ORIGINAL RESEARCH

Comparative Evaluation of Wear Strength and Compressive Strength of Two Pit and Fissure Sealants with a Nanofilled Resin Coating: An *In Vitro* Study

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Abstract

Introduction: The role of sealants for pits and fissures has been emphasized in caries prevention. Considering the advantages of a surface sealer and the effects of its application over restorative materials; the study is aimed at evaluating two pit and fissure sealants with a nanofilled resin coating.

Materials and methods: In this *in vitro* double-blinded study, a total of 60 caries-free extracted third molars were collected and divided into two groups of 30 each receiving either a resin-based sealant (Helioseal F) or a glass ionomer-based sealant (GC Fuji VII). Each sample was then applied with GCoat Plus surface sealer. 15 samples each containing GC Fuji VII and 15 containing Helioseal F were then subjected to wear. Another 15 samples of GC Fuji VII and 15 of Helioseal F were subjected to compressive load.

Results: On assessing the wear strength, the weight loss in group I (resin sealant with surface sealer) was 1.73 ± 0.50 (μg) which was statistically significant ($p = 0.023$). There was no significant difference in comparing the wear depth between both groups. There was a high statistically significant difference when assessing the compressive strength, group II (glass ionomer sealant with surface sealer) had 3566.4 ± 757 (μm) when compared to group I (resin sealant with surface sealer) 1568.53 ± 680 ($p \leq 0.01$).

Conclusion: Sealants are known for their poor retention and keeping that in mind we designed this study to evaluate the physical properties of sealants with a resin coating over them. Within the limitations of this study, the conclusions are glass ionomer sealant showed greater resistance to wear when compared to the resin-based sealant and the resin-based sealant showed higher compressive strength values than the glass ionomer sealant.

Keywords: Coating, Caries, Compressive strength, Nanofilled resin, Pit and fissure sealant, Wear strength.

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Introduction

Dental caries remains to be one of the most widespread diseases of mankind. Caries in children begins shortly after the eruption of deciduous teeth and continues to increase at a remarkable rate as age progresses.[1] Recently it has been reported that the prevalence of occlusal caries is 56–70% in children 5–17 years of age.[2]

The complex morphology of occlusal pits and fissures make them ideal sites for retention of food and microorganisms. The lack of access to saliva in these regions due to surface tension also plays a major role in preventing remineralization and reducing the effectiveness of topical fluorides. Considering all these factors and the rampant nature of caries into account, various preventive materials and techniques have been advocated.[3] Although fluoride has been widely used in prevention, it only delays the onset of caries in pits and fissures but fails to prevent it. Hence, applying sealants to pits and fissures has been emphasized.[4]

Resin sealants have been widely put into use due to their enhanced physical qualities, superior wettability, and low viscosity. However, polymerization shrinkage is a significant drawback of composite resin-based materials resulting in bacterial infiltration, microleakage, and restoration failure. Conversely, products made of glass ionomer can bond immediately to the enamel without surface etching. Numerous pieces of evidence have proved that glass ionomer sealants possess poor retention when compared to their resin counterparts.[3] This brings into discussion the emergence of a surface sealer to overcome this drawback of glass ionomer materials. Petroleum jelly, cocoa butter, and waterproof varnishes have been recommended as surface coating agents that act as barriers to the loss of water resulting in unaffected hardening and maturation.

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With time these coatings are lost due to oral masticatory wear, but during this period, the cement tends to become more resistant.

GCoat Plus was introduced by GC Corporation to be used along with glass ionomer cement to improve their physical properties. With this in mind, a novel technique was devised by us advocating the use of a surface sealer over a pit and fissure sealant to see if there is any improvement in their physical properties. Considering the advantages of a surface sealer and the effects of its application over restorative materials, this investigation attempts to assess the compressive strength and wear strength of two pit and fissure sealants along with a nanofilled resin coating over them.

Materials and Methods

This *in vitro* study was carried out in the Department of Pediatric and Preventive Dentistry, Faculty of Dentistry, Meenakshi Ammal Dental College. The study was approved by the Institutional Review Board of Faculty of Dentistry, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (declared as Deemed to be University under section 3 of the UGC Act 1956), Chennai with protocol number MADC/IRB–IX/2016/180.

A total of 60 noncarious teeth were selected from a pool of freshly extracted third molars which were indicated for extraction. The teeth were cleaned to remove soft tissue debris and calculus using an ultrasonic scaler with an attached surface scaler tip.

Methodology

Before the start of the experiment, the gathered samples were kept in distilled water. The samples were sectioned 2 mm below the cementoenamel junction (CEJ) using diamond disks attached to a straight handpiece on a micromotor.[12] The sectioned samples were mounted onto an acrylic resin base by means of a putty mold of 2 × 2 × 2 cm size.

