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IN VITRO EVALUATION OF WEAR RESISTANCE OF DIFFERENT FISSURE SEALANTS AFTER AGING PROCEDURES

Naglaa Ibrahim Ezz El-Din Soliman* *and* Mona Fadel Mohamed**

ABSTRACT

Objective: The purpose of this study is to evaluate the ability of unfilled resin based sealant (Clinpro), glass ionomer fissure sealants (Fuji Triage) and nanofilled resin based fissure sealant (Tetric N-Flow) to resist surface degradation using chewing simulator combined with thermocycling.

Methodology: A total of 30 disk shaped specimens were prepared, 10 disks for each material. Surface roughness (Ra) and weight loss were quantitatively measured after 2-body wear testing by using a chewing simulator integrated with thermocycling. Data were statistically analyzed using one-way ANOVA and Bonferroni's post-hoc test ($P \leq 0.05$)

Result: Both unfilled resin based sealant (RS) and glass ionomer fissure sealant (GI) showed statistically significant higher (Ra) than nanofilled resin based fissure sealant (NS) before aging procedure. After chewing simulator and thermocycling; there was no statistically significant difference between the (Ra) of three fissure sealant materials. As regard to weight loss (GI) showed the highest mean weight loss followed by (RS) while (NS) showed the lowest mean weight loss. ***Conclusion:*** nanofilled resin based fissure sealant showed good resistance to surface degradation compared to other sealants.

KEYWORDS: nanofilled resin based fissure sealant, glassionomer fissure sealant, surface roughness, weight loss.

INTRODUCTION

Although the prevalence of dental caries has decreased worldwide, the incidence of dental caries on the occlusal surface of posterior teeth is still increasing [1,2]. It represents 90% of the carious lesion occurring in the oral cavity [3]. This may be related to natural anatomy of pits and fissures providing protective shelters for food entrapment and bacterial colonization. In addition, good standards for oral hygiene including tooth brushing are not always fulfilled [4].

Different therapeutic interventions have been proposed for prevention of initial occlusal caries. These involving plaque control using tooth

* Lecturer of Pediatric and Community Dentistry department, Faculty of Dentistry, Modern Sciences and Arts University, Egypt.

** Lecturer of Conservative Dentistry department, Faculty of Dentistry, Modern Science and Arts University, Egypt.

brushing, mouth washes containing antibacterial or remineralizing agents, in addition to varnishes or pits and fissure sealants [5].

Application of sealants in pits and fissures is a non-invasive preventive measure used to arrest or protect against development of occlusal caries [6]. Materials used for occlusal sealing should provide proper marginal seal, antibacterial properties, proper retention in fissures and good penetration ability. The materials are either resin based or glass ionomer based sealants. Resin composite sealant show high retention rate to enamel and high mechanical properties compared to glass ionomer [5]. However its success is compromised when the operative field cannot be isolated as in permanent molars that are not fully erupted or primary molars in children. In such clinical situation, glass ionomer is highly recommended [7]. It does not require etching procedures prior to application which decrease the moisture sensitivity. In addition to the anticariogenic properties which resulted in great decrease in caries incidence even after the sealant disappeared microscopically [6].

These materials are subjected to different environmental conditions that might affect their success rate. During habitual chewing, wide ranges of masticatory load or high sudden impacts are exerted on dental materials [8], added to this the continuous change in the intraoral temperature from frequent eating and drinking [9]. These factors influence different parameters of physical and mechanical properties of restorative materials. The interaction that takes place on the surface of the dental materials with surrounding environment may cause the leaching out of some constituents that affect its surface hardness [10]. To be able to face these challenges, the dental materials are under continuous innovations. As for resin composite materials, the changes include alteration in filler volume, size, and shape or changes in the matrix composition [11]. Incorporating nanotechnology aided in the production of sealants with superior mechanical and physical properties compared to their earlier generations [12].

Therefore this study was conducted to evaluate the influence of different material composition on resisting surface degradation using chewing simulator combined with thermocycling.

MATERIALS AND METHODS

The fissure sealants materials tested in this study are listed in (table 1).

TABLE (1) The fissure sealants materials tested in this study.

Sealant name	**Composition**	**Manufacture**
Clinpro Lot: N676893	*BisGMA/TEGDMA, unfilled resin composition releasing fluoride	3M ESPE, USA
TetricN-Flow Lot: 604046	36 wt. % di methacrylate with TEGDMA, 63wt. % fillers (barium glass, ytterbium triflouride, high dispersed silica and mixed oxide) and 1wt. % catalysts, stabilizers and pigments. 39 vol. % inorganic fillers,the size of inorganic fillers is between 40 and 3000 nm.	IvoclarVivadent AG FL-9494 Schaan/Liechtenstien
GC Fuji Triage Lot: 1504142	Glassionomer, alimuno fluorosilicate glass, poly acrylic acid, distilled water and poly base carboxylic acid	GC Corporation, Tokyo, Jaban
* BisGMA: bisphenolglycidul methacrylate, TEGDMA:triethyleneglycoldimethacrylate.		

Specimen preparation

A total of 30 disk shaped specimens were prepared;10 disks for each material using Teflon mold with dimensions; 9mm in diameter and 3 mm in thickness,. The materials were handled according to the manufacturer's instructions then injected and packed into the mold slightly excessively. Mylar strip was then placed on the mold and followed by glass plate. A slight pressure was applied on the glass plate then the extruded excess was removed. Each specimen was cured according to the manufacturer's instructions using EliperLED curing light (3M ESPE, USA) with wave length range 430-480 nm and light intensity 1200 mW/cm^2 for 20 seconds. The samples were polished by aluminum oxide discs and stored in distilled water at 37˚C for 24 h in a dark environment (incubator).

Wear test

The 2-body wear testing was made by using a programmable controlled equipment that was conducted to four stations multimodal ROBOTA chewing simulator (figure 1) integrated with thermo-cyclic protocol operating on servo-motor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY)

The ROBOTA chewing simulator has four chambers applying simultaneous vertical and horizontal movements in thermodynamic condition. Each chamber consists of an upper Jackob's chuck acting as a holder for the antagonist which can be tightened to the chuck using a screw and a lower plastic sample holder containing a Teflon housing in which the specimen can be embedded.

In this study natural teeth were utilized as antagonist. 30 longitudinal sections of freshly extracted non carious human premolars were used. The premolars were extracted for orthodontic treatment then cleaned to remove tissue remnants and calculus using sharp hand scaler then stored in phosphate buffer saline containing 0.2% sodium azide at 4^0C to inhibit microbial growth for the maximum period of one month until being used.

A weight of 5 kg, which is comparable to 49 N of chewing force, was exerted on the specimens. The cyclic movements were repeated 75,000 times to be clinically equivalent to 6 months chewing condition, accompanying with thermocycling. The parameters for the wear test are presented in (table 2). The wear of the specimens was encountered by quantitatively detecting roughness and weight loss.

TABLE (2) Wear test parameters

Wear test parameters	
Cold/hot bath temperature: 5´/55´	Dwell time: 60 s
Vertical movement: 1 mm	Horizontal movement: 2 mm
Rising speed: 90 mm/s	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Cycle frequency 1.6 Hz	Weight per sample: from 5 kg
Torque; 2.4 N.m	

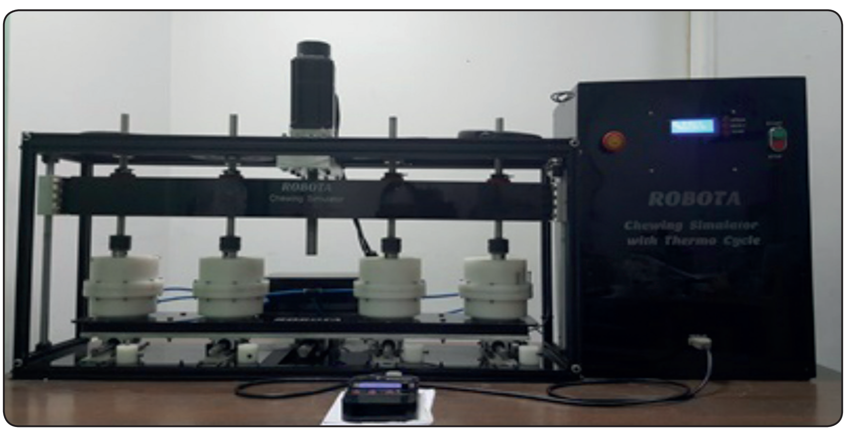

Fig. (1) ROBOTA chewing simulator

Roughness measurement

The optical profilometry was used for quantitative characterization of surface topography without contact. Quantitative analysis of two-body wear was made before and after loading in a 3D-surface analyzer system. Specimens were photographed using USB Digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) connected with an IBM compatible personal computer using a fixed magnification 120X.The images were saved using a resolution 1280 × 1024 pixel per image.

Then the digital microscope images were cropped to 350 x 400 pixels by using Microsoft office picture manager to specify and standardize area of roughness measurement.

The cropped images were tested by using WSxM software, all limits, sizes, frames and measured parameters were showed in pixels. Therefore, system calibration was applied to transfer the pixels into real world units. Calibration was performed by comparing an object of known size (a ruler in this study) with a scale formed by the software WSxM. The average of heights (Ra) was calculated by using software which expressed in µm, this can be supposed as a reliable indices of surface roughness. Subsequently, a 3D image of the surface profile of the specimens was made using a digital image analysis system (Image J 1.43U, National Institute of Health, USA). The unworn surface was used as a reference. With this method, a 3-dimensional geometry of the rough surface was created.

Wear measurement by weight loss

The substance loss of the specimens was measured by weighing in the electronic analytical balance (Sartorius, Biopharmaceutical and Laboratories, Germany) with an accuracy of 0.0001 gram to determine the difference in weight before and after 75,000 cycles. This electronic balance has an automated calibration technology and a micro weighing scale such that the values of all the mounted discs were accurately measured. Each disc was cleaned and dried with tissue paper before weighing. To ensure accuracy, the balance was placed on a free standing table at all times, away from vibrations. Then weighed the discs with the glass doors of the balance closed to avoid the effect of air drafts.

Statistical Analysis

Numerical results were tested for normality by testing the distribution of the results and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Surface roughness (Ra) results represented parametric distribution and weight loss data represented non-parametric distribution. Data were represented as mean, median, standard deviation (SD), minimum, maximum and 95% Confidence Interval (95% CI) for the mean values. For the parametric data; repeated measures ANOVA was used to check the effect of material and thermocycling on mean surface roughness. One-way ANOVA test was used to compare between changes in surface roughness of the three materials. Bonferroni's post-hoc test was used for pair-wise comparisons in case the ANOVA test is significant.

For non-parametric data, Kruskal-Wallis test was used for weight loss comparison between the three materials. Mann-Whitney U test with Bonferroni's adjustment was used for pair-wise comparisons in case the Kruskal-Wallis test is significant.

The significance level was set at $P \leq 0.05$. Statistical analysis was done with IBM[1]® SPSS[2]® Statistics Version 20 for Windows.

RESULTS

1) Surface roughness (Ra)

Regarding the effect of the fissure sealant materials, one- way ANOVA showed no statistically significant difference between unfilled resin based fissure sealant Clinpro (RS) and glass ionomer fissure sealant Fuji Triage (GI) before chewing simulator and thermocycling; both showed statistically significant higher mean surface roughness (Ra) than nano filled resin based fissure sealant Tetric N-Flow (NS).

After chewing simulator and thermocycling; there was no statistically significant difference between mean roughness (Ra) of three fissure sealant materials (table 3).

2) Weight loss

Glass ionomer sealant Fuji Triage (GI) showed the statistically significant highest mean weight loss, Clinpro unfilled resin based fissure sealant (RS) showed statistically significant lower mean value while nano filled resin based fissure sealant Tetric N-Flow (NS) showed the statistically significant lowest mean weight loss (table 4).

TABLE (3) The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between Ra (μm) of the three materials before and after thermocycling

Thermocycling	RS		NS		GI		*P*-value
	Mean	SD	Mean	SD	Mean	SD	
Before	0.2559 ^{A}	0.0007	0.2542 ^{B}	0.0017	0.2554 ^{A}	0.0013	0.016*
After	0.2553	0.0005	0.2542	0.0017	0.2554	0.0013	0.069

****: Significant at P ≤ 0.05, Different superscripts in the same row are statistically significantly different***

TABLE (4) Descriptive statistics and results of Kruskal-Wallis test for comparison between weight loss (g) of the three materials after thermocycling

Material	Mean	SD	Median	Minimum	Maximum	95% CI		*P*-value
						Lower bound	Upper bound	
RS	0.0063 ^{B}	0.0063	0.0050	0.0000	0.0150	0.0018	0.0108	<0.001*
NS	0.0018 ^{C}	0.0012	0.0017	0.0000	0.0033	0.0010	0.0027	
GI	0.0333 ^{A}	0.0198	0.0233	0.0183	0.0617	0.0192	0.0475	

****: Significant at P ≤ 0.05, Different superscripts in the same column are statistically significantly different***

DISCUSSION

Sealing of pits and fissures in permanent molars has proven to be effective in reducing caries incidence by 76% in two to three years follow up based on report released by American Dental Association council [13].

Different types of sealing materials are available in the market. The clinical performances of this material in oral cavity depend on many factors. The resistance of the material to wear is one of these factors. It determines the degree of surface roughness that paves the way for plaque retention which accelerates the risk for dental caries. Therefore in this study different types of resin and glass ionomer based sealers were tested for surface roughness using chewing simulator accompanied with thermocycling.

In this study, the surface roughness of specimens was measured using optical profilometry. It combines both optical technique and computer system to measure an area of surface roughness from the specimen in a non-contact mode [(14)]. In this in vitro wear test, the teeth were loaded at 49N chewing force as the normal chewing cycles expected to range from 49N to 150N [(15)]. The number of cycles 75000 was equivalent to 6 months since, 750000cycles were found to represent 5 clinical years [(16)].

Two types of resin based materials were used, unfilled resin sealant (Clinpro) and nano hybrid resin sealant (Tetric N-flow). The unfilled resin has great ability to penetrate pits and fissures related to its low viscosity, however they undergo abrasive wear due to low filler content [(17)]. In this study the roughness of unfilled resin showed higher score after finishing procedures. The smoothest surface of resin composite is mostly obtained using polyester matrix strip. However in clinical situation removal of premature contact or excess material at margins require proper finishing and polishing. This results in microcracks that contribute to roughness [(18)]. Moreover, during finishing procedure two body wear take place, where the abrasive discs causes the removal of the softer resin matrix increasing surface roughness.

During thermocycling, the resin composite is subjected to thermal changes in addition to water storage. This results in water sorption within the polymer matrix [(19)]. Water has a plasticizing effect causing the sliding movement of the polymerize chains together with the forces exerted during chewing cycles by natural antagonist; microcracks propagates and coalesce resulting in microploughing of composite in layers [(20)]. This result in regular wear pattern [(21)] which may explain the reduced roughness after aging procedure.

The recommended use of flowable resin composite as pits and fissure sealers may be related the drawback of unfilled resin mainly their low mechanical properties [(17)]. It is known that adding fillers to resin may contribute in improving the mechanical properties. However to maintain the fluidity of resin composite the filler content should be of 20%-25% compared to 50%-70% of the classical resin composite [(22)]. Based on nano-science the structure of the materials can be manipulated in nano scale where the size of fillers corresponds to 40 nm or 0.4 µm [(23)]. This allowed the increase in the filler load without affecting its viscosity. In this study, Tetric N-Flow showed 63% filler content according to the manufacturer; this would explain the non-significant change in surface roughness after chewing simulator with thermocycling. This was in agreement with Beun et al., [(17)], they compared different types of flowable composite and pits and fissure sealants (unfilled resin) regarding their viscosity and mechanical properties. They found that the filler content ranged from 45% for revolution formula and 77% for Grandio flow, while the unfilled resin Clinpro in cooperated only 6.5%. Correspondingly, the microhardness was highest for Grandio flow and lowest for Clinpro. Also in study performed by Karinzadeh et al.,[(24)] they showed no change in hardness of nanofilled composite after thermocycling. This was contradicted by Nathaniel and John, [(25)] as they showed that nanofilled composite with filler content higher than 25% showed higher surface roughness compared to those with lower filler content. They explained as the filler content increase, filler agglomeration takes place acting as flaws inducing cracks.

Several modifications have been adopted to improve the properties of glass ionomer. In this study, a resin free commercially available glass ionomer GC Fuji Triage was used. According to the manufacturer it has a high compressive strength 159 Mpa which even increases after one week to171Mpa. According to ISO standard the least possible compressive strength for glass ionomer should be 100 Mpa to be used as restorative cement [26]. Added to that, the surface hardness for Triage is higher than the hardness value recorded for nanofilled resin modified glass ionomer (Ketac N100) according to Bala et al., [27]. However the high hardness number doesn't mean greater wear resistance for dental materials. Reis et al. [28] showed that the particles size plays a crucial role in the roughness of the materials. The larger the particle size the rougher the surface. On the contrary Glady et al., [29] demonstrated that some glass ionomers with smaller particles size are 10 times rougher than those with larger particles size.

In this study glass ionomer sealant showed higher roughness after finishing and polishing compared to nanofilled resin sealant. However this roughness value didn't change after chewing procedure. This might be related to good surface properties of the tested glass ionomer sealant. El Lakuria et al., [30] showed no change in micro hardness of some glass ionomer cements after one year of storage in distilled water compared to resin modified glass ionomer cements. This was in contrary to Rios et al., [31] as they revealed high roughness in glass ionomer after simulated wear test which may be related to the different type of glass ionomer used in their study.

In dentistry, wear investigations can be performed by direct abrasive wear (two body or three body wear) with or without lubricant followed by weight loss measurement [32]. Regarding the weight loss, the three tested samples should significant weight loss in the following descending order; glass ionomer Fuji Triage, resin sealant Clinpro and nano sealant Tetric N-Flow. This was in agreement to other studies [33, 34] where the resin composite displayed lower weight loss compared to glass ionomer.

For glass ionomer; the significant weight loss might be related to the high fluoride release which is six times more than other sealants according to manufacturer. This high fluoride release was also shown in studies performed by Poggio et al., [35] and Markovic et al., [36]. Contrarily Galo et al., [37] showed no difference in weight loss between glass ionomer and resin sealant. They utilized resin modified glass ionomer and the number of loading cycles was lower compared to the present study.

After 24 hours of setting, glass ionomer constitute a polymatrix formed of calcium and aluminum surrounding unreacted glass particles as core and each particle is surrounded by silica sheet according to Wasson and Nichlson [38]. They also observed the presence of all the components of the unreacted glass fillers and large portion of silicon when glass ionomer is immersed in aqueous media. This might be justified that when water is absorbed through micro cracks or pores [39]; it reacts with filler matrix interface (siliceous gel) and release the aluminum and calcium ions in the glass particles [38]. This might also explain the significant weight loss in glass ionomer.

As for the resin composite sealants of both types; the cyclic change in temperature in hot and cold baths together with water storage causes hydrolysis of resin matrix which may release constituents of resin matrix causing weight loss [40].

In the nano hybrid resin composite; thermal stress can build up at the filler matrix interface due to difference in coefficient of thermal expansion and contraction. In addition water react with silane coupling agent causing its hydrolysis, these mechanisms together with mechanical wear can cause dislodgment of fillers and leaching out of resin matrix components [41].

However the reduction in weight for nanofilled sealant was significantly lower compared to other tested materials. This may be justified by the presence higher filler content with nano-reduced size. They are closely packed providing proper protection of the soft resin matrix against simulating aging conditions [39].

CONCLUSIONS

- Nanofilled resin based fissure sealant can be used as excellent alternative to unfilled resin based fissure sealant
- Although glass ionomer showed greater wear loss compared to other sealants, it presented good surface properties. Therefore it can be used as temporary alternative to resin based sealants when proper field isolation cannot be achieved.

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