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ORIGINAL RESEARCH

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The evaluation of the effects of saliva contamination on microhardness and fracture strength of different aged restorative materials

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Abstract

Background: This research aimed to investigate the effects of saliva contamination on the microhardness and fracture strength of different types of aged restorative materials under *in vitro* conditions. **Methods**: 90 samples assigned to compomer, glass hybrid restorative (GHR), and conventional glass ionomer restoratives (CGIR) were prepared using round-shaped molds (diameter: 6 mm, depth: 2 mm). Samples in main groups were subdivided to simulate a saliva-contaminated (n = 15) and non-contaminated conditions/cases (n = 15). In saliva-contaminated subgroups, artificial saliva solution was applied to all surfaces of the molds, and restorative materials were placed. All samples were thermocycled with a temperature of 5–55 °C, 30 seconds dwell time and 5000 cycles for aging. The surface hardness and then fracture strength were measured and recorded. Statistical tests were performed with Kruskal-Wallis-H and Mann-Whitney U tests. The significance level was set at 0.05. **Results**: In both saliva-contaminated and non-saliva-contaminated samples, glass hybrid restorative showed the highest microhardness, while compomer provided the best fracture strength ($p < 0.05$). For compomer material, no significant difference was found in terms of hardness and fracture strength between saliva-contaminated and non-contaminated samples ($p > 0.05$). For glass hybrid restorative material, non-saliva contaminated samples showed significantly higher fracture strength ($p < 0.05$). In conventional glass ionomer material, non-saliva contaminated samples showed significantly higher microhardness values ($p < 0.05$). **Conclusions**: Within the limitations of this study, it is recommended that saliva contamination be prevented as much as possible in order not to adversely affect the fracture strength in glass hybrid restorations and microhardness values in conventional glass ionomer restorations.

Keywords

Compomer; Conventional glass ionomer; Fracture strength; Glass hybrid restorative; Microhardness; Saliva contamination

1. Introduction

Restorative treatments are part of a comprehensive oral health treatment plan, and this field is always available for updates due to the constantly evolving nature of dental materials science [1, 2]. However, some undesirable situations can negatively affect the clinical success of restorative treatments [3, 4]. In restorative treatment procedures, contamination of the operative field with saliva and/or other fluids is a negative factor for achieving a successful dental restoration [4–7]. Therefore, the placement of the filling material in the prepared cavity or its application to the tooth surface should be performed in a moisture-free environment. However, in a clinical operative scenario, this is mostly a challenge for clinicians [7, 8]. There are some clinical recommendations to prevent saliva and blood contamination of the restorative field. The most cost-effective of these is the use of rubber dams, which provide the dentist the ability to manage the contamination and focus on the restorative operation [4, 9]. However, despite all efforts, salivary contamination cannot be prevented and remains a major clinical problem for clinicians [7, 8, 10, 11].

Recent advances in the field of dental restorative materials follow changes that embrace the principles of evidence-based dentistry and minimal interventional dentistry [2]. However, despite all the advances and developments *involving* restorative materials, the clinical application procedures of these materials are highly sensitive. Regarding that, salivary contamination, which is one of the challenge factors, has adverse effects on the material and tooth-material integrity [7, 8]. Composite resins, one of the most widely used forms of restorative dental materials in dentistry, are often preferred

by clinicians, even though their bond strength decreases dramatically when contaminated with saliva [2, 4]. Similarly, contamination of glass ionomer restoratives with moisture at the initial stage of the setting reaction, especially if a coating material has not been applied, causes softening and cracking of the material surface and a decrease in fracture resistance [2, 4]. As mentioned, the negative effects of saliva contamination on setting reactions are frequently reported in the literature. Therefore, preventing saliva contamination is extremely important for clinical success. Otherwise, if saliva contamination cannot be prevented, the risk of microleakage and secondary caries increases, especially at the restoration margins and tooth-restoration interfaces, due to decreased bond strength of the restorations [3–8].

A comprehensive review of the dental literature reveals that the effects of salivary contamination on the bond strength values of restorations have been mostly investigated. On the other hand, it was also found that there is very limited data examining the effects of salivary contamination on the fracture strength and microhardness of restorative materials, especially in the field of pediatric dentistry. On the other hand, a certain number of studies have included artificially aged restorative materials. Based on this information, it is necessary to investigate to what extent the fracture resistance and microhardness of restorative materials are affected by salivary contamination due to the negative effects caused by salivary contamination. Therefore, this *in vitro* study intended to compare and investigate the effects of saliva contamination on the microhardness and fracture strength of different types of aged restorative materials under *in vitro*. The null hypothesis (H0) was that there would be no significant difference between restorative materials in terms of microhardness and fracture strength in saliva-contaminated and non-contaminated samples.