The mounted samples were divided into two groups after randomization (Fig. 1):

- Group I**:** Resin sealant with surface sealer (*n* = 30).
- Group II**:** Glass ionomer sealant with surface sealer (*n* = 30).

The groups were further subdivided into two groups:

- Group IA**:** Wear strength (*n* = 15).
- Group IB**:** Compressive strength (*n* = 15).
- Group IIA**:** Wear strength (*n* = 15).
- Group IIB**:** Compressive strength (*n* = 15).

The study comprised the following steps:

- Preparation of the occlusal surface.
- Sealant application.
- Application of surface sealer.
- Thermocycling.
- Application of compressive load.
- Wear testing of the samples.

Sealant Application

Each sealant was applied onto the tooth surface by the use of a Teflon mold with a 3 mm diameter × 3 mm depth cavity in it.[12] Acid etching was done before the application of the resin-based sealant using 37% orthophosphoric acid for 30 seconds. In compliance with the instructions from the manufacturers, the sealants were applied. Light curing was done for 20 seconds using a light-emitting diode (LED) curing unit (woodpecker mini S) for the resin sealant.

Application of Surface Sealer

In compliance with the manufacturer's instructions, the sealants were coated with GCoat Plus and light-cured for a time of 20 seconds. Before testing, the samples were kept for 48 hours at room temperature in distilled water.

Thermocycling

The specimens underwent 500 cycles of thermocycling at 5–55 ± 2° C with dwell times of 15 seconds and transfer times of 10 seconds. The specimens were once more kept in distilled water until testing following thermocycling.[18]

Application of Compressive Load

The samples to be tested for compressive strength were mounted onto the lower holding jig of the universal testing machine (Instron, India), and a gradual load of 1 mm/minute until failure was applied to the sample.[3,13,19] The readings were noted and tabulated (Fig. 2).

Wear Testing of the Samples

The samples to be tested for wear strength were preweighed separately using an electronic precision weigh balance (Citizen,

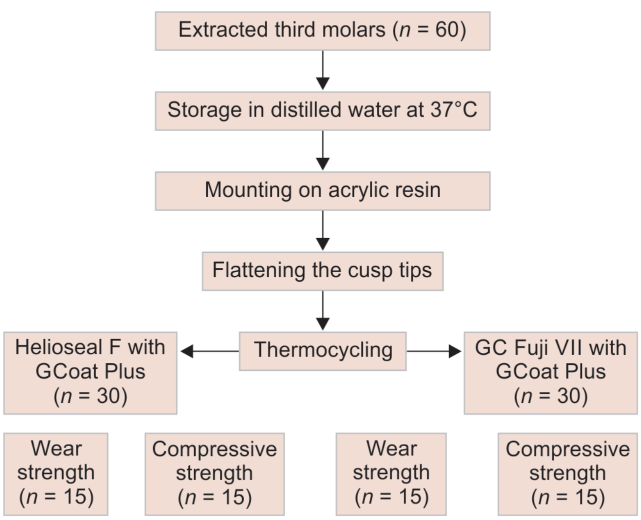

Fig. 1: Materials and methodology

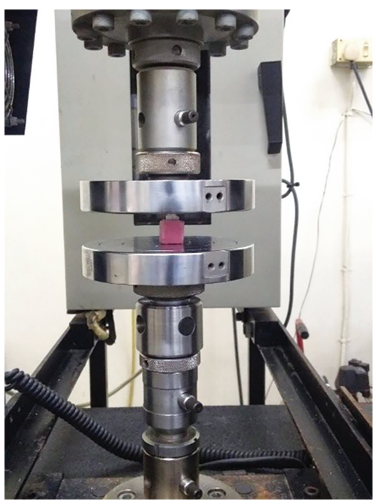

Fig. 2: Samples tested for compressive strength using the universal testing machine

India). Each sample was then mounted onto the pin-on-disk wear simulator (DUCOM, Asia) and abraded against a disk coated with zirconia with a force of 10 N, over a track length of 6 mm amounting to a total of 3,000 cycles. Artificial saliva was used as a lubricant. The amount of wear was recorded via a linear variable differential transducer (LVDT) sensor connected to the device. The samples were again weighed after the tests. The amount of wear was determined by calculating the difference in weight (µg) and also the LVDT sensor reading (µm). The collected data were tabulated (Fig. 3).

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software (version 19.0, United States of America). Mean and standard deviation were estimated using a one-way analysis of the variance.

Results

All the values were tabulated and subjected to statistical analysis using SPSS version 19.0 software (IBM, United States of America). The data obtained was tested for normality using the Shapiro–Wilk test. Since the data followed a normal distribution, parametric tests of significance were used. The comparison between the weight difference (µg), wear depth (µm), and compressive strength (Newton) was done using an unpaired "*t*" test.

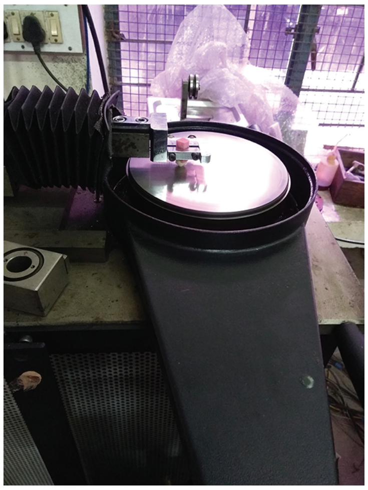

Fig. 3: Wear of the samples using the wear simulator

For all the tests, a *p*-value of <0.05 was considered statistically significant. The results show that there was a statistically significant difference between the two groups for wear strength and compressive strength.

Wear Strength

The results of wear testing showed there was a statistically significant difference between the two groups for the parameter weight loss (µg). Group II showed lower wear when compared to group I. There was no statistically significant difference between the two groups for the parameter wear depth (µm) (Table 1).

Compressive Strength

The results showed there was a statistically significant difference between the two groups for the parameter of compressive load (Newton) (Table 2).

Discussion

Pits and fissures are more susceptible to dental caries formation when compared to smooth surfaces. The use of sealants for pits and fissures has been the norm to prevent the onset of dental caries in the pits and fissures. Various resin-based and glass ionomer-based sealants are available each having their own merits and demerits. But to date, resin-based sealants have been preferred owing to their superior physical properties even though glass ionomer sealants have the potential for fluoride release. The major drawback of sealants is their poor retention in the oral cavity.[20–22]

Surface sealers have been widely used to protect restorative materials from initial wear before the material completes the initial set. Previously, various agents were put into use but they weren't long-lasting to provide prolonged protection to the restorative materials.[23]

Throughout a restorative material's lifetime, wear is a continuing process that occurs, and the material's characteristic degradation is correlated with the clinical outcome. Resin-based materials cleave polymer chains into oligomers and monomers, but glass ionomers exhibit intricate processes of absorption, outward ion transit, and disintegration.[24] Wear resistance is a result of various factors like

Table 1: Comparison of mean weight loss and mean wear depth

Variables	*Group*	*N*	*Mean*	*Standard deviation*	*Mean difference*	*p-value*
Weight loss (µg)	1	15	1.73	0.50	0.47267	0.023
	2	15	1.25	0.57		
Wear depth (µm)	1	15	145.47	32.34	20.80000	0.114
	2	15	145.47	32.34		

*, unpaired *t*-test

Table 2: Comparison of compressive strength between the two groups

Groups	*N*	*Mean*	*Standard deviation*	*Mean difference*	*95% confidence interval of the difference*		*t*	*Significance (2-tailed)*
					Lower	*Upper*		
I	15	1568.53	680.52	1997.9	1459.3	2536.4	7.599	<0.001
II	15	3566.40	757.47					

*, unpaired *t*-test

hardness, size, the portion of the surface that filler particles occupy, and how the particles and matrix interact.[25] The applied force and the distance from the center may alter the degree of conversion of the polymer resin matrix affecting the wear.[26]

Compressive strength is among the crucial physical characteristics of a material used in restoration when subjected to occlusal forces. It is a means to measure the ability of a given material to withstand masticatory forces before breakdown/failure. According to the International Standards Organization, compressive strength testing is an approved means to test the quality of water-based cement used in dentistry.[27]

In the present study, freshly extracted third molars which were indicated for extraction (due to impaction) were used. Caries-free teeth were included as the pits and fissures would be devoid of any damage and would not hinder the bonding of the material with the tooth surface.

After extraction and before the experimentation commenced, the materials were kept in distilled water at 37°C. Reena et al., Bagheri et al., and Mensudar et al. have suggested the use of distilled water and isotonic saline as the ideal storage media for extracted human teeth.[10,13,28]

The samples were all sectioned 2 mm below the CEJ using diamond disks[12] before being mounted onto the acrylic resin. The cusps of the teeth were flattened using a diamond disk after mounting,[16] washed in distilled water, polished using a polishing wheel, and stored at room temperature. The surfaces were flattened to produce an even platform for the material to be placed.[17]

A Teflon mold with a cylindrical slot of 3 mm diameter and 3 mm height was used to apply the materials to the occlusal surfaces. Galo et al. used a Teflon device to apply the materials onto the tooth surface to test the wear inflicted on two pit and fissure sealants against primary teeth.[12] This was done to limit the material flow on the occlusal surface and also to standardize the quantity of the material used for each sample. The glass ionomer sealant (GC Fuji VII, GC Asia) was manipulated using an amalgamator and applied according to the instructions given by the manufacturer using a capsule applier. Acid etching the enamel surface for 30 seconds using 37% orthophosphoric acid, the resin sealant (Helioseal F, Ivoclar Vivadent) was applied and light cured using an LED curing unit (Woodpecker Mini S) for 20 seconds. Once the materials were set, the surface sealer (GCoat Plus, GC Asia) was applied to the materials and light cured using the LED curing unit for 20 seconds.

The specimens underwent 500 cycles of thermocycling at 5–55 ± 2° C with dwell times of 15 seconds and transfer times of 10 seconds. They were all stored in distilled water at 37° C. Thermocycling was done to simulate oral conditions before the samples were subjected to testing.[29]

The wear testing was done using a pin-on-disk wear simulator. Two body wear simulations were performed to simulate oral conditions and the force of 10 N was standardized after adjustments for testing were done as the masticatory load can vary between 3 and 150 N.[30]

Before and after wear testing, each sample was weighed using an electronic precision weigh balance. Wear was calculated based on the weight lost (μg) during the procedure and the readings of an LVDT sensor which showed wear in terms of material lost (μm) Rios et al. studied the wear of glass ionomer cements after tooth brushing wherein weight loss was considered a parameter of wear.[7] Pardi et al. observed replicas under a scanning electron microscope to evaluate the wear of sealants.[2] Lohbauer et al. used impressions of the worn materials and observed them under a confocal microscope.[5] Santos et al. used contact profilometry to evaluate the wear of composites coated with surface sealers.[11] Galo et al. used X-ray diffraction (diffractometry) to analyze the wear of two sealants in contact with primary teeth.[12]

For compressive testing, the samples were subjected to a compressive load of 1 mm/minute using an Instron machine. Kavaloglu Cildir and Sandalli evaluated the compressive strength of four fissure sealants using an Instron machine at a crosshead speed of 1 mm/minute.[3] Koenraads et al. studied the compressive strength of two glass ionomer cements using a CR rectangular testing rod at a cross-head speed of 1 mm/min.[18] Mensudar et al. evaluated the compressive strength of three glass ionomer materials with a surface coating using a Lloyd machine at a crosshead speed of 1 mm/minute.[13]

The results of the wear testing show that there was a statistically significant difference ($p < 0.05$) seen when the weight loss was compared between the two groups. Group II showed significantly lower values of weight loss when compared to group I. This can be attributed to the fact that the nanofillers present in GCoat Plus produce a "micro-lamination effect" which brings about uniform flow and complete wetting of the cement surface.[10] Bonifácio et al. and Mensudar et al. have suggested that the mechanical properties of glass ionomer materials, especially initial wear resistance, improved with the use of GCoat Plus.[9,13]

The results of compressive strength testing show that there was a statistically significant difference between the two groups. Group I showed higher compressive strength when compared to group II. Forss and Halme, Mejäre and Mjör, Songpaisan et al., and Poulsen et al. have suggested that the retention of resin sealants has always been superior to glass ionomer materials. Although resin-based sealants exhibit better mechanical properties, glass ionomer sealants provide better protection from caries with the fluoride release.[29,31,32]

Although resin-based sealants have been proven to have superior physical properties, the results of this study have shown that the use of a surface sealer has reduced the wear of the glass ionomer sealant. Whereas the resin sealant exhibited higher compressive strength when compared to the glass ionomer sealant. Since the study has been carried out under *in vitro* conditions, the scope of this research can be fully understood only after thorough clinical trials are conducted.

Conclusion

Within the limitations of this study, the following conclusions can be drawn:

- Glass ionomer sealant showed greater resistance to wear when compared to the resin-based sealant.
- The resin-based sealant showed higher compressive strength values than the glass ionomer sealant.

Clinical Significance

Although various studies have shown that resin-based sealants have better retention owing to their superior physical properties when compared to glass ionomer sealants, glass ionomer sealants with the ability for fluoride release and recharge would be a better alternative for use in children where proper isolation cannot be maintained. Surprisingly, the results of our study have shown that the use of a surface sealer on the glass ionomer sealant has increased the resistance to wear and thereby paves the way for more such laboratory studies in the future to assess the physical properties of the glass ionomer materials and clinical studies to support and promote their use as pit and fissure sealants.

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