ORIGINAL RESEARCH

In Vitro Evaluation of Viscosity, Depth of Penetration, Microleakage, and Shear Bond Strength of Conventional and Hydrophilic Sealants

Jayashri Prabakar[1], Ganesh Jeevanandan[2], Shivashankar Kengadaran[3]

Abstract

Background: Sealants are effective in preventing and arresting pit and fissure caries. Newer brands of sealants continue to be developed despite the lack of scientifically based information addressing the caries-preventive properties of these materials. Hence, laboratory *in vitro* tests play a vital role in providing the necessary information regarding the efficacy of new products in a short period of time.

Objectives: To compare and evaluate the viscosity, resin tag length, microleakage, and shear bond strength between conventional and hydrophilic sealants.

Materials and methods: A total of 40 extracted third molars were selected. Only 20 were evaluated for microleakage and resin tag length and another 20 for shear bond strength evaluation between group I—ClinPro and group II—UltraSeal XT hydro. After sealant placement, specimens were immersed in 0.1% rhodamine dye, followed by thermocycling. Microleakage testing was done using a confocal laser scanning microscope and resin tag length evaluation using a scanning electron microscope (SEM) and shear bond strength using an Universal Instron machine. Viscosity was assessed using an Anton Paar viscometer. Results were subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS) software version 20.

Results: Viscosity and mean microleakage scores for group I (0.92 MPa and 1.50) were found to be higher than for group II (0.72 MPa and 0.60). Mean resin tag length and mean shear bond strength for group I (7.46 ± 0.95 μm and 13.71 ± 0.94 MPa) were found to be less compared to group II (10.03 ± 1.00 μm and 20.39 ± 0.98 MPa). The results were found to be statistically significant ($p < 0.05$).

Conclusion: Group II was found to be less viscous, which resulted in the formation of resin tags of sufficient length and showed less microleakage and higher shear bond strength than group I.

Keywords: Caries risk, Dental caries, Dental sealants, Hydrophilic sealants.

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Introduction

Occlusal surfaces with deep crevices or cleft are susceptible to dental caries to a greater extent,[1] and it is accountable for 56–70% of carious lesions among the 5–17-year-old population.[2,3] Anatomical fissures or indentations on occlusal surfaces of the posterior tooth are more prone to retaining food particles, which ultimately encourage the formation of bacterial biofilm and caries development. Consequently, sealing these surfaces can arrest caries formation, which contributes to primary prevention and comprehensive dental caries treatment protocol.[4] In addition to the interruption of caries formation, there exists significant data that fissure sealants may curb the progression of noncavitated lesions and are considered a part of secondary prevention.[5]

Numerous preventive protocols have been implemented for many years to tackle this problem, which comprises of forming a protective barrier with the help of various approaches such as mechanical fissure elimination,[6] prophylactic odontomy,[7] use of zinc phosphate cement,[8] and chemical treatment of the fissure using silver nitrate.[9]

A systematic review of sealants disclosed that fissure sealants are effective in preventing as well as in arresting the occlusal fissure caries lesion on deciduous and permanent teeth when compared to the fluoride varnish and lack of use of sealant.[10]

A broad range of resin-incorporated pit and fissure sealant materials were introduced in the trade in the present day. Among them is UltraSeal XT hydro sealant, which is 53% highly filled resin with ideal viscosity (thixotropic) and advanced adhesive technology, which enables the sealant to flow into pits and fissures and adhere completely to the enamel. The increased bond strength results in less microleakage and better marginal retention.[11] The movement

[1]Department of Public Health Dentistry, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India

[2]Department of Pedodontics and Preventive Dentistry, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India

[3]Department of Public Health Dentistry, Indira Gandhi Institute of Dental Sciences, Sri Balaji Vidyapeeth University (Deemed to be University), Puducherry, India

Corresponding Author: Jayashri Prabakar, Department of Public Health Dentistry, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu, India, Phone: +91 9841788803, e-mail: jayashriprabakar@yahoo.com

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of fluids, microorganisms, and ions between the sealing material and teeth is said to be microleakage.[12] Moisture contamination and microleakage are considered to be the major causative factors for direct restorative procedure failure.[13] The mechanical retention of these sealants is established *via* micromechanical interconnect and tag formation between the sealant material and the enamel.[14] Cochrane Review reported a decrease in caries prevalence, which ranged from 86% in 12 months to 57% in a 48–54 months time period.[15] Even if there is tooth wear, the resin tags continue to exist, and the occlusal surface is preserved.[16] Hence, the sealant consistency influences the sealant flow into the fissure and length resin tag length.

The ideal sealant should have better adhesion to enamel.[17] The bonding of sealant to the enamel of the tooth was measured by shear bond strength. Increased shear bond strength results in enhanced performance and longevity of the sealant.[18] Therefore, the success of these types of sealants depends upon the microleakage, viscosity, resin tag length, and shear bond strength of the material. *In vitro* tests provide needed data on the use and potency of recently developed products in a short time period. The present study was planned with the aim of determining the viscosity, depth of penetration, microleakage, and shear bond strength of conventional and hydrophilic sealants.

Materials and Methods

The sample size for the present was estimated using the Prabhakar[19] study, and the total study sample that arrived was 40 teeth.

Study Sample

A total of 40 extracted third molars were selected. Only 20 were evaluated for microleakage and resin tag length and another 20 for shear bond strength evaluation.

Eligibility Criteria

Sound teeth free of dental caries and developmental defects were included.

Randomization

All the sound teeth were arbitrarily distributed to both groups.

Preservation of the Samples

The samples were cleansed and soaked in 5% sodium hypochlorite. A microscopic examination of all the teeth was done to rule out defects, cracks, and incipient caries.

Blinding

The dye penetration was evaluated by an examiner who wasn't aware of the study regimen.

Study Setting

The resin tag length was assessed using a scanning electron microscope (SEM) at the Central Institute of Plastic Engineering Technology (CIPET), Guindy, and viscosity testing was done using an Anton Paar viscometer at CSIR-CLRI. Dye penetration was evaluated using a confocal laser electron microscope at V ClinBio Laboratory, Ramachandra University, and shear bond strength estimation was done using an Universal Instron machine at CIPET.

Armamentarium

Equipment Used

- SEM.
- Anton Paar viscometer.
- Confocal laser scanning microscope.
- Universal Instron testing machine.
- Thermocycling water bath.
- Micromotor handpiece and 0.02 mm thickness of diamond wheel.
- Light curing polymerizing unit.

Application of Sealant

Acid etching was done using 37% orthophosphoric acid, and the surfaces were rinsed with water. Air spray was used to dry the teeth in order to accomplish the chalky, frosty white appearance of tooth enamel with respect to ClinPro sealant. But, with UltraSeal, the typical glacial look was not needed. Comparatively, the surfaces should be slightly air-dried and left mildly wet with a shiny look. Finally, the material was applied and light-cured.

Procedure for Microleakage and Resin Tag Length Evaluation (Figs 1 and 2)

Application of Nail Varnish

Glazing with two layers of nail varnish was done for all the tooth surfaces except the occlusal surface in order to avoid dye leakage. Two different nail colors were used for group differentiation.

- Blue: ClinPro sealant.
- Magenta: UltraSeal sealant.

Dye for 24 hours

The tooth was immersed in such a way that the occlusal surfaces were in contact with the 0.1% rhodamine B isothiocyanate at 37°C for 24 hours.

Thermocycling

Temperature range of 5–55°C for 500 cycles.

Sectioning

Longitudinal sectioning of the tooth was performed in a mesiodistal direction using a diamond wheel.

Evaluation under Confocal Laser Scanning Microscope

Confocal laser scanning, microscopic evaluation, and scoring were done by the blinded investigator. The microleakage assessment was done using Overbo and Raadal guidelines (1990).[20]

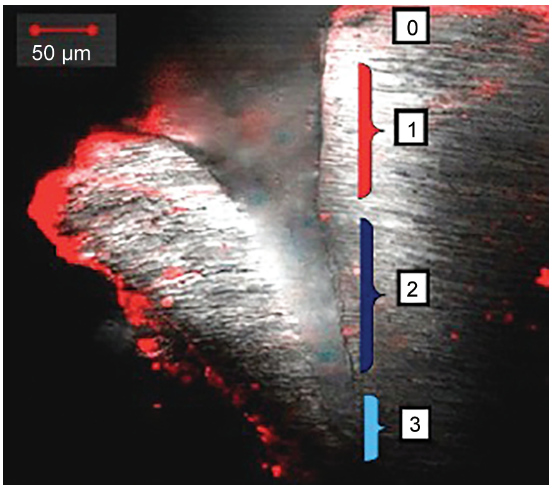

Fig. 1: Confocal laser microscopy image for dye penetration

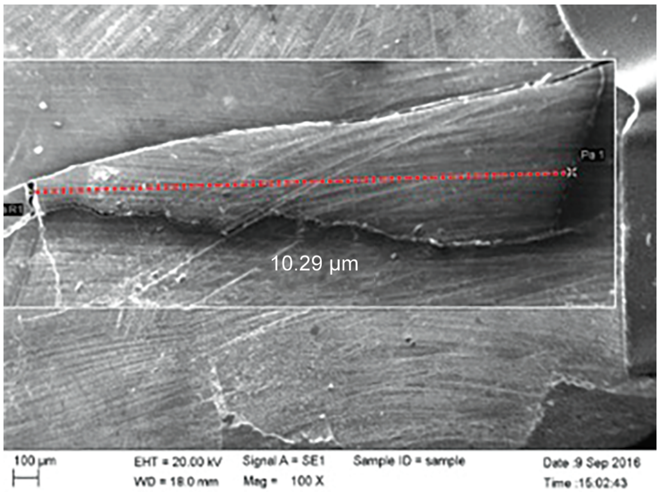

Fig. 2: Scanning electron microscope (SEM) analysis

Fig. 3: Prepared samples for viscosity measurements

Evaluation under SEM (Carl Zeiss Pvt LTD, United Kingdom Model: EVO MA 15)

Preparation, mounting, gold spluttering, and tag length analysis. Polishing of tooth samples was done, and the sections were subjected to decalcification to remove unsupported mineral constituents that were unguarded by the sealants. Mounting of tooth specimens on the brass ring was established using a protector-resistant band. These mountings were ion-spluttered for a duration of 30 minutes. The spluttered segments were examined using an SEM, and the segments were photographed.

Viscosity Analysis

The viscosity of the sealants was estimated by diluting with methyl methacrylate monomer. Monomer viscosity was determined first before analyzing the sealant consistency. Anton Paar viscometer was used for analysis (Fig. 3).

Preparation of Samples for Shear Bond Strength Evaluation

The tooth specimens were acid-etched using 37% phosphoric acid. An elastomeric impression mold with a dimension of 3 mm diameter and 3 mm height was placed in such a way that the mold is perpendicular to the polished surfaces (Fig. 4).

Fig. 4: Testing of shear bond strength

The sealants were placed in an incremental fashion to form a button and cured as per the manufacturer's instructions. To avoid dehydration of the materials, light-cured samples were kept in distilled water at 37°C for 24 hours.

Finally, the specimens were implanted in an acrylic block with treated buccal surfaces uncovered. Color coding of the mounted specimens was done for both groups, and the bond strength was evaluated.

Data Analysis

Statistical Package for the Social Sciences (SPSS) software, version 20, was used. Mean differences in microleakage scores were compared by the Mann–Whitney *U* test between the two sealants. An independent *t*-test was used to determine the difference in the groups with respect to resin tag length, viscosity readings, and shear bond strength.

Results

The mean microleakage scores for groups I and II sealants were found to be 12.95 and 8.05, respectively, and the difference was statistically significant (Table 1). The mean difference in resin tag length of groups I and II was estimated using an independent *t*-test. The mean difference between the groups was found to be –2.56, and *t*-value of –5.86. Independent *t*-test showed a *p*-value of 0.001, revealing a statistically highly significant difference in mean resin tag length between the groups, which in turn signifies group II sealant (10.03 ± 1.00 µm) found to be superior to the group I sealant (7.46 ± 0.95 µm) (Table 2). The viscosity of group I was 0.9 MPa, which was higher than group II (0.7 MPa) (Fig. 5). Table 3 shows the mean difference in shear bond strength of groups I and II sealant. The shear bond strength for group II was 20.39 ± 0.98, which was more than group I (13.71 ± 0.94). The relationship between viscosity, resin tag length, microleakage, and shear bond strength was depicted in Figure 6, which showed that the ideal viscosity of group II results in better penetration and resin tag formation of sufficient length and minimal microleakage when compared with group I sealants.

Discussion

Fissure sealants are an excellent adjunct to various caries prophylactic approaches, which help to halt the caries mechanism.[21] The preventive effect of resin sealants is due to the development of strong marginal adaptation, which ultimately prevents microleakage.[12] A superior restorative sealant material should furnish adequate bond strength and nominal microleakage.[22]

Table 1: Mean difference in microleakage score between groups I and II

Groups	*N*	*Mean rank*	*Mann–Whitney U score*	*Significance*
I	10	12.95	25.50	$p < 0.05$*
II	10	8.05		

Mann–Whitney test ($p < 0.05$)

Table 2: Mean difference in resin tag length measurements of groups I and II

Groups	*Mean ± SD*	*Degree of freedom*	*Mean difference*	*t-value*	*p-value*
Group I	7.46 ± 0.95	9	−2.56	−5.86	0.001*
Group II	10.03 ± 1.00	9			

Independent *t*-test ($p < 0.05$)

Table 3: Mean difference in shear bond strength of groups I and II sealants

Groups	*Mean ± SD*	*Degree of freedom*	*Mean difference*	*t-value*	*p-value*
Group I	13.71 ± 0.94	9	−6.68	−15.44	0.001*
Group II	20.39 ± 0.98	9			

Independent *t*-test ($p < 0.05$)

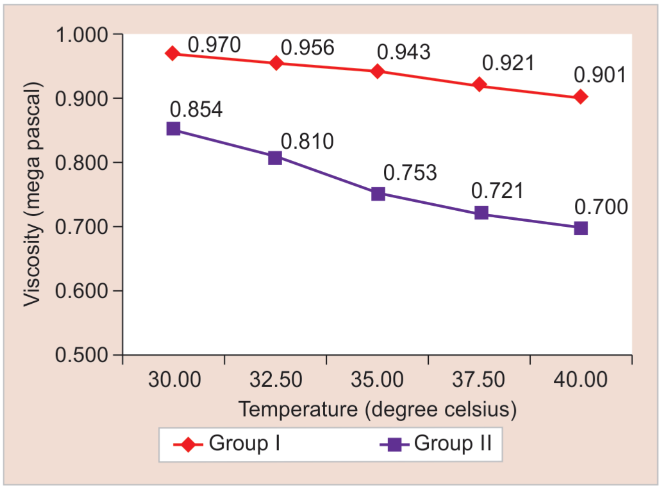

Fig. 5: Viscosity measurements of groups I and II at various temperature

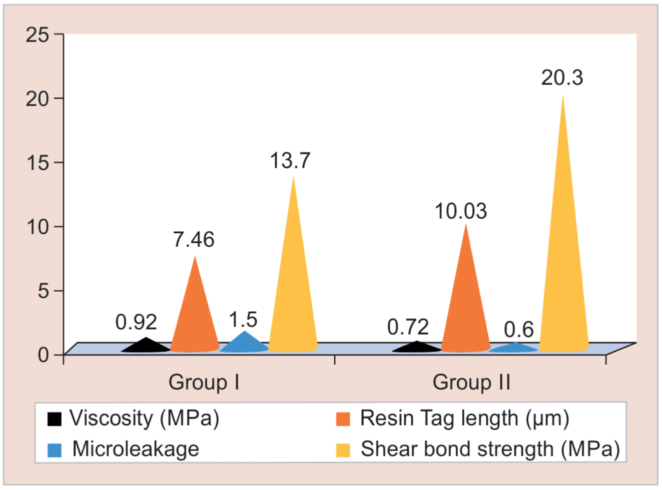

Fig. 6: Relationship between viscosity, resin tag length, microleakage, and shear bond strength

Marginal seal or adequate marginal adherence is pivotal for the effectiveness and longevity of the sealant because the penetration of microorganisms underneath the sealants can develop dental caries.[23]

The principal factor influencing the sealant durability is enamel adherence, which consequently reduces microleakage.[24,25] Dye penetration is a broadly used method, which is less expensive, nontoxic, and detects even minimal amounts of leakage.[13] It is also considered to be a more accurate technique as the dye particle size is the same as the bacterial lipopolysaccharides.[26] Intraoral temperature is imitated by means of a thermocycling procedure. The sealant-treated teeth were exposed to temperatures tolerant with temperatures observed inside the mouth.[27]

The microleakage score of group I (ClinPro) sealant was found to be 20% for scores 0 and 1 and 30% for scores 2 and 3. The mean microleakage score for group I (ClinPro) sealant was found to be 1.5 ± 1.08 more than group II (UltraSeal XT Hydro), which was 0.60 ± 0.69. The results were in accordance with the study done by Borsatto et al.,[28] where microleakage in the ClinPro sealant was more compared to glass ionomer. Another study revealed that glass ionomer cement (GIC) possessed better marginal adaptation than the fluoride-releasing ClinPro sealant under damp conditions. Identical findings were observed in various studies.[23,29] Rirattanapong's study[30] proclaimed that light-cured resin sealants yielded better adaptation under dry conditions than the Fuji VII glass ionomer sealant group. Controversial results were provided by Ashwin and Arathi,[25] which showed that there was no significant difference in microleakage score for the GIC and resin sealant group.

Our study showed a lower microleakage score and higher shear bond strength for group II (UltraSeal XT Hydro) than for group I (ClinPro) sealant. The reason could be due to its thixotropic property, advanced adhesive technology, and hydrophilic nature of the sealant.[11] Insufficient penetration of resin due to moisture contamination in the case of conventional ClinPro sealants causes deficit number and length of resin tag, which ultimately affects the sealant retention.[31]

Viscosity measures the resistance of a sealant to flow.[32] A thick, viscid liquid flows slowly. Sealant viscosity impacts its penetration.[33] In the present study, the viscometer used requires only a limited sample quantity to determine the viscosity. Glass ionomers are the only moisture control sealants so far used.[34] The sealant adhesion is mainly due to ionic bonding, not due to micromechanical retention. A study done by Pardi et al.[35] concluded that GIC was found to exhibit less adhesion. The moisture-tolerant sealant used in the present study exhibited ideal viscosity and better adhesion, which facilitated the sealant to flow into crevices.[11]

The resin tag length observed in the current study was in the range of 5.42–8.70 µm for group I and 8.41–11.75 µm for group II. The present study findings were in accordance with a few *in vitro* studies,[19,36] which had 5–10 µm length. The viscosity of group I was more than that of group II in our study. Current study findings with respect to sealant thickness were consistent in a study,[32] which revealed that higher sealant viscosity might cause less adaptation and insufficient penetration, resulting in reduced retention. On the contrary, a few authors[37] have concluded that sealant consistency will not affect their sealing ability.

Bond strength is considered to be a predictive measure of material retention.[38] Group I (ClinPro) sealant in our study had a mean shear bond strength of 13.71 ± 0.94 MPa. Similar results were reported by Dhillon[39] and Rirattanapong[40] with bond strengths of 13.43 ± 0.90 and 12.42 ± 2.95. The mean shear bond strength of group II in our study was found to be 20.39 ± 0.98, which was comparatively higher than group I (ClinPro) sealant. A significant difference in mean shear bond strength was noticed between the two groups using an independent *t*-test. Our findings with respect to shear bond strength were in agreement with a study,[41] which tested the shear bond strength of filled and unfilled sealants. They reported that ClinPro had lesser bond strength compared to Delton. The presence of fillers in Delton contributed to the increased material mechanical resistance to abrasion.[42]

Conclusion

Overall, our research findings provide key insights into the relationship between the use of hydrophilic sealants and moisture contamination. Moisture contamination plays a crucial role in the retention of the sealants. The minimum level of microleakage, ideal viscosity, and higher shear bond strength were observed in group II hydrophilic sealants.

Clinical Significance

As dental caries is deemed to be a major global problem affecting the younger population,[43,44] it is very much needed to treat the disease at its early stage, or else it can lead to serious consequences.[45–48] Hence, minimally invasive preventive approaches such as sealants should be advocated at an early stage of dental caries intervention. Moisture contamination is the major drawback associated with resin sealants, which impacts the bond strength, tag length, and, ultimately, sealant retention. The use of moisture-tolerant sealants can overcome the stumbling block for retention. Clinical trials using moisture-tolerant sealants need to be conducted to justify the results.

Orcid

Ganesh Jeevanandan https://orcid.org/0000-0003-3631-6982
Shivashankar Kengadaran https://orcid.org/0000-0002-6868-9639

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