2. Materials and methods

2.1 Research design

This research was planned as an *in vitro* design *involving* the dental restorative material samples produced in the laboratory environment. Therefore, the present study has been performed by following the Checklist for Reporting *In-Vitro* Studies (CRIS) guidelines [12].

2.2 Sample size analysis

To analyze the statistical differences between the groups and subgroups included, a power calculation (by ZÖ) was performed using G*Power version 3.1.9.2 (Buchner, Erdfelder, Faul and Lang, Düsseldorf, NRW, Germany). This calculation revealed that a minimum of 30 tooth samples would be required for each main group (90% power and 5% type I error, effect size (f) = 0.7).

2.3 Definition of the study groups and subgroups

The study protocol consisted of three main groups of compomer (n = 30), glass hybrid (GHR) (n = 30) and conventional glass ionomer restoratives (CGIR) (n = 30). After that, each study group was divided into 2 subgroups as “saliva contaminated (n = 15)” and “non-saliva contaminated (n = 15)”. The study groups and subgroups were given below in detail.

Group 1: Dental restorative material samples in this group were produced using compomer material.

Group 1a: Saliva contaminated compomer samples.

Group 1b: Non-saliva contaminated compomer samples.

Group 2: Dental restorative material samples in this group were produced using GHR.

Group 2a: Saliva contaminated GHR samples.

Group 2b: Non-saliva contaminated GHR samples.

Group 3: Dental restorative material samples in this group were produced using CGIR.

Group 3a: Saliva contaminated CGIR samples.

Group 3b: Non-saliva contaminated CGIR samples.

The product information about the restorative materials is presented in Table 1 ([13]). Also, the composition of the artificial saliva is presented in Table 1.

2.4 Sample preparation and study procedure

The round metal molds with a diameter of 6 mm and a depth of 2 mm were used for sample preparation (Fig. 1a). Also, in saliva-contaminated subgroups, artificial saliva solution was applied to all surfaces of the molds using a microbrush, and then restorative materials were placed. Sample preparation in all groups was presented in detail below. All the restorative materials and clinical steps were applied in accordance with the manufacturer’s instructions (Fig. 1b).

Group 1a (n = 15) and 1b (n = 15)—Compomer (Dyract XP): For Group 1a, artificial saliva was applied to all the surfaces of the molds and compomer material was placed in the molds. However, artificial saliva was applied to the upper surface of the material with a microbrush without placing a strip on the material mass. The compomer was sealed with a transparent strip and pressed with a flat surface glass. After that, restorative material was light cured for 20 seconds, and prepared samples were finished and polished with polishing and finishing disks (Sof-Lex Discs, 3M ESPE, St. Paul, MN, USA). For Group 1b, these procedures were applied without simulating saliva contamination.

Group 2a (n = 15) and 2b (n = 15)—GHR (Equia Forte HT): For Group 2a, artificial saliva was applied to all the surfaces of the molds and GHR material was placed in the molds. However, artificial saliva was applied to the upper surface of the material with a microbrush without placing a strip on the material mass. GHR material was sealed with a transparent strip and pressed with a flat surface glass. After the setting time, prepared samples were finished and polished with polishing and finishing disks. After finishing procedures, Equia Forte Coat (GC America Inc., Alsip, IL, USA) was applied to specimen surfaces and light cured for 20 s. For Group 2b, these procedures were applied without simulating saliva contamination.

Group 3a (n = 15) and 3b (n = 15)—CGIR (Voco Ionofil Molar): For Group 3a, artificial saliva was applied to all the surfaces of the molds and CGIR material was placed in the

TABLE 1. Compositions of the restorative materials and artificial saliva solution used in this study.

Study Subgroup/s	Material Type	Trade Mark	Composition	Manufacturer
Group 1a and 1b	Compomer	Dyract XP	UDMA Strontium-fluoro-silicate glass, strontium fluoride, TCB resin, photoinitiator and stabilizers	Dentsply, DeTrey, Konstanz, Germany
Group 2a and 2b	Glass Hybrid Restorative System	Equia Forte® HT	Powder: fluoroaluminosilicate glass, polyacrylic, acid, iron oxide Liquid: polybasic carboxylic acid, water	GC Corporation, Tokyo, Japan
Group 3a and 3b	Conventional Glass Ionomer	Ionofil Molar	Water, pure polyacrylic acid, tartaric acid, aluminofluorosilicate glass and pigments	Voco, Cuxhaven, Germany
Group 1a, 2a and 3a	Artificial Saliva	N/A. Prepared by modifying the recipe of McKnight-Hanes and Whitford [13]	For 1 liter; pH: 7.0 Methyl-p-hydroxybenzoate (2.00 g) Sodium carboxymethyl cellulose (10.00 g) KCl (0.626 g) $MgCl_26H_2O$ (0.059 g) $CaCl_22H_2O$ (0.166 g) K_2HPO_4 (0.804 g) KH_2PO_4 (0.326 g)	N/A

N/A: Not applicable; UDMA: Urethane dimethacrylate; TCB: Carboxylic acid modified dimethacrylate; KCl: Potassium chloride; $MgCl_26H_2O$: Magnesium chloride hexahydrate; $CaCl_22H_2O$: Calcium chloride dihydrate; K_2HPO_4: Dibasic potassium phosphate; KH_2PO_4: Monobasic potassium phosphate.

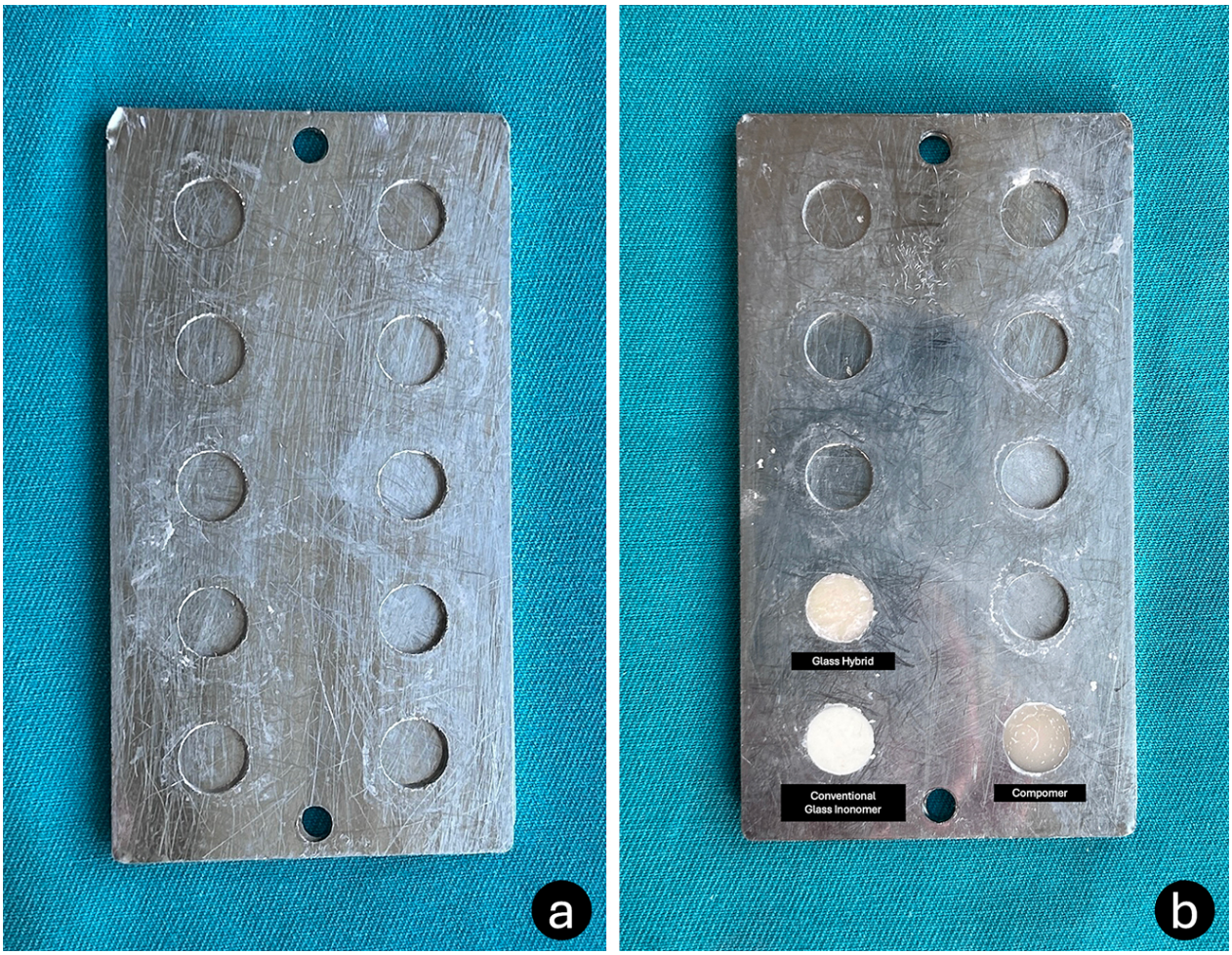

FIGURE 1. Metal molds used in this study (a) and prepared restorative material samples (b).

molds. However, artificial saliva was applied to the upper surface of the material with a microbrush without placing a strip on the material mass. CGIR material was sealed with a transparent strip and pressed with a flat surface glass. After 7 min, prepared samples were finished and polished with polishing and finishing disks. Then, Final Varnish LC (Voco, Cuxhaven, Germany) was applied to specimen surfaces and light cured for 10 s. For Group 3b, these procedures were applied without simulating saliva contamination.

2.5 Artificial aging procedures

Specimens belonging to all subgroups were stored in distilled water (at 37 °C) and thermocycled (SD Mechatronik GMBH, Feldkirchen-Westerham, Germany) for 5000 cycles in the water at 5 and 55 °C, with a 30 s dwell time (equal to approximately 500 days) [14].

2.6 Vickers microhardness test

The surface microhardness test was performed on the center of all the specimens using a Vickers microhardness tester (HVS-1000 Microhardness tester, Laryee Corporation, Beijing, China). Before the test procedures, the Vickers hardness tester was calibrated by the operators (AAD and AD), and a load of 100 gram was applied to the master samples and the margin of error was set to a maximum of 0.5%. To prepare smooth surfaces for indent placement, silicon carbide paper (with a grit size of 600) was used under the tap water. Subsequently, the test was performed by applying a pyramid-shaped diamond micro indenter (with 200 g—equivalent to 1961.4 mN—for a 20 s dwell time) (Fig. 2a). Then, the surface microhardness values were measured three times, and the mean value was calculated and recorded (in HV unit: N/mm^2).

2.7 Fracture strength test

Fracture strength of each specimen was tested by using a universal testing machine (Lloyd Instruments, LRX, Ametek, Fareham Hants, UK). Before the test procedures, the universal testing machine was calibrated by the operators (AAD and AD). A load of 100 N was applied to the master samples and the margin of error was set to a maximum of 0.05%. The stainless-steel bar (with a diameter of 4 mm) was located perpendicularly into the center of the disc-shaped specimen. The above-mentioned bar was adjusted to contact all the surfaces of the restorative discs simultaneously during the test period. The pressure of the device was set at 1 mm/min crosshead speed, and the fracture strength values were recorded in Newton units at the time of the first surface fracture observed (Fig. 2b). The fracture was observed visually. Afterwards, the presence of the fracture was confirmed with a stereomicroscope (Leica Microsystems GmbH, Leica MZ21, Wetzlar, HE, Germany).

2.8 Statistical analysis

Obtained data were analyzed using SPSS 22 software (IBM Corporation, Armonk, NY, USA). The data was analysed for normality with Shapiro-Wilk test. Since the data were not normally distributed, Kruskall-Wallis H test was used for three-group comparisons. The Mann-Whitney U test was used for two-group comparisons. A significance level of 0.05 was taken.

3. Results

According to the results obtained, in both saliva contaminated and non-saliva contaminated samples, the restorative material with the highest microhardness values (125.65 HV and 125.73 HV, respectively) was found to be GHR, while the material with the lowest microhardness values (53.16 HV and 62.00 HV, respectively) was found to be CGIR. Additionally, in both saliva contaminated and non-saliva contaminated samples, the restorative material with the highest fracture strength values (198.40 N and 204.08 N, respectively) was found to be compomer, while the material with the lowest fracture strength values (18.47 N and 24.24 N, respectively) was found to be CGIR. Saliva contamination caused a decrease in both surface microhardness and fracture strength values for all restorative materials included.

In the first part of the study results, the statistical comparisons between the restorative materials (in terms of microhardness and fracture strength) for both saliva contaminated, and non-saliva contaminated samples were given (Tables 2 and 3). Subsequently the statistical comparisons (in terms of microhardness and fracture strength) between saliva contaminated and non-saliva contaminated samples were given for each restorative material (Tables 4,5,6).

In saliva contaminated samples, a statistically significant difference was found between all the restorative materials in terms of microhardness and fracture strength values (p = 0.0001 and p = 0.0001, respectively). For all tested parameters, *post-hoc* tests were performed to determine between which two restorative materials there was a statistically significant difference. Accordingly, GHR material showed statistically significantly higher microhardness results than both the compomer and the CGIR material (p = 0.0030 and p = 0.0001, respectively). In addition, in terms of microhardness values, the compomer material showed higher microhardness values with a statistically significant difference than CGIR material (p = 0.0390) (Table 2). On the other hand, compomer showed statistically significantly higher fracture strength than both GHR and CGIR material in saliva contaminated samples (p = 0.0001 and p = 0.0001, respectively). In addition, in terms of fracture strength values, the GHR material showed higher microhardness results with a statistically significant difference than the CGIR material (p = 0.0130) (Table 2).

In non-saliva contaminated samples, a statistically significant difference was found between all the restorative materials in terms of microhardness and fracture strength values (p = 0.0001 and p = 0.0001, respectively). *Post-hoc* tests were performed to determine between which two restorative materials there was a statistically significant difference. Accordingly, GHR material showed statistically significantly higher microhardness results than both the compomer and the CGIR material (p = 0.0190 and p = 0.0001, respectively). Additionally, in terms of microhardness values, the compomer material showed higher microhardness values with a statistically significant difference than CGIR material (p = 0.0060) (Table 3). On the other hand, compomer showed statistically significantly

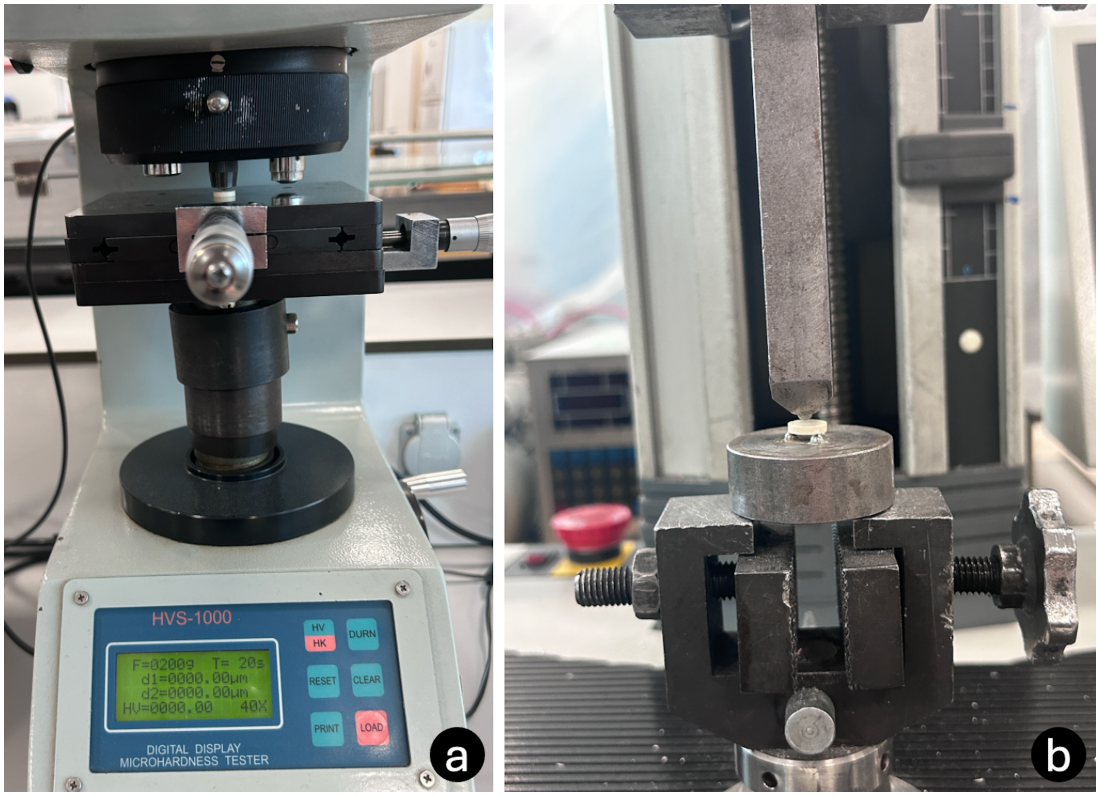

FIGURE 2. Vickers microhardness testing (a) and fracture strength testing (b).

TABLE 2. Statistical comparisons between the restorative materials in terms of microhardness and fracture strength for saliva contaminated samples.

Tested Parameters	Tested Subgroups	n	Mean	Median	Min	Max	SD	Kruskal-Wallis H Test		
								Mean Rank	χ^2	*p*	*Post-Hoc* Tests (Binary Comparisons)
Microhardness (HV)											
	Group 1a—Saliva contaminated Compomer	15	79.14	77.37	50.64	97.83	13.55	21.67	33.90	0.0001*	Groups 1a–2a: $p = 0.0030$* Groups 1a–3a: $p = 0.0390$* Groups 2a–3a: $p = 0.0001$*
	Group 2a—Saliva contaminated GHR	15	125.65	124.98	94.51	148.54	14.71	37.60			
	Group 3a—Saliva contaminated CGIR	15	53.16	47.94	37.02	115.85	19.26	9.73			
	Total	45	85.98	83.62	37.02	148.54	34.13	-			
Fracture Strength (N)											
	Group 1a—Saliva contaminated Compomer	15	198.40	187.07	94.98	320.64	71.29	38.00	30.40	0.0001*	Groups 1a–2a: $p = 0.0001$* Groups 1a–3a: $p = 0.0001$* Groups 2a–3a: $p = 0.0130$*
	Group 2a—Saliva contaminated GHR	15	31.50	23.68	3.61	80.28	21.99	18.00			
	Group 3a—Saliva contaminated CGIR	15	18.47	17.85	2.64	34.62	9.16	13.00			
	Total	45	82.79	34.62	2.64	320.64	93.07	-			

Min: Minimum; Max: Maximum; SD: Standard Deviation; χ^2: Chi-Square; p: Probability Value; GHR: Glass Hybrid Restorative; CGIR: Conventional Glass Ionomer Restorative.
**Indicates statistical significance.*

TABLE 3. Statistical comparisons between the restorative materials in terms of microhardness and fracture strength for non-saliva contaminated samples.

Tested Parameters	Tested Subgroups	n	Mean	Median	Min	Max	SD	Kruskal-Wallis H Test			
								Mean Rank	χ^2	*p*	*Post-Hoc* Tests (Binary Comparisons)
Microhardness (HV)											
	Group 1b—Non-saliva contaminated Compomer	15	87.77	89.22	76.77	96.80	6.09	23.53	33.8	0.0001*	Groups 1b–2b: *p* = 0.0190* Groups 1b–3b: *p* = 0.0060* Groups 2b–3b: *p* = 0.0001*
	Group 2b—Non-saliva contaminated GHR	15	125.73	131.37	70.76	151.73	20.84	36.67			
	Group 3b—Non-saliva contaminated CGIR	15	62.00	63.63	42.43	80.94	13.49	8.80			
	Total	45	91.83	86.33	42.43	151.73	32.15	-			
Fracture Strength (N)											
	Group 1b—Non-saliva contaminated Compomer	15	204.08	201.12	130.84	280.41	41.97	38.00	36.8	0.0001*	Groups 1b–2b: *p* = 0.0030* Groups 1b–3b: *p* = 0.0001* Groups 2b–3b: *p* = 0.0190*
	Group 2b—Non-saliva contaminated GHR	15	48.35	42.30	31.59	107.86	20.28	22.07			
	Group 3b—Non-saliva contaminated CGIR	15	24.24	27.79	4.14	45.19	11.09	8.93			
	Total	45	92.22	40.11	4.14	280.41	88.76	-			

Min: Minimum; Max: Maximum; SD: Standard Deviation; χ^2: Chi-Square; p: Probability Value; GHR: Glass Hybrid Restorative; CGIR: Conventional Glass Ionomer Restorative.
**Indicates statistical significance.*

TABLE 4. Statistical comparisons between the saliva contaminated and non-saliva contaminated samples in terms of microhardness and fracture strength for compomer material.

Tested Parameters	Tested Subgroups	Compomer						Mann-Whitney U Test		
		n	Mean	Median	Min	Max	SD	Mean Rank	U	*p*
Microhardness (HV)										
	Group 1a—Saliva contaminated Compomer	15	79.14	77.37	50.64	97.83	13.55	12.40	66	0.054
	Group 1b—Non-saliva contaminated Compomer	15	87.77	89.22	76.77	96.80	6.09	18.60		
	Total	30	83.46	86.33	50.64	97.83	11.22	-		
Fracture Strength (N)										
	Group 1a—Saliva contaminated Compomer	15	198.40	187.07	94.98	320.64	71.29	14.87	103	0.694
	Group 1b—Non-saliva contaminated Compomer	15	204.08	201.12	130.84	280.41	41.97	16.13		
	Total	30	201.24	188.70	94.98	320.64	57.55	-		

Min: Minimum; Max: Maximum; SD: Standart Deviation; p: Probability Value.

TABLE 5. Statistical comparisons between the saliva contaminated and non-saliva contaminated samples in terms of microhardness and fracture strength for GHR material.

Tested Parameters	Tested Subgroups	GHR						Mann-Whitney U Test	
		n	Mean	Median	Min	Max	SD	Mean Rank	U	*p*
Microhardness (HV)										
	Group 2a—Saliva contaminated GHR	15	125.65	124.98	94.51	148.54	14.71	15.17		
	Group 2b—Non-saliva contaminated GHR	15	125.73	131.37	70.76	151.73	20.84	15.83	107.5	0.836
	Total	30	125.69	126.56	70.76	151.73	17.72	-		
Fracture Strength (N)										
	Group 2a—Saliva contaminated GHR	15	31.50	23.68	3.61	80.28	21.99	12.20		
	Group 2b—Non-saliva contaminated GHR	15	48.35	42.30	31.59	107.86	20.28	18.80	63.0	0.041*
	Total	30	39.92	39.20	3.61	107.86	22.48	-		

Min: Minimum; Max: Maximum; SD: Standard Deviation; p: Probability Value; GHR: Glass Hybrid Restorative.
**Indicates statistical significance.*

TABLE 6. Statistical comparisons between the saliva contaminated and non-saliva contaminated samples in terms of microhardness and fracture strength for CGIR material.

Tested Parameters	Tested Subgroups	CGIR						Mann-Whitney U Test	
		n	Mean	Median	Min	Max	SD	Mean Rank	U	*p*
Microhardness (HV)										
	Group 3a—Saliva contaminated CGIR	15	53.16	47.94	37.02	115.85	19.26	11.67		
	Group 3b—Non-saliva contaminated CGIR	15	62.00	63.63	42.43	80.94	13.49	19.33	55	0.017*
	Total	30	57.58	51.14	37.02	115.85	16.94	-		
Fracture Strength (N)										
	Group 3a—Saliva contaminated CGIR	15	18.47	17.85	2.64	34.62	9.16	12.93		
	Group 3b—Non-saliva contaminated CGIR	15	24.24	27.79	4.14	45.19	11.09	18.07	74	0.111
	Total	30	21.36	22.31	2.64	45.19	10.42	-		

Min: Minimum; Max: Maximum; SD: Standard Deviation; p: Probability Value; CGIR: Conventional Glass Ionomer Restorative.
**Indicates statistical significance.*

higher fracture strength than both GHR and CGIR material (p = 0.0030 and p = 0.0001, respectively). Moreover, in terms of fracture strength, the GHR material showed higher microhardness results with a statistically significant difference than the CGIR material (p = 0.0190) (Table 3).

For the compomer material, in terms of microhardness values, no statistically significant difference was found between saliva contaminated and non-saliva contaminated samples (p = 0.054). Similarly, for the fracture strength values of the compomer, no statistically significant difference was found between saliva contaminated and non-saliva contaminated samples (p = 0.694) (Table 4).

For the GHR material, in terms of microhardness values, no statistically significant difference was found between saliva contaminated and non-saliva contaminated samples (p = 0.836). However, for the fracture strength values of the GHR, non-saliva contaminated samples showed statistically significant higher fracture strength than saliva contaminated samples (p = 0.041) (Table 5).

For the CGIR material, in terms of microhardness values, non-saliva contaminated samples showed statistically significant higher microhardness than saliva contaminated samples (p = 0.017). However, for the fracture strength values of CGIR, no statistically significant difference was found between saliva contaminated and non-saliva contaminated samples (p = 0.111) (Table 6).

4. Discussion

Primary teeth are essential for the growth and development process, and every effort should be performed to keep primary teeth in the mouth as much as possible until the physiological

exfoliation in pediatric dental patients [2, 15, 16]. Restorative treatments and dental fillings are mostly applied to restore the integrity of the dental structure, reduce the pain caused by dental caries, and help control the oral diseases. However, intraoperative fluid contamination is an important clinical problem in restorative pediatric dentistry [4, 17–19]. Saliva contamination has negative effects on the longevity of the restoration and can lead to post-operative sensitivity, discoloration and ultimately loss of the restoration [20, 21].

This paper included both statistical comparisons between the restorative materials in saliva contaminated and non-saliva contaminated samples and statistical comparisons between saliva contaminated and non-saliva contaminated samples for each restorative material. Accordingly, the null hypothesis that there are no differences among the restorative materials included regarding microhardness and fracture strength was rejected. As a general finding, regardless of statistical comparisons, saliva contamination caused a decrease in both microhardness and fracture strength values in all restorative materials included. Although there were methodological differences and similar parameters have not been evaluated, many authors and previous studies have stated that the success of restorations decreases with saliva contamination as in the present study [2, 4, 7, 17, 19]. Chaudhari *et al.* [19] reported that saliva contamination acted as a major factor in reducing the shear bond strength of the bonding agent. Also, the authors emphasized that it was necessary to provide adequate steps to eliminate or minimize the saliva contamination. Researchers have reported that saliva reduces the bond strength of dentin adhesives due to its water content [21]. Also, Pashley *et al.* [22] reported that occlusion of open dentinal tubules by salivary proteins also decreases adhesion. Aidaros and Abdou [23] emphasized in their study that contamination with artificial saliva during the application of bulk-fill flowable resin composite reduces the compressive strength 1 month after photocuring rather than affecting the surface microhardness value. As can be concluded from the previous studies, it could be seen how saliva contamination affected bond strength, which is one of the most investigated parameters. However, there was limited data in the dentistry literature on how microhardness and fracture strength, which are the parameters investigated in the present study, were affected by saliva contamination.

In the second part of the present study, statistical comparisons were performed regarding the success of restorative materials in terms of both microhardness and fracture strength in saliva-contaminated and non-saliva-contaminated specimens. Accordingly, in both saliva contaminated and non-saliva contaminated samples, GHR was found to be the material with the highest microhardness value, and the material with the lowest microhardness values was determined as CGIR. The surface of the GHR material used in this study was coated with the nano-filled resin coating (Equia Forte Coat) recommended by its manufacturer after the sample preparation stage. Indeed, Handoko *et al.* [24] stated that nano-filled resin coat significantly improved the surface hardness of EQUIA Forte restorative material in their study. Similarly, Alqasabi *et al.* [25] stated for their study that applying EQUIA® Forte Coat resulted in the highest hardness compared to that produced by other groups. Consequently, the GHR surface microhardness level in this study showed superior results compared to other materials even after saliva contamination. In the microhardness test, compomer showed significantly superior results than CGIR material.

Additionally, in both saliva contaminated and non-saliva contaminated specimens, compomer showed the highest fracture strength, and the material with the lowest fracture strength values was found to be CGIR. Although there were no available data examining the fracture strength of glass ionomer and resin-containing restorative materials, there were data on the fracture resistance of pediatric dental restorative materials in the literature. Demirel *et al.* [26] reported that for restorative materials placed in extracted tooth cavities after two different caries removal techniques, the fracture resistance of compomer was statistically significantly higher than that of glass ionomer-based (conventional and glass hybrid) restorative materials. On the other hand, similar to the present study, the authors emphasized that the glass hybrid restorative system showed higher fracture strength than conventional glass ionomer [26]. Similarly, Moshaverinia *et al.* [27] investigated the mechanical features of three glass ionomer systems and discovered that EQUIA Forte showed the highest hardness in comparison to Fuji IX GP and ChemFil Rock.

The present work had some positive aspects and study limitations. The fact that the specimens were artificially aged for approximately 500 days indicated the scientific strength of this study. In particular, it was attempted to mimic the intraoral use of restorative materials by predicting that the surface properties and fracture strength of aged specimens may change. Additionally, although artificial saliva was used, the same amount of this solution was applied to all the specimens included, demonstrating the standardization of the study methodology. In the case of natural saliva, standardization errors could have occurred due to the non-homogenization characteristics of the saliva fluid. On the other hand, the fact that the study was conducted under *in vitro* conditions is an important limitation of the study. Since both resin and glass ionomer-based restorative materials have bonding ability to enamel and dentin [16], it is recommended that the parameters tested in this study be further investigated on the extracted tooth samples or under prospective *in-vivo* conditions to confirm the results of this paper. On the other hand, the fact that this current study was carried out under *in-vitro* conditions prevented the physiological parameters and environmental alterations of the oral environment from being fully reflected in the methodology. Moreover, the dynamic structure of saliva, which changes even during the day in the real oral environment, was considered in an artificial form in this laboratory study. Therefore, the effects of artificial saliva on the properties of restorative materials frequently used in pediatric dentistry should be strengthened with more comprehensive further studies. In addition, microhardness and fracture resistance parameters were investigated under *in-vitro* conditions in this study, and it is quite important to consider other physical and biomechanical properties of restorative materials within the scope of further and comprehensive study designs. However, since we, as authors, predict that the unfavorable effects of salivary contamination on restorative

materials included in this study will also result in similar negative outcomes in the clinical success of the restorative materials, we contend that our findings should be confirmed by further clinical research.

In conclusion, it is recommended that saliva contamination be prevented as much as possible in order not to adversely affect the fracture strength in glass hybrid restorations and microhardness values in conventional glass ionomer restorations. Further and comprehensive *in vitro* and *in vivo* study designs are needed to confirm the results of this research.

5. Conclusions

Within the limitations of this study, since the saliva contamination caused a decrease in both surface microhardness and fracture strength values for all resin and glass ionomer-based restorative materials. On the other hand, the fracture strength of glass hybrid restorations and the microhardness of conventional glass ionomer restorations decreased significantly with saliva contamination.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

AD and ZÖ—conceived and designed the experiments; prepared the tables. AAD and AD—performed the *in-vitro* experiments. AAD, AD and ZÖ—analyzed the data; authored and reviewed drafts of the article; approved the final draft. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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