

## ORIGINAL RESEARCH

# *In vitro* evaluation of wear resistance, microhardness and superficial roughness of different fissure sealants after aging

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**Abstract**

The aim of this study was to compare the aging effects on wear, surface roughness and microhardness of fissure sealants having varying contents. Four fissure sealant types were used in the study: Aegis (Bosworth, USA) (Group A), Beautisealant (Shofu, Japan) (Group B), Clinpro (3M, USA) (Group C), and Ultraseal XT/Hydro (Ultradent, USA) (Group U). Hundred disc-shaped specimens (5 mm diameter/3 mm width) were designed according to the manufacturer's instructions and assigned for microhardness/Vickers Hardness (VHN), surface roughness, and wear tests. Thermocycling (10,000 times/5–55 °C ± 2 °C/20 s) and chewing simulator (75,000 times/49 N) were applied as the aging procedures. Measurements were made before and after the aging procedures. The specimens were examined by Scanning Electron Microscopy (SEM). Data was statistically analyzed through Kruskal Wallis, Wilcoxon and Welch tests. The highest and the lowest changes in mean microhardness values were obtained for Group U (9.88 ± 1.46) and Group A (4.40 ± 0.46), respectively; and a significant difference ( $p < 0.001$ ) was found between the mean changes in microhardness numbers (U > B > C > A). The median roughness values had no significant difference; the surface roughness had the highest mean differences in Groups U and C (U = C > A > B). Significant difference was found between the mean changes in wear/weight values ( $p < 0.001$ ); the highest and the lowest mean weight losses were recorded in Group U (0.0097 ± 0.0003 gr), and Group C (0.0041 ± 0.0006 gr), respectively (U > B > A > C). The highest physical changes were determined in Group U after the aging procedures. It is concluded that the aging procedures affect physical structures of all test materials with varying degrees, however Ultraseal XT/Hydro is the most affected. The individual treatment needs and material properties must be considered to select a fissure sealant material.

**Keywords**

Fissure sealant; Wear; Microhardness; Roughness; Aging procedure

## 1. Introduction

Dental caries is a dynamic, chronic and multifactorial disease characterized by the loss of substance from the teeth hard tissues. The dental caries prevalence has decreased worldwide, however its incidence on the occlusal surface of molar teeth is on the rise which may be closely related to the fissures morphology [1–4].

Various therapeutic interventions have been proposed to prevent the initial occlusal caries. They include plaque control through tooth brushing, mouthwashing, varnishing and fissure sealing [5, 6].

Nowadays, the higher incidence of pit and fissure caries in children and adolescents requires preventive methods and materials. The preventive measures are based on controlling the oral biofilm population. The methods to prevent pit and fissure caries include mechanical and chemical plaque controls,

and pit and fissure sealant applications. The occlusal sealing materials have proper marginal seal, antibacterial properties, retention in fissures and penetration ability. Resin composite sealants have high retention rate towards enamel compared to the other sealant materials [5]. However, their efficacy is undermined when the operative field cannot be isolated. This is the case in permanent molars not fully erupted or primary molars in children [7].

The physical structure of dental materials and prognosis of applied treatments can be negatively affected by the mechanical movements and temperature changes in oral cavity. The *in vitro* evaluation of dental materials has been preferred to simulate the oral cavity conditions (thermocycling, water aging and chewing forces) in laboratory environment for mimicking the natural aging process since *in vivo* evaluation of dental materials has been difficult in the clinical trials. Thus, the *in vitro* examination of dental materials before and after the aging

procedures is important nowadays. It is observed from the literature that there are limited studies examining the changes in physical properties of fissure sealant materials after the *in vitro* aging procedures [8].

The aim of this study is to evaluate and compare the effects of aging procedures on surface characteristics of fissure sealants including various chemical ingredients. The resin-based Clinpro, glass ionomer-based (S-PRG (surface reacted glass filler)), Beautisealant, hydrophilic Ultraseal XT Hydro, and ACP (amorphous calcium phosphate)-based Aegis are compared as the sealants after *in vitro* aging procedures.

## 2. Materials and methods

The study was conducted at the Department of Pediatric Dentistry, Faculty of Dentistry, Istanbul University, and the nanoelectronics research laboratory of Department of Physics, Faculty of Science, Istanbul University.

In this study, the resin-based Clinpro (3M ESPE, USA), glass ionomer-based (S-PRG), Beautisealant (BS; Shofu Inc. Kyoto, Japan), hydrophilic Ultraseal XT Hydro (Ultradent, South Jordan, USA), and ACP-based Aegis (Bosworth Company, USA) as the fissure sealants were evaluated and compared after the *in vitro* aging procedures. These four types of fissure sealant materials are listed in Table 1 as Group A, Group B, Group C and Group U.

The ready-made silicone molds of 5 mm diameter and 3 mm height were used to create disc-shaped specimens [9–12]. According to the manufacturers' recommendation, the fissure sealant materials were applied in equal amounts to silicone molds placed on flat glass plate. The excess materials were removed by lightly pressing the glass plate placed on top of the molds. The fissure sealant samples were polymerized for 20 seconds using curing light (VALO, Ultradent, South Jordan, Utah, USA) as per the manufacturers' recommendation. The samples surfaces were wet sanded with 600, 800 and 1200 grit sandpapers in water for 30 seconds each, respectively. The samples were polished with polishing wheel and kept in distilled water at 37 °C until the day of experiment [10, 12].

The experimental samples in Discs form were grouped for testing the microhardness, surface roughness and wearing. Hundred disc-shaped specimens were arranged as follows: eight specimens from each group for wear measurements, seven for roughness, nine for microhardness and one randomly selected after wearing test for scanning electron microscopic (SEM) analysis.

The samples were stored in distilled water at 37 °C for 24 h prior to the testing.

According to the Power analysis conducted using G\*Power (Version 3.1.9.7, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) program, the minimum sample size determined for each group was  $n = 7$  for the roughness levels with effect size ( $d$ ) of 0.730, power of 0.80, and  $\alpha$  of 0.05. Similarly, the minimum sample size was  $n = 9$  for the microhardness levels with effect size ( $d$ ) of 0.468, power of 0.80, and  $\alpha$  of 0.05. The minimum sample size for the wear levels was  $n = 8$  with effect size ( $d$ ) of 0.695, power of 0.80, and  $\alpha$  of 0.05.

In the first aging procedure, the disc-shaped specimens were thermocycled 10,000 times using electronic thermal cycling machine at Istanbul University, Faculty of Dentistry Research Laboratory named as Dentester Salubris Technica (Massachusetts, ABD) (Fig. 1). They were put in water baths at  $5 \pm 2$  °C, and  $55 \pm 2$  °C with 20 seconds dwell time in each bath [13].

In the other aging process, the chewing simulator procedures were conducted using S.D Mechatronik Chewing Simulator CS-4 (S.D Mechatronik, Munich, Germany) (Fig. 2). In this study, the steel components were used as an antagonist. A weight of 5 kg equivalent to 49 N chewing force was exerted on the specimens. The cyclic movements were repeated 75,000 times accompanied by thermocycling. The wear test parameters are presented in Table 2.

The microhardness of 36 specimens (nine per each sealant) was measured in triplicate using microhardness tester (Innovatest™ 400 Series, Maastricht The Netherlands) with 500 g load and 15 second dwell time. The average measurement was recorded (VHN (Vickers Hardness Number)) before and after the thermocycling.

**TABLE 1. Fissure sealant materials and their compositions tested in this study.**

Group	Sealant	Composition	Manufacturer
A	Aegis Lot: 17B152B	Amorphous Calcium Phosphate (ACP), Urethane Dimetacrylate (UDMA), mono- and di-methacrylate, modified Bis-GMA, 38.5% inorganic filler	Bosworth, USA
B	BeautiSealant® Lot: 022001	Surface Pre Reacted Glassionomer (S-PRG) particles, fluoroboroaluminosilicate glass, silica, UDMA, TEGDMA (triethylene glycol dimethacrylate)	Shofu, Kyoto, Japan
C	3M Clinpro™ Lot: NC93055	Bis-GMA, TEGDMA, silane, tetrabutylammonium tetrafluoroborate, diphenyl hexafluorophosphate, ethyl-4-(dimethylamino) benzoate (EDMAB), titanium hydroxide, hydroquinone	3M ESPE, St. Paul, Minnesota, USA
U	UltraSeal XT® hydro™ Lot: BKPD6	TEGDMA, diurethane dimethacrylate (DUDMA), methacrylic acid, aluminum oxide, titanium dioxide, sodium monofluorophosphat	Ultradent, South Jordan, USA



FIGURE 1. Thermal Cycle Dentester Salubris Technica (Massachusetts, ABD).

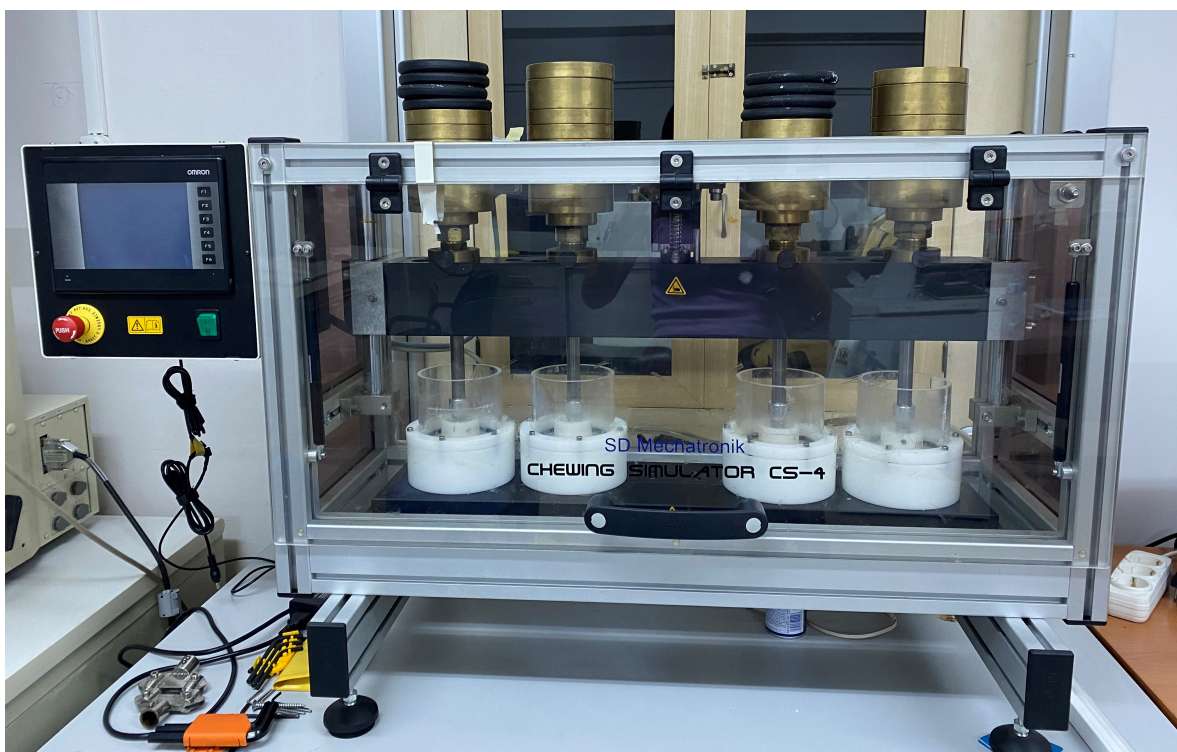


FIGURE 2. S.D Mechatronik Chewing Simulator CS-4 (Germany).

**TABLE 2. Wear test parameters.**

Wear test parameters	
Cold/hot bath temperatures: 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	

The surface roughness of 28 specimens (seven per each sealant) was measured using 2-dimensional profilometer (Taylor Hobson S25 Surtronic Profilometer, Illinois, USA) with 5  $\mu\text{m}$  diamond stylus angled at 90°. Three measurements were made in different directions starting from the midpoint of each specimen with 0.25 mm cut-off length. The average roughness for each specimen was calculated and recorded (Ra, in  $\mu\text{m}$ ).

The substance loss for specimens was determined by weighing before and after the chewing simulator cycles on electronic weighing balance (Densi HZY 2200, Istanbul, Turkey) having accuracy of 0.0001 gram.

A randomly selected sample from each fissure sealant group was taken for SEM evaluation before and after the chewing process. SEM were recorded in low vacuum of 20 kV at various magnifications ( $\times 250$ ,  $\times 500$ ,  $\times 1000$ ).

The data were analyzed with IBM SPSS V23 (Armonk, NY, USA), and conformity to the normal distribution was evaluated using Shapiro-Wilk test. Kruskal-Wallis test was employed to compare the microhardness roughness, and roughness difference values which were not normally distributed according to the materials. Dunn test examined the multiple comparisons made. Welch test compared the microhardness and wear changes which were normally distributed according to the materials and their variance was not homogeneous. Tamhane's T2 test examined the multiple comparisons made. A one-way analysis of variance (ANOVA) compared the wear values with normally distributed and homogeneous variance. Wilcoxon test compared the non-normally distributed roughness and microhardness values within the materials according to time. The paired sample *t*-test compared the normally distributed wear values. Results were presented as mean  $\pm$  s for the quantitative data being deviation and median (minimum–maximum). The significance level was considered as  $p < 0.050$ .

### 3. Results

The microhardness test results depicted the highest median values before and after the cycles for Group U ( $32.12 \pm 1.91/22.25 \pm 0.71$  VHN), and the lowest for Group C ( $18.27 \pm 1.24/11.84 \pm 0.31$  VHN). A significant difference was found between the median values before and after the cycles in all groups ( $p < 0.001$ , Table 3).

The microhardness test results showed the highest mean of change in Group U ( $9.88 \pm 1.46$ ), while the lowest in Group A

( $4.40 \pm 0.46$ ) (U > B > C > A). A significant difference was found between the mean values of changes in all groups ( $p < 0.001$ ).

The microhardness test results revealed statistically significant difference between the median values of materials after thermal cycling procedure. After thermal cycling, the median microhardness of groups A, B, C and U were 14.90, 14.24, 11.91 and 22.33, respectively. The highest median was obtained in group U and the lowest in group C. The median microhardness values were significantly different before and after the thermal cycling in groups A, B, C and U ( $p = 0.008$ ). The mean VHN changes were  $4.40 \pm 0.46$ ,  $7.56 \pm 0.54$ ,  $6.42 \pm 1.19$  and  $9.88 \pm 1.46$  in Groups A, B, C and U, respectively. The highest mean change was found in group U and the lowest in group A.

The highest average roughness was found in group B before the thermal cycling, while it was the highest in group C after thermal cycling. Upon examining the average roughness change rates, the highest were in groups C and U while the lowest in groups A and B. The median roughness values before and after thermal cycling for groups A, B, C and U were 0.73–1.40, 0.78–1.45, 0.79–1.59 and 0.83–1.52, respectively.

The roughness medians and roughness change values had no significant difference before and after the thermal cycling among materials. However, differences were found in the roughness before and after thermal cycling in groups A, B, C and U ( $p = 0.018$ ) (Table 4).

Before and after the chewing simulation procedure, the highest average weights were found in group B while the lowest in group A. Upon examining the percentage change in average weights before and after chewing simulation, the highest change rate was in group U, while the lowest in group C ( $p < 0.001$ ).

The average weights before and after the chewing simulation for each material had no statistically significant difference ( $p > 0.05$ ). However, differences were found between the average weights before and after chewing simulation procedure in groups A, B, C and U ( $p < 0.001$ ) (Table 5).

According to the materials, there was a statistically significant difference in the mean weight change values ( $p < 0.001$ ). The mean weight change was lower in group C and higher in group U compared to the materials in other groups.

The smooth and the homogeneous SEM image was observed for Group A in the beginning. Groups C and U particles were large and heterogeneous (Fig. 3A,4A,5A). Particles in each group were observed before the chewing simulator process. Wear on samples after the process was due to the horizontal and vertical forces applied in the procedure.

An irregular surface was observed in all groups after the chewing simulator procedure because of the displacement of particles by vertical and horizontal forces. The cracks significantly increased in Groups A and C, however could not be clearly observed in Groups B and U after chewing simulator process (Fig. 3B,4B,5B).

### 4. Discussion

The dentists are required to know the etiology of caries and develop preventive measures against the involved factors. Pre-

**TABLE 3. Microhardness values (VHN) (mean  $\pm$  SD) of the tested materials.**

Group	Before thermocycling	After thermocycling	<i>p</i>
A	19.48 $\pm$ 1.18 19.53 (17.77–21.62) <sup>ac</sup>	15.08 $\pm$ 1.39 14.90 (13.05–17.62) <sup>ab</sup>	<i>Z</i> = –2.666 0.008
B	21.74 $\pm$ 0.60 21.61 (20.94–22.69) <sup>ab</sup>	14.18 $\pm$ 0.36 14.24 (13.60–14.57) <sup>ac</sup>	<i>Z</i> = –2.666 0.008
C	18.27 $\pm$ 1.24 18.68 (16.68–19.85) <sup>c</sup>	11.84 $\pm$ 0.31 11.91 (11.19–12.13) <sup>c</sup>	<i>Z</i> = –2.666 0.008
U	32.12 $\pm$ 1.91 33.05 (27.96–33.62) <sup>b</sup>	15.08 $\pm$ 1.39 14.90 (13.05–17.62) <sup>ab</sup>	<i>Z</i> = –2.666 0.008
<i>p</i>	$\chi^2 = 29.344$ <0.001	$\chi^2 = 30.099$ <0.001	

$\chi^2$ : Kruskal-Wallis; *Z*: Wilcoxon; a–c: No difference between the materials with same letter; mean  $\pm$  s: deviation, median (minimum–maximum).

A: Aegis (Bosworth Company, ABD); B: Beautisealant (BS; Shofu Inc., Kyoto, Japan); C: 3M Clinpro Sealant (3M ESPE, USA); U: Ultraseal XT Hydro (Ultradent, South Jordan, USA).

**TABLE 4. Surface roughness (Ra,  $\mu$ m) (mean  $\pm$  SD) of the tested materials.**

Group	Before thermocycling	After thermocycling	<i>p</i>
A	0.76 $\pm$ 0.19 0.73 (0.55–1.11)	1.38 $\pm$ 0.22 1.40 (1.03–1.71)	<i>Z</i> = –2.366 0.018
B	0.84 $\pm$ 0.16 0.78 (0.69–1.12)	1.45 $\pm$ 0.12 1.45 (1.25–1.58)	<i>Z</i> = –2.366 0.018
C	0.78 $\pm$ 0.25 0.79 (0.39–1.13)	1.49 $\pm$ 0.41 1.59 (0.63–1.81)	<i>Z</i> = –2.366 0.018
U	0.75 $\pm$ 0.18 0.83 (0.51–0.99)	1.46 $\pm$ 0.12 1.52 (1.31–1.59)	<i>Z</i> = –2.366 0.018
<i>p</i>	$\chi^2 = 1.071$ 0.784	$\chi^2 = 3.524$ 0.318	

$\chi^2$ : Kruskal-Wallis; *Z*: Wilcoxon; mean  $\pm$  s: deviation, median (minimum–maximum).

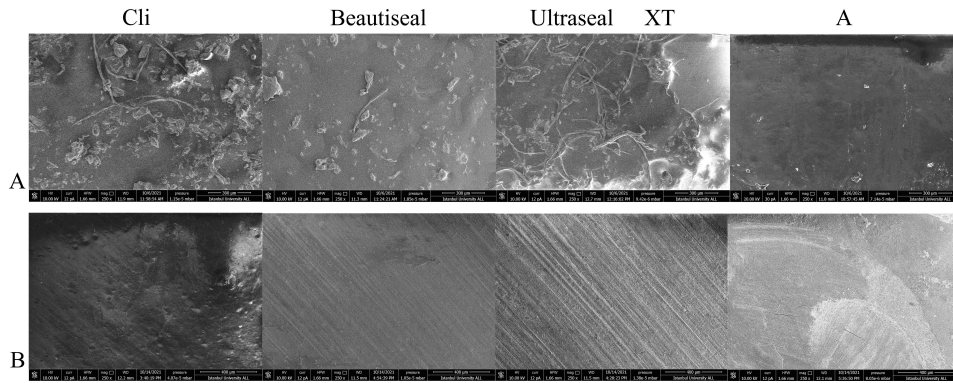
A: Aegis (Bosworth Company, USA); B: Beautisealant (BS; Shofu Inc., Kyoto, Japan); C: 3M Clinpro Sealant (3M ESPE, USA); U: Ultraseal XT Hydro (Ultradent, South Jordan, USA).

**TABLE 5. Weight loss (g) of the tested materials.**

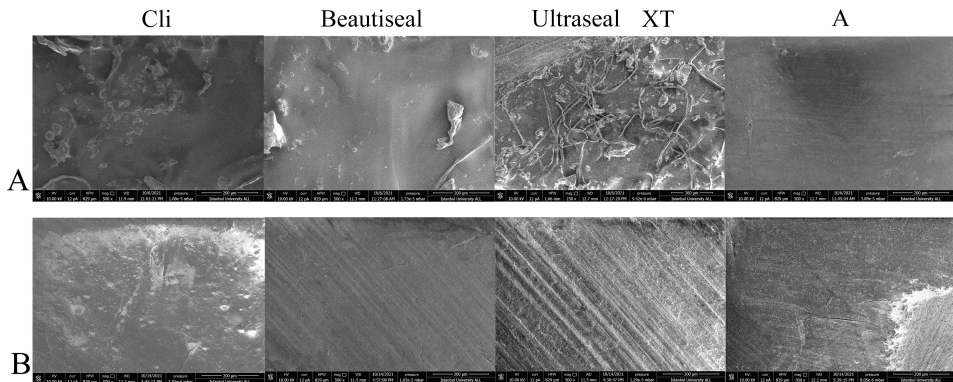
Group	Before chewing process	After chewing process	<i>p</i>
A	12.746 $\pm$ 0.484 12.521 (12.16–13.54)	12.739 $\pm$ 0.484 12.513 (12.16–13.53)	<i>t</i> = 21.172 <0.001
B	13.028 $\pm$ 0.596 13.226 (12.05–13.98)	13.02 $\pm$ 0.596 13.218 (12.05–13.97)	<i>t</i> = 38.834 <0.001
C	12.969 $\pm$ 0.645 12.913 (12.17–14.14)	12.965 $\pm$ 0.645 12.908 (12.16–14.14)	<i>t</i> = 50.328 <0.001
U	12.995 $\pm$ 0.905 12.917 (11.25–14.08)	12.985 $\pm$ 0.905 12.908 (11.24–14.07)	<i>t</i> = 14.426 <0.001
<i>p</i>	<i>F</i> = 0.288 <sup>b</sup> 0.833	<i>F</i> = 0.286 <sup>b</sup> 0.835	

<sup>b</sup>*F*: Analysis of variance test statistics; *t*: Paired samples *t*-test statistics; mean  $\pm$  s: deviation, median (minimum–maximum).

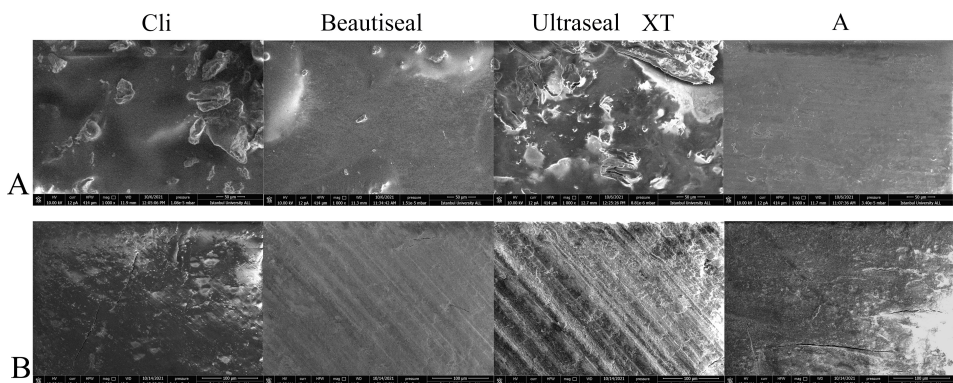
A: Aegis (Bosworth Company, USA); B: Beautisealant (BS; Shofu Inc., Kyoto, Japan); C: 3M Clinpro Sealant (3M ESPE, USA); U: Ultraseal XT Hydro (Ultradent, South Jordan, USA).



**FIGURE 3. Sem Images 250 $\times$ .** (A) SEM images of Clinpro, Beautisealant, Ultraseal XT Hydro, and Aegis before the chewing process (250 $\times$ ). The smooth and homogeneous image was observed for Group A in the beginning. Groups C and U particles were large and heterogeneous. (B) SEM images of Clinpro, Beautisealant, Ultraseal XT Hydro, and Aegis after chewing process (250 $\times$ ). An irregular surface was observed after the chewing simulator procedure for all groups due to the particles displacement by vertical and horizontal forces. The cracks significantly increased in the samples of Groups A and C, however they could not be clearly observed in Groups B and U after the chewing simulator process.



**FIGURE 4. Sem images 500 $\times$ .** (A) SEM images of Clinpro, Beautisealant, Ultraseal XT Hydro, and Aegis before the chewing process (500 $\times$ ). Group A exhibited the smooth and homogeneous image in the beginning while Groups C and U had shown large and heterogeneous particles. (B) SEM images of Clinpro, Beautisealant, Ultraseal XT Hydro, and Aegis after chewing process (500 $\times$ ). All groups showed irregular surface after the chewing simulator procedure due to the particles displacement by vertical and horizontal forces. Samples from Groups A and C exhibited significant increase in crack appearance, however, it was not clearly observed in Groups B and U after the chewing simulator process.



**FIGURE 5. Sem images 1000 $\times$ .** (A) SEM images of Clinpro, Beautisealant, Ultraseal XT Hydro, and Aegis before the chewing process (1000 $\times$ ). Group A exhibited the smooth and homogeneous image in the beginning while Groups C and U had shown large and heterogeneous particles. (B) SEM images of Clinpro, Beautisealant, Ultraseal XT Hydro, and Aegis after the chewing process (1000 $\times$ ). All groups showed irregular surface after the chewing simulator procedure due to the particles displacement by vertical and horizontal forces. Samples from Groups A and C exhibited significant increase in cracks, however they were not clearly observed in Groups B and U after the chewing simulator process.

venting the cavities and preserving dental tissues are less costly and time-consuming than the procedures restoring the existing cavities [14, 15].

More than 85% caries are seen on occlusal surfaces because of the complex morphology of pits and fissures. Oral and dental health education and fluoride application are not sufficient to prevent the occlusal caries, and thus the pit and fissure sealants are widespread [16, 17]. The pit and fissure sealant effectiveness in preventing occlusal caries has led to the studies on developing these materials.

In this study, the physical values of fissure sealant materials after aging procedures are compared to determine the most suitable for the clinical applications.

In literature, no study is found that compares the microhardness of fissure sealant materials used in this study before and after the thermal cycling and aging. In addition, there is no study examining the microhardness of Beautisealant, a fissure sealant containing surface prereacted glass ionomer (S-PRG). Beautisealant creates long-lasting glass ionomer phase using S-PRG, which yields urethane resin having silica upon combining with polyalkenoic acid. There is an improved giomer sealant's fluoride release capability [18].

This study is unique regarding Aegis® pit and fissure sealant containing ACP as no similar study is found. This light-curing sealant exhibits comparable characteristics to the conventional resin-based sealants. Amorphous calcium phosphate (ACP) serves as a precursor for creating hydroxyapatite (HAP) which is the stable product when calcium and phosphate ions precipitate from neutral or alkaline solutions. ACP has anti-cariogenic characteristics with the potential for remineralization. Bioactive materials containing ACP stimulate the minerals growth by elevating calcium and phosphate concentrations in the lesion, particularly in acidic oral environments which surpass those in the natural oral fluids. This shift in thermodynamic driving forces promotes apatite formation. ACP sustains supersaturation conditions for prolonged periods. ACP exhibits preventive and restorative properties for applying in dental cements, sealants, composites, and orthodontic adhesives. ACP-filled composite resins restore 71% of minerals lost in demineralized teeth [19].

Material hardness promotes the efficacy of fissure sealants by resisting to deforming forces. The material hardness is associated with fracture resistance, yield strength, and modulus of elasticity. An ideal fissure sealant requires high hardness value [20].

Acid-based glass ionomer cement (GIC) materials have the ability to chemically bond with tooth structure and release fluoride over time. However, the mechanical properties of glass ionomer fissure sealants are weak. Their durability is increased through thermo-curing method. The thermo-curing of acid-based GIC fissure sealants can increase their compressive and flexural strengths, and surface hardness which in turn improve their longevity and clinical performance [21].

The findings of this study exhibited a decrease in microhardness values of all the fissure sealant materials after thermal cycle procedure. The lowest microhardness value was of Clinpro before the thermal cycle procedure ( $18.27 \pm 1.24$  VHN), which was consistent with the studies by Beun *et al.* [22] and Kuşgöz *et al.* [23]. The decreased microhardness in Clinpro group was

observed after the thermal cycle procedure. This decreased microhardness was like Botsalı *et al.* [24] studies which examined the effects of various light sources on microhardness of fissure sealants. The decreased microhardness values of Ultraseal XT Hydro and Aegis materials after thermal cycle were similar to the results of Güçlü *et al.* [25].

Dental materials' surface roughness defines clinical success and aesthetic appearance of the materials. The materials' high surface roughness increases plaque accumulation on restorations which leads to caries and gingival irritation [26, 27].

The physical properties of fissure sealants in this study are also evaluated through another parameter, *i.e.*, the roughness values before and after thermal cycle procedure. Diverse opinions exist regarding the minimum surface roughness value to prevent bacterial attachment to restoration surface. According to Weitman and Eames, the plaque deposition was observed on composite materials with the surface roughness between 0.7 and 1.44  $\mu\text{m}$  [22]. In Kapoor *et al.* [28, 29] study, the threshold roughness was determined as 0.2  $\mu\text{m}$  above which the bacterial attachment occurred.

Ra values above the threshold are observed in all fissure sealants regarding roughness values before and after the thermal cycle. The surface roughness of restorative materials is linked to the material content and particle size. The surface roughness increases with the increase in particle size [30–32]. Accordingly, Beautisealant material containing pre-reacted glass particles has the highest roughness before thermal cycle in this study.

According to Bürger *et al.* [33] and Cildir *et al.* [34], the resin containing Clinpro and hydrophilic Ultraseal XT Hydro materials had the lowest roughness values, which were consistent with the roughness values before thermal cycle procedure in this study.

The high wear resistance of restoration affects its efficacy. The biological particles released into oral environment due to abrasion may cause inflammatory response [35]. The amount of wear on materials after chewing simulator procedure is thus evaluated in this study. A study compared the wear rates of three fissure sealants after the aging procedure with weight loss method. Fuji Triage with glass ionomer showed the highest weight loss while Clinpro material had the least [11].

Various *in vitro* aging methods are applied to predict the issues of restorations in intraoral conditions. Thermal cycling alone is applied for aging in most studies to evaluate the fissure sealants [10, 36, 37]. In two studies, a chewing simulator with thermal cycling was used as the aging method, wherein the microleakage and edge compatibility of resin-containing fissure sealant materials were evaluated [38, 39].

SEM analysis examines the surface properties of materials [40]. The particle sizes and distributions in the materials are observed in SEM images at proper magnification ratios [41, 42]. In this study, the surface properties of fissure sealants before and after the chewing simulation procedure were examined with SEM. The roughness and wear values of fissure sealant materials were compatible with the SEM images. The homogeneous and smooth surface images were observed in Aegis material, and heterogeneous particle structures in Clinpro and Ultraseal XT Hydro materials in the SEM analysis before chewing simulation. The material surfaces after

chewing simulation were evaluated to monitor the changes. The particle appearances were declined in all fissure sealant materials, and cracks were observed on irregular surfaces. The most cracks were observed in the order of Clinpro, Aegis, Ultraseal XT Hydro, and Beautisealant material samples. In literature, no study was found regarding the SEM imaging method to examine the surface properties of fissure sealants used in this study. Some studies reported materials showing similar morphological surface patterns in SEM despite differences in mean roughness values [43]. Other studies reported differences and changes in roughness values as observed in SEM images [44].

## 5. Conclusions

The surface properties of fissure sealant materials after aging procedures were affected in various degrees. The fissure sealant material containing ACP (Aegis) showed the least change than other materials after aging procedures; and the sealant material containing S-PRG (Beautisealant) was found as the second material exhibiting less change after aging procedures. These materials were not affected by aging procedures as much as the resin-based sealant material (Clinpro); thus, they could be used in clinics by postoperative controls. The study findings demonstrated Ultraseal XT Hydro as the most affected material by aging procedures; however, its use with periodic check-ups exhibit advantages in children who cannot provide moisture isolation or requiring special care. In addition to the findings of *in vitro* studies, the selection of fissure sealant material in children should consider the content, advantages/disadvantages, long-term clinical success rates, specific features of pediatric patient, and individual treatment needs. The findings obtained through *in vitro* aging procedures should be supported by long-term clinical studies.

## AVAILABILITY OF DATA AND MATERIALS

Authors regret to inform that the data used in this study is not available for sharing. The data may contain sensitive information or be subject to copyright or patent restrictions, which restrict their disclosure. Additionally, ethical or privacy considerations, participant consent, or other legal regulations may prevent data sharing. Furthermore, authors may not have access to the necessary resources for data sharing. However, for any further information or verification requests regarding the findings of this study, please feel free to contact corresponding author.

## AUTHOR CONTRIBUTIONS

HCA and OA—designed the research study, analyzed the data, wrote the manuscript. HCA—performed the research. OA—provided help and advice on. 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.

## REFERENCES

- [1] Wen PYF, Chen MX, Zhong YJ, Dong QQ, Wong HM. Global burden and inequality of dental caries, 1990 to 2019. *Journal of Dental Research*. 2022; 101: 392–399.
- [2] Pitts NB, Twetman S, Fisher J, Marsh PD. Understanding dental caries as a non-communicable disease. *British Dental Journal*. 2021; 231: 749–753.
- [3] Butera A, Maiorani C, Morandini A, Simonini M, Morittu S, Trombini J, *et al*. Evaluation of children caries risk factors: a narrative review of nutritional aspects, oral hygiene habits, and bacterial alterations. *Children*. 2022; 9: 262.
- [4] Kharouba J, Gonoratsky AA, Brosh T, Masri M, Iraqi R, Blumer S. Effect of different etching times on pit-and-fissure sealant micro-shear bond strength to the enamel of primary teeth. *Children*. 2023; 10: 461.
- [5] Chen W, Jiang Q, Yan G, Yang D. The oral microbiome and salivary proteins influence caries in children aged 6 to 8 years. *BMC Oral Health*. 2020; 20: 295.
- [6] Strużycka I. The oral microbiome in dental caries. *Polish Journal of Microbiology*. 2014; 63: 127–135.
- [7] Memarpour M, Rafiee A, Shafiei F, Dorudizadeh T, Kamran S. Adhesion of three types of fissure sealant in saliva-contaminated and noncontaminated conditions: an *in vitro* study. *European Archives of Paediatric Dentistry*. 2021; 22: 813–821.
- [8] Rodriguez TM, Ardu S, Daeniker L, Krejci I. Evaluation of marginal adaptation, seal and resistance against fatigue cracks of different pit and fissure sealants under laboratory load. *American Journal of Dentistry*. 2011; 24: 367–371.
- [9] Pala K, Tekçe N, Tuncer S, Serim ME, Demirci M. Evaluation of the surface hardness, roughness, gloss and color of composites after different finishing/polishing treatments and thermocycling using a multitechnique approach. *Dental Materials Journal*. 2016; 35: 278–289.
- [10] Pardi V, Sinhoreti MAC, Pereira AC, Ambrosano GMB, Meneghim MDC. *In vitro* evaluation of microleakage of different materials used as pit-and-fissure sealants. *Brazilian Dental Journal*. 2006; 17: 49–52.
- [11] Soliman N, Mohamed M. *In vitro* evaluation of wear resistance of different fissure sealants after aging procedures. *Egyptian Dental Journal*. 2017; 63: 1729–1737.
- [12] Tekçe N, Pala K, Tuncer S, Demirci M. The effect of surface sealant application and accelerated aging on posterior restorative surfaces: an SEM and AFM study. *Dental Materials Journal*. 2017; 36: 182–189.
- [13] Chowdhary N, Prabakar T, Konkappa KN, Vundela RR, Balamurugan S. Evaluation of microleakage of different types of pit and fissure sealants: an *in vitro* comparative study. *International Journal of Clinical Pediatric Dentistry*. 2023; 15: 535–540.
- [14] Kashbour W, Gupta P, Worthington HV, Boyers D. Pit and fissure sealants versus fluoride varnishes for preventing dental decay in the



- permanent teeth of children and adolescents. *Cochrane Database of Systematic Reviews*. 2020; 11: CD003067.
- [15] Li F, Jiang P, Yu F. Comparison between fissure sealant and fluoride varnish on caries prevention for first permanent molars: a systematic review and meta-analysis. *Scientific Reports*. 2020; 10: 2578.
- [16] Gimenez T, Estevam LR, de Oliveira Ponte Y, Dalboni A, Calvo AFB, Tedesco TK, *et al.* Is there an acceptable surrogate for caries clinical trials? Evidence from a systematic review of primary studies. *Community Dentistry and Oral Epidemiology*. 2023. [Preprint].
- [17] Jafarzadeh D, Rezapour R, Abbasi T, Tabrizi J, Zeinolabedini M, Khalili A, *et al.* The effectiveness of fluoride varnish and fissure sealant in elementary school children: a systematic review and meta-analysis. *Iranian Journal of Public Health*. 2022; 51: 266–277.
- [18] Trehan M, Yadav S, Senthilkumar A, Chhabra C, Pradhan S, Shamsudeen NH. Comparative evaluation of fluoride release from glass ionomer, compomer, and giomer sealants following exposure to fluoride toothpaste and fluoride varnish: an *in vitro* study. *International Journal of Clinical Pediatric Dentistry*. 2023; 15: 736–738.
- [19] Zawaideh FI, Owais AI, Kawaja W. Ability of pit and fissure sealant-containing amorphous calcium phosphate to inhibit enamel demineralization. *International Journal of Clinical Pediatric Dentistry*. 2016; 9: 10–14.
- [20] Saati K, Khansari S, Mahdisiar F, Valizadeh S. Evaluation of microhardness of two bulk-fill composite resins compared to a conventional composite resin on surface and in different depths. *Journal of Dentistry*. 2022; 23: 58–64.
- [21] Subramaniam P, Kiran K, Vojjala B. Comparison of clinical efficacy of glass ionomer-based sealant using ART protocol and resin-based sealant on primary molars in children. *International Journal of Clinical Pediatric Dentistry*. 2023; 15: 724–728.
- [22] Beun S, Bailly C, Devaux J, Leloup G. Physical, mechanical and rheological characterization of resin-based pit and fissure sealants compared to flowable resin composites. *Dental Materials*. 2012; 28: 349–359.
- [23] Kuşgöz A, Tüzüner T, Ülker M, Kemer B, Saray O. Conversion degree, microhardness, microleakage and fluoride release of different fissure sealants. *Journal of the Mechanical Behavior of Biomedical Materials*. 2010; 3: 594–599.
- [24] Altunsoy M, Botsali MS, Tosun G, Yaşar A. Effect of different exposure times on the amount of residual monomer released from adhesive systems. *Acta Odontologica Turcica*. 2013; 30: 6–12. (In Turkish)
- [25] Güçlü ZA, Dönmez N, Hurt AP, Coleman NJ. Characterisation and microleakage of a new hydrophilic fissure sealant—UltraSeal XT® hydro™. *Journal of Applied Oral Science*. 2016; 24: 344–351.
- [26] Kessler A, Kapor S, Erdelt K, Hickel R, Edelhoff D, Syrek A, *et al.* Two-body wear and fracture behaviour of an experimental paediatric composite crown in comparison to zirconia and stainless steel crowns dependent on the cementation mode. *Dental Materials*. 2021; 37: 264–271.
- [27] Zhou Y, Huang X, Wu L, Liang Y, Huang Y, Huang S. Microleakage, microgap, and shear bond strength of an infiltrant for pit and fissure sealing. *Heliyon*. 2023; 9: e16248.
- [28] Kapoor V, Kumar A, Manjunath BC, Yadav V, Sabbarwal B. Comparative evaluation of retention and cariostatic effect of glass ionomer, hydrophobic & hydrophilic resin-based sealants: a systematic review and meta-analysis. *Evidence Based Dentistry*. 2023; 24: 41–42.
- [29] Heintze S, Forjanic M, Rousson V. Surface roughness and gloss of dental materials as a function of force and polishing time *in vitro*. *Dental Materials*. 2006; 22: 146–165.
- [30] Bayraktar DY, Doğan DD, Ercan E. Effect of the different polishing systems and techniques on surface roughness of three different composite resin. *Current Research in Dental Sciences*. 2013; 23: 192–198. (In Turkish)
- [31] Moda MD, Godas AGDL, Fernandes JC, Suzuki TYU, Guedes APA, Briso ALF, *et al.* Comparison of different polishing methods on the surface roughness of microhybrid, microfill, and nanofill composite resins. *Journal of Investigative and Clinical Dentistry*. 2018; 9.
- [32] Ryba TM, Dunn WJ, Murchison DF. Surface roughness of various packable composites. *Operative Dentistry*. 2002; 27: 243–247.
- [33] Bürgers R, Cariaga T, Müller R, Rosentritt M, Reischl U, Handel G, *et al.* Effects of aging on surface properties and adhesion of *Streptococcus mutans* on various fissure sealants. *Clinical Oral Investigations*. 2009; 13: 419–426.
- [34] Kavaloglu Cildir S, Sandalli N. Compressive strength, surface roughness, fluoride release and recharge of four new fluoride-releasing fissure sealants. *Dental Materials Journal*. 2007; 26: 335–341.
- [35] Dederichs M, Fahmy MD, An H, Guentsch A, Viebranz S, Kuepper H. Comparison of wear resistance of prefabricated composite veneers versus ceramic and enamel. *Journal of Prosthodontics*. 2021; 30: 711–719.
- [36] Baygin O, Korkmaz FM, Tüzüner T, Tanriver M. The effect of different enamel surface treatments on the microleakage of fissure sealants. *Lasers in Medical Science*. 2012; 27: 153–160.
- [37] Mosleh AA, Abdallah SA, Shishiny SA, Mourad YO. Comparison of microleakage of different surface pre-treatment modalities of ionoseal® pit and fissure sealant in primary teeth: an *in vitro* study. *Journal of the Indian Society of Pedodontics and Preventive Dentistry*. 2022; 40: 453–458.
- [38] Koyuturk AE, Kusgoz A, Ulker M, Yesilyurt C. Effects of mechanical and thermal aging on microleakage of different fissure sealants. *Dental Materials Journal*. 2008; 27: 795–801.
- [39] Rodriguez TM, Ardu S, Daeniker L, Krejci I. Evaluation of marginal adaptation, seal and resistance against fatigue cracks of different pit and fissure sealants under laboratory load. *American Journal of Dentistry*. 2011; 24: 367–371.
- [40] Kakaboura A, Fragouli M, Rahiotis C, Silikas N. Evaluation of surface characteristics of dental composites using profilometry, scanning electron, atomic force microscopy and gloss-meter. *Journal of Materials Science: Materials in Medicine*. 2007; 18: 155–163.
- [41] Nikolaidis A, Vouzara T, Koulaouzidou E. Pit and fissure nanocomposite sealants reinforced with organically modified montmorillonite: a study of their mechanical properties, surface roughness and color stability. *Dental Materials Journal*. 2020; 39: 773–783.
- [42] Ruivo MA, Pacheco RR, Sebold M, Giannini M. Surface roughness and filler particles characterization of resin-based composites. *Microscopy Research and Technique*. 2019; 82: 1756–1767.
- [43] Bala O, Arisu DH, Yikilgan I, Arslan S, