according to the Occupational Safety and Health Administration guidelines and regulations (Gerberding et al. 2003).

D. Groups Interventions

Based on the calculated sample, the total 38 teeth were divided equally into 2 restoration groups (19 per group); group 1 was assigned to Zirconomer and group 2 for Riva Light Cure. Each group was further divided as mentioned previously to subgroups according to the outcome being assessed.

Group (1); Zirconia Reinforced Glass Ionomer (Zirconomer Improved):

Subgroup (1a): 12 extracted second primary molars for testing marginal microleakage.

Subgroup (1b): 7 extracted second primary molars for testing surface roughness.

Group (2); Resin Modified Glass Ionomer (Riva light cure):

Subgroup (2a): 12 extracted second primary molars for testing marginal microleakage.

Subgroup (2b): 7 extracted second primary molars for testing surface roughness.

E. Sample Preparation

The principle investigator prepared the molars to standard non-beveled Class V cavities (measuring 2 mm in length, 4 mm in width and 2 mm in depth) in the middle third of their buccal surfaces using a high-speed handpiece (Apple Dental Air motor Handpiece, China) and round diamond bur size BR-40 (Guangzhou Hicare Medical, China) under a water coolant system (Bajabaa et al. 2021). A periodontal probe was used to measure and confirm the dimensions of the cavities (Sedradent, Pakistan). The prepared molars in both groups 1 and 2 were restored with Zirconomer and Riva light cure respectively, according to the manufacturing instructions.

F. Surface Roughness Assessment

Molars were first stabilized by mounting them in cold cure acryl and base line measurements of their surface roughness were taken using Atomic Force Microscope (AFM) (Tosca200, Lecica Microsystems, Germany), before simulating tooth brushing motions.

• Simulated Tooth Brushing Procedures

A Specially designed automated tooth brushing simulator was used, along with a manual toothbrush (Oral B kids, United States) and toothpaste (Colgate Natural Extract, Turkey). The toothbrush was held inside the customized machine against the molars with a standardized constant load (200g) at a frequency of 100 strokes per minute using a dentifrice slurry (Colgate and distilled water in 1:1 ratio) for 20,000 strokes to represent 2 years of brushing twice a day **Figure 1(a & b)** (Komalsingsakul, Srisatjaluk & Senawongse 2022).

- **Atomic Force Microscope Reading**

Two-dimensional (2D) and three-dimensional (3D) images were recorded twice for the molars; at the base line before simulated tooth brushing, and after. At a resolution of 400×400, a scan size of 10 μ × 10 μ and the mean square heights (Sq) were recorded using arrow NCR (Non-contact reflex) tapping Cantilever **Figure 2**. Data were processed using Tosca analysis software specialized program (*Gadallah et al. 2023*). This was done at The National Research Center (NRC), Cairo, Egypt.

G. Microleakage Assessment

- **Thermocycling and preparing for stereomicroscopic assessment:**

Molars were subjected to thermocycling (SD Mechatronic Thermocycler, Germany) for 250 cycles at temperature of 5 degrees, 37 degrees and 60 degrees. Molars' apices were sealed with acrylic resin layer and a nail varnish was applied to them leaving 1 mm window around the cavities. After that, molars were immersed in 0.5 % methylene blue dye at room temperature for 24 hours, then they were dried and sectioned bucco-lingually with a slow-speed cutting machine (Isomet 4000, Buehler, Germany) to be prepared for the microscopic assessment **Figure 3 (a, b &c)**. (*Agarwal et al. 2019 ; Dhivya et al. 2022*).

- **Stereomicroscope assessment:**

Molars were examined under Stereomicroscope (Nikon SMZ745T, Japan), on a magnification of

×20, to measure the degree of dye penetration on occlusal and gingival walls. Scores of dye penetration were given following the scoring system described by Khera and Chan 1978: **Figure 4**

0 No leakage

1 Dye penetrating is less than or up to half the prepared cavity.

2 Dye penetrating is to more than one-half of the cavity but not reaching the junction of the axial and occlusal or gingival wall.

3 Dye penetrating reaching the junction but not including the axial wall

4 Dye penetration including the axial wall (*Agarwal et al. 2019*) .

H. Statistical Analysis

Statistical analysis was performed with SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. All quantitative data were presented as minimum, maximum values, mean, and standard deviation. All qualitative data were presented as frequency (N) and percentage (%). Shapiro Wilk and Kolmogorov tests were used for normality testing, independent t test to compare between groups regarding surface roughness, Paired t test to compare between before and after regarding surface roughness and Chi square test to compare between groups regarding microleakage.

Table (1): Materials used, composition, manufacturer, and LOT number

Materials	Composition	Manufacture	LOT#
Zirconia reinforced glass ionomer (Zirconomer Improved)	It contains zirconium oxid glass powder, tartaric acid (1–10%), polyacrylic acid (20–50%), and deionized water as its liquid	SHOFU, United Kingdom	0813022
Light cured resin reinforced glass ionomer restorative material (Powder/Liquid Kit) RIVA® Light Cure	Ion glass filler is made of : unique blend of different sizes of ultrafine, highly reactive glass particles.	SDI Limited Bayswater, Victoria, Australia	11761441
Methylene blue dye	C16H18CIN3S	Piochem, Egypt	Me2750KSL3001



Figure 1 (a): A customized machine for simulation of tooth brushing, (b): Brushing cycles.

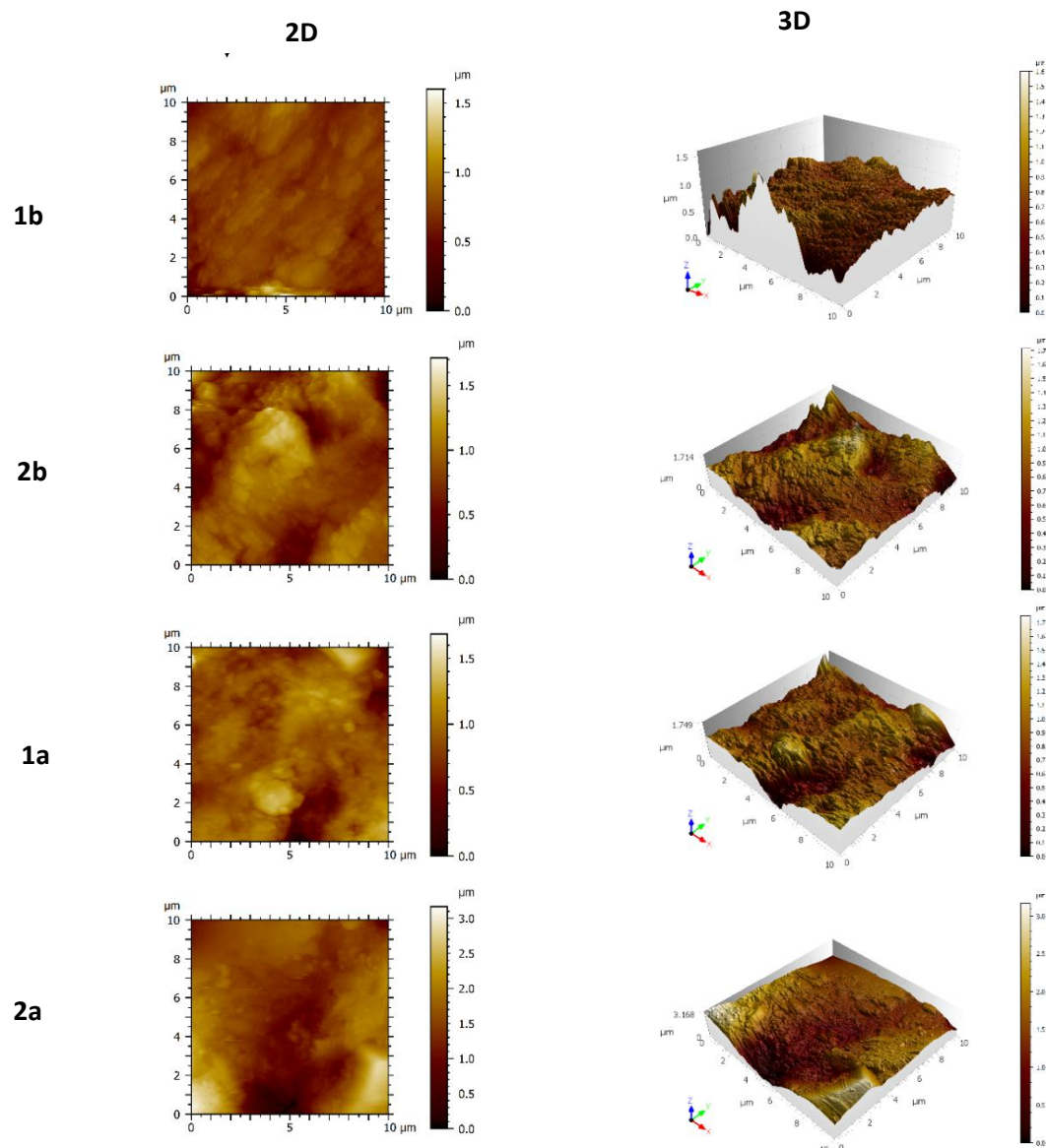


Figure 2: AFM 2D and 3D representation of the samples before and after tooth brushing on a magnification of $10 \mu \times 10 \mu$; (1b,2b) represent group 1 (zirconomer) and group 2 (Riva LC) respectively before brushing. (1a,2a) represent group 1 (zirconomer) and group 2 (Riva LC) respectively after brushing.

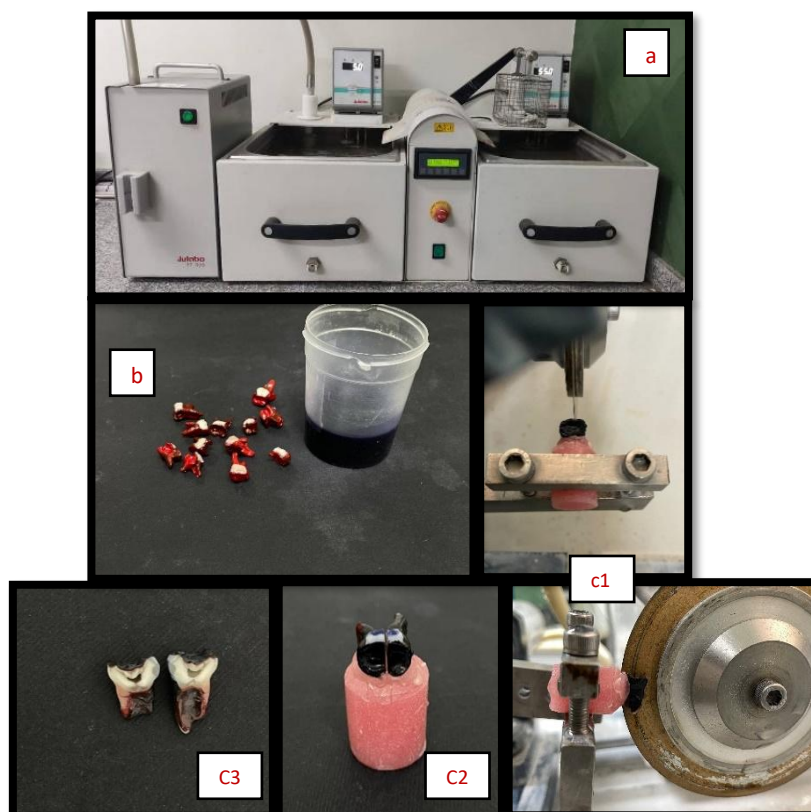


Figure 3 :(a): Thermocycling machine (b): Molars painted with nail varnish and ready to be immersed in methylene blue dye (c): c1 Molar inside the cutting machine, c2 Molar is sectioned bucco-lingually and c3 Two halves of the molar.

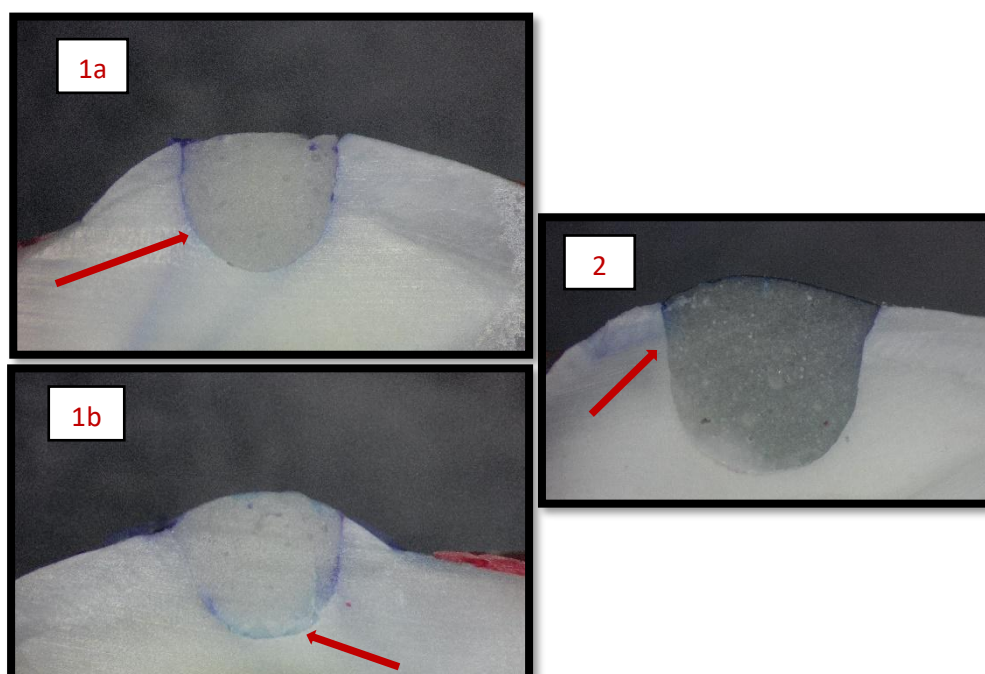


Figure 4: Stereomicroscope images of the bucco-lingual sections of the molars revealing the degree of dye penetration. (1a): score 2 in zirconomer group, (1b): score 4 in zirconomer group and (2): score 1 in Riva LC group.

III. Results

A. Surface Roughness

Regarding surface roughness, the results of the study revealed that before simulated tooth brushing: Zirconomer showed statistically significant lower surface roughness values than Riva LC with the values of (0.074 ± 0.01) and (0.21 ± 0.03) , respectively. After simulated tooth brushing: Zirconomer also showed statistically significant lower surface roughness values than Riva LC with the values of (0.17 ± 0.03) and (0.32 ± 0.05) , respectively. For both groups, there was a statistically insignificant difference between values of surface roughness before and after simulated tooth brushing. **Table (2) and Figure (5)**

B. Marginal Microleakage

Regarding the gingival margin microleakage scores for both groups, there was a statistically significant difference between them ($P=0.024$), as the highest microleakage score percentage in Zirconomer group was score 2 (41.70%),

followed by score 1 and 3, each represented (25%) while score 4 represented only (8.30%) and none of the samples scored 0. In Riva LC group, the highest score percentage was score 1 (83.30%), followed by score 2 and 4, each represented (8.30 %), and none of the samples scored 0 or 3.

Regarding the occlusal margin microleakage scores, there was a statistically insignificant difference between them ($P=0.35$). The highest microleakage score in Zirconomer group was score 1 (41.7%), followed by score 2 (33.3%), score 4 (16.7%) while score 3 represent only (8.3%) and none of the samples scored 0. In Riva LC group the highest score was score 1 (75%), followed by score 2, 3 and 4 each represented (8.3 %) and none of the samples scored 0.

Moreover, the mean score in Zirconomer group was (2.00 ± 1.13) while in Riva LC group was (1.5 ± 1.01) . Comparison between mean scores in both groups revealed insignificant difference ($P=0.26$). **Table (3) and Figure (6)**

Table (2): Comparison between group 1(Zirconomer) and group 2 (Riva LC) regarding surface roughness before, after, and difference between before and after simulated tooth brushing:

	Group 1		Group 2		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
	M	SD	M	SD			Lower limit	Upper limit	
Before	0.074	0.014	0.215	0.034	0.141	0.014	-0.171	-0.111	0.0001*
After	0.174	0.036	0.328	0.050	0.153	0.023	-0.204	-0.103	0.0001*
Difference	0.100	0.045	0.113	0.039	0.013	0.022	-0.062	0.036	0.586

*Significant difference as $P<0.05$.

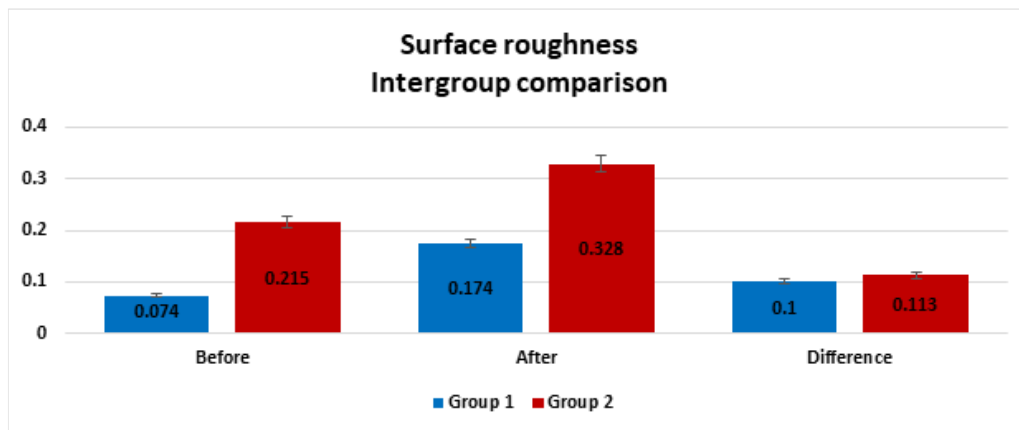


Figure (5): bar chart representing Comparison between group 1(Zirconomer) and group 2 (Riva LC) regarding surface roughness before and after simulated tooth brushing.

Table (3): Comparison between Microleakage scoring in gingival and occlusal margin in group 1 (Zirconomer) and 2 (Riva LC):

Microleakage	Gingival				P value	occlusal				P value
	Group 1		Group 2			Group 1		Group 2		
	N	%	N	%		N	%	N	%	
Score 0	0	0%	0	0%	0.024*	0	0%	0	0%	0.35
Score 1	3	25.00%	10	83.30%		5	41.7%	9	75.0%	
Score 2	5	41.70%	1	8.30%		4	33.3%	1	8.3%	
Score 3	3	25.00%	0	0.00%		1	8.3%	1	8.3%	
Score 4	1	8.30%	1	8.30%		2	16.7%	1	8.3%	
M ± SD	2.16	0.93	1.33	0.88	0.03*	2	1.13	1.5	1.01	0.26

*Significant difference as $P < 0.05$.

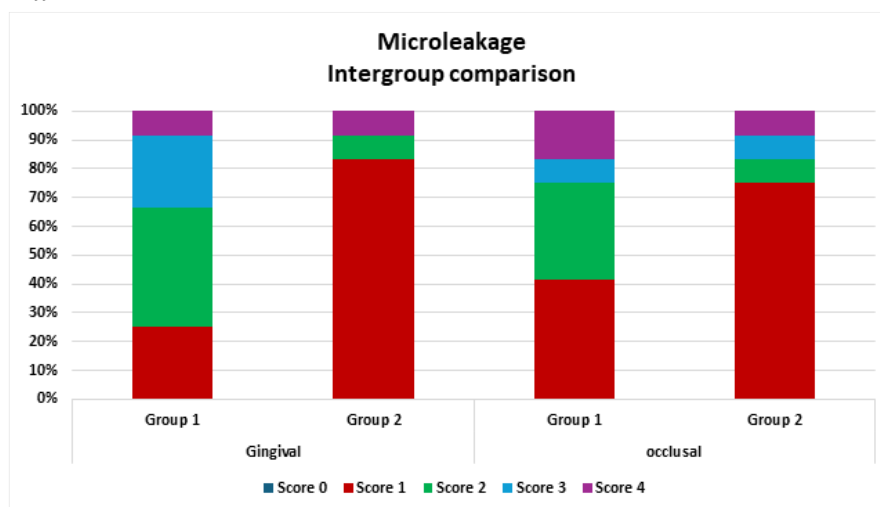


Figure (6): Stacked bar chart representing different microleakage scores in group 1 (Zirconomer) and 2 (Riva LC).

IV. Discussion

This study aimed to assess and compare the surface roughness and the marginal microleakage of Zirconomer and Riva LC, since these two properties are principal factors affecting the durability of a restoration (*Goldstein et al. 2017*).

Simulated tooth brushing was the technique employed in the present study to evaluate surface roughness, since it is proven that the use of a brush and abrasive toothpaste results in inevitable changes in the restoration, and plays a role in surface roughness observed in dental materials. The automated tooth brushing simulator used in our study helped in delivering a uniform force and standardizes the brushing frequency, load and motions, to ensure maximum accuracy. The number of strokes and the constant applied load of brushing was calculated from a previous observational study on the tooth brushing habits (*Dudás, Forgó & Kerekes-Máthé 2017; Sarangadharan et al. 2023*).

The atomic force microscopy (AFM) was used to assess the changes occurred in the restoration surface characteristics after simulated tooth brushing procedure. It provides a three-dimensional (3D) visualization of the surface topography, and provides imaging at a nanometric resolution, without altering the surface of the sample (*Kumari, Bhat & Bansal 2016; Mei & Guan 2023*).

Regarding the microleakage assessment, like several previous studies (*Saini et al. 2020; Shrikant P et al. 2020*), the current study employed dye penetration evaluation method under stereomicroscope to assess the microleakage due to its simplicity, cost effectiveness and fast results obtained from it. Methylene blue dye, in particular, was chosen since it is the most used organic dye in microleakage assessment studies. It has a low molecular weight which enables it to penetrate through small gaps, and it is easily visualized and accurately recorded under the microscope.

Moreover, like previous studies (*Bonilla et al. 2012; Gupta et al. 2012; Morresi et al. 2014; Saini*

et al. 2020; Shrikant P et al. 2020), thermocycling was the technique of choice used for the microleakage assessment simulating temperature variability taking place in the oral cavity. Thermocycling is basically employed to artificially age the restorations, as it stresses the cavity restoration interface, to test the sealing ability of the restoration (*Agarwal et al. 2019*).

The results of the present study indicated that the Zirconomer group exhibited statistically significant lower mean surface roughness values before and after simulated toothbrushing procedure, as compared to the mean values obtained from Riva LC group. These findings come in agreement with a previous study (*Khalid Aljandan et al. 2019*), which also showed lower mean surface roughness values of zirconomer compared to Equia forte fil/Equia forte coat, after being subjected to simulated tooth brushing.

The explanation of this as suggested by *Khalid Aljandan et al. 2019*, could be attributed to the resistance offered by zirconia particles in the structure of Zirconomer, which decreased the degradation of the material. Also, the size of the lost filler from the surface of the restoration after being subjected to brushing motions could influence the surface roughness; the larger the size, the greater the degree of roughness recorded. The nano structure of zirconia filler would leave smaller spaces and therefore less roughness will be observed.

In contrast to the results of the present study, several studies (*Asafarlal 2017; Sharafeddin & Bahrani 2021*) reported higher surface roughness values of zirconomer in comparison to RMGI, conventional glass ionomer cement and other restorative materials. The explanation of the different findings may be related to the different methodology performed to the tested materials before obtaining surface roughness values.

Regarding microleakage, recorded scores at gingival and occlusal margins were statistically analyzed and the results revealed that the Zirconomer group exhibited statistically significant higher microleakage scores at the

gingival margin, as the highest scores recorded were score 2 (41.7%), as compared to score 1 (83.3%) recorded in Riva LC. On the other hand, at the occlusal margin, the highest score recorded in both Zirconomer and Riva LC groups was score 1 (41.7%) and (75%) respectively.

These findings come in agreement with several previous studies (*Asafarlal 2017; Salman et al. 2019; Patil & Winnier 2021; Kumari & Singh 2022; Sardana, Kumar & Taneja 2022; Aly et al. 2023; Baskar, Hari & Anirudhan 2023*), in which higher microleakage values in Zirconomer compared to RMGI and other different tested materials were reported.

Salman et al. 2019 and Aly et al. 2023 explained the higher microleakage values in Zirconomer by the fact that the ceramic particles (zirconia filler) present in its structure resulted in poor adaptation of the restoration to the tooth surface. Another possible explanation is that zirconia would interfere with the chelating reaction that takes place between the carboxylic group (-COOH) in polyacrylic acid structure and the calcium ions (Ca^{++}) present in tooth structure.

In disagreement to the results of the present study, **Dhivya et al. (2022)** reported lower microleakage values for zirconomer compared to Cention N and Equiaforte. Also, **Walia et al. 2016; Albeshti & Shahid 2018**, stated similar results. This disagreement could be attributed to the different teeth samples included in the formerly mentioned studies; as they tested the materials on permeant molars, while in the present study, primary teeth were tested exclusively. The conditions during preparation for microleakage evaluation may have differed according to that.

The limitations of this study include being conducted in a controlled laboratory setting with a limited number of samples, while the oral cavity is a dynamic environment, with multiple factors influencing the performance of a restorative material. Being an in vitro investigation, the results of the study could not wholly predict the performance of the restorations tested. Future in vivo studies are necessary to reach a conclusion about the performance of the material.

V. Conclusion

Zirconomer exhibited lower surface roughness values before and after simulated tooth brushing than Riva LC. On the other hand, Zirconomer exhibited higher mean microleakage scores than Riva LC, which could be related to its chemical structure, and its bonding mechanism to the tooth surface.

Conflict of Interest:

The authors declare no conflict of interest.

Funding:

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Ethics:

This study protocol was approved by the ethical committee of the faculty of dentistry- Cairo university on: 28/3 /2023, approval number: 14-3-23

Data Availability:

Data will be available upon request

Credit Statement:

Author 1: Data curation, Writing - original draft, Methodology, Conceptualization, Resources.

Author 2: Data curation, Conceptualization, Project administration, Supervision, Methodology, Writing - review & editing.

Author 3: Methodology, Writing - review & editing, Supervision, Investigation, Formal analysis, Data curation.

VI. References

1. **Agarwal, N, Jabin, Z, Anand, A, Kalita, S & Kamble, A** 2019, 'A Comparative evaluation of different techniques for microleakage reduction of zirconomer restorations in primary teeth', *International Journal of Dental Science and Innovative Research (IJDSIR)*, vol. 2, no. 6, pp. 686–693

2. **Alsari, A, Ghilotti, J, Sanz, JL, Llena, C, Folguera, S & Melo, M** 2024, 'Comparative Evaluation of the Microleakage of Glass Ionomers as Restorative Materials: A Systematic Review of In Vitro Studies', *Applied Sciences* 2024, Vol. 14, Page 1729, vol. 14, no. 5, p. 1729.
3. **Aly, H, Samaha, AW, Abdel Kader, S & Zeitoun, S** 2023, 'MICROLEAKAGE AND SHEAR BOND STRENGTH EVALUATION OF ZIRCONIA REINFORCED GLASS IONOMER RESTORATIVE IN PRIMARY MOLARS (IN VITRO STUDY)', *Alexandria Dental Journal*, vol. 47, no. 4, pp. 39–39.
4. **American Academy of Pediatric Dentistry** 2023, 'Pediatric Restorative Dentistry', pp. 443–56.
5. **Anthonappa, RP & King, NM** 2019, 'Oral and Dental Manifestations in Noonan Syndrome', in A Bhangoo (ed.), *Noonan Syndrome: Characteristics and Interventions*, Academic Press, pp. 135–158.
6. **Asafarlal, S** 2017, 'Comparative Evaluation of Microleakage, Surface Roughness and Hardness of Three Glass Ionomer Cements – Zirconomer, Fujii IX Extra GC and Ketac Molar: An In Vitro Study', *Dentistry*, vol. 7, no. 5.
7. **Bajabaa, S, Balbaid, S, Taleb, M, Islam, L, Elharazeen, S & Alagha, E** 2021, 'Microleakage Evaluation in Class V Cavities Restored with Five Different Resin Composites: In vitro Dye Leakage Study', *Clinical, Cosmetic and Investigational Dentistry*, vol. 13, pp. 405–411.
8. **Baskar, H, Hari, A & Anirudhan, S** 2023, 'Comparative evaluation of flexural strength, modulus of elasticity, and microleakage of three different glass ionomer restorative materials in Class V preparations – An In vitro study', *Indian Journal of Dental Sciences*, vol. 15, no. 2, p. 67.
9. **Bonilla, E, Stevenson, R, Caputo, A & White, S** 2012, 'Microleakage Resistance of Minimally Invasive Class I Flowable Composite Restorations', *Operative Dentistry*, vol. 37, no. 3, pp. 290–298.
10. **Dhivya, S, Vasanthakumari, A, Selvabalaji, A, Archana, SP, Anagha, C & Kumar, K** 2022, 'Comparative Evaluation of Microleakage of Three Different Restorative Materials (Cention N, Zirconomer Improved and Glass Hybrid Restorative System) in Class V Cavity Restoration Using Stereomicroscope: In vitro Study', *Journal of Pharmaceutical Research International*, pp. 34–42.
11. **Faul, F, Erdfelder, E, Lang, A-G & Buchner, A** 2007, 'G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences', *Behavior Research Methods*, vol. 39, no. 2, pp. 175–191.
12. **Gadallah, LK, Safwat, EM, Saleh, RS, Azab, SM & Azab, MM** 2023, 'Effect of silver diamine fluoride/potassium iodide treatment on the prevention of dental erosion in primary teeth: an in vitro study', *BDJ Open*, vol. 9, no.

13. Gerberding, JL, Director Dixie Snider, ME, Chu, SY, Thacker, SB, Ward, JW, Hewitt, SM, ... Erica Shaver, MR 2003, 'Dental Health-Care Settings-2003', *MMWR*, vol. 52, no. 17.
14. Goldstein, RE, Lamba, S, Lawson, NC, Beck, P, Oster, RA & Burgess, JO 2017, 'Microleakage around Class V Composite Restorations after Ultrasonic Scaling and Sonic Toothbrushing around their Margin', *Journal of Esthetic and Restorative Dentistry*, vol. 29, no. 1, pp. 41–48.
15. Gupta, S, Gupta, J, Saraswathi, V, Ballal, V & Acharya, S 2012, 'Comparative evaluation of microleakage in Class V cavities using various glass ionomer cements: An in vitro study', *Journal of Interdisciplinary Dentistry*, vol. 2, no. 3, p. 164.
16. Khalid Aljandan, J, Mohammad Algarzai, R, Mongith Alammar, S, Ayad, NM & Bahgat, HA 2019, 'Evaluation of Surface Hardness and Surface Roughness of Different Nano Glass Ionomer Restorative Materials', *Saudi Journal of Oral and Dental Research*, vol. 4, no. 8, pp. 543–554.
17. Komalsingsakul, A, Srisatjaluk, RL & Senawongse, P 2022, 'Effect of brushing on surface roughness, fluoride release, and biofilm formation with different tooth-colored materials', *Journal of Dental Sciences*, vol. 17, no. 1, pp. 389–398.
18. Komandla, DR, Acharya, SR & Pentapati, KC 2021, 'Comparative evaluation of surface roughness of resin-modified glass ionomer and glass hybrid restorative materials simulated by tooth brushing: An in-vitro study', *Pesquisa Brasileira Em Odontopediatria e Clinica Integrada*, vol. 21, no. 259, pp. 1–8.
19. Kumari, Cm, Bhat, Km & Bansal, R 2016, 'Evaluation of surface roughness of different restorative composites after polishing using atomic force microscopy', *Journal of Conservative Dentistry*, vol. 19, no. 1, p. 56.
20. Manisha, S, Shetty, SS, Mehta, V, SA, R & Meto, A 2023, 'A Comprehensive Evaluation of Zirconia-Reinforced Glass Ionomer Cement's Effectiveness in Dental Caries: A Systematic Review and Network Meta-Analysis', *Dentistry Journal*, vol. 11, no. 9.
21. Mei, L & Guan, G 2023, 'Profilometry and atomic force microscopy for surface characterization', *Nano TransMed*, vol. 2, no. 1, p. e9130017.
22. Opydo-Szymaczek, J, Borysewicz-Lewicka, M, Andrysiak, K, Witkowska, Z, Hoffmann-Przybylska, A, Przybylski, P, ... Gerreth, K 2021, 'Clinical Consequences of Dental Caries, Parents' Perception of Child's Oral Health and Attitudes towards Dental Visits in a Population of 7-Year-Old Children', *International Journal of Environmental Research and Public Health*, vol. 18, no. 11, p. 5844.
23. Saini, S, Chauhan, A, Butail, A & Rana, S 2020, 'Evaluation of Marginal Microleakage and Depth of Penetration of Different Materials Used as Pit and Fissure Sealants: An In Vitro Study', *International Journal of Clinical Pediatric Dentistry*, vol. 13, no. 1, pp. 38–4

24. **Salman, KM, Naik, SB, Kumar, NK, Merwade, S, Brigit, B & Jalan, R** 2019, 'Comparative evaluation of microleakage in Class V cavities restored with giomer, resin-modified glass ionomer, zirconomer and nano-ionomer: An *In vitro* study', *Journal of the International Clinical Dental Research Organization*, vol. 11, no. 1, p. 20.
25. **Sapkale, K, Sane, R, Abrar, S & Ahmed, B** 2018, 'Comparative Evaluation of Dentin Bond Strength of Zirconomer, Conventional Glass Ionomer Cement, and Resin-Modified Glass Ionomer Cement-An in Vitro Study', *International Journal of Science and Research*.
26. **Sarangadharan, V, Priya, VV, Somasundaram, J, R, Gayathri & Kavitha.S** 2023, 'Evaluation of Surface Roughness of Teeth Post Brushing Simulation with Different Commercially Available Ultrasoft Toothbrush', *HIV Nursing*, vol. 23, no. 3, pp. 146–156.
27. **Sharafeddin, F & Bahrani, S** 2021, 'Effect of Hydroxyapatite on Surface Roughness of Zirconomer, and Conventional and Resin-Modified Glass Ionomers', *Frontiers in Dentistry*.
28. **Shetty Chitharanjan M, Sadananda Vandana & Hegde Mithra Nidarsh** 2017, '(PDF) Comparative Evaluation of Compressive Strength of Ketac Molar, Zirconomer, and Zirconomer Improved', *Scholars Journal of Dental Sciences (SJDS)*, vol. 4, no. 6, pp. 259–261.
29. **Shrikant P, Ankita P, Nihar RN, Shweta B, Keyura Parakh & Gagan M** 2020, 'An In-Vitro Stereomicroscopic Evaluation of Microleakage in Class II Open-Sandwich Restorations Using Resin Modified Glass Ionomer Cement & Zirconomer', *European Journal of Molecular & Clinical Medicine*, vol. 7, no. 11, pp. 8516–8524.
30. **Walia, R, Jasuja, P, Verma, K, Juneja, S, Mathur, A & Ahuja, L** 2016, 'A comparative evaluation of microleakage and compressive strength of Ketac Molar, Giomer, Zirconomer, and Ceram-x: An in vitro study', *Journal of Indian Society of Pedodontics and Preventive Dentistry*, vol. 34, no. 3, p. 280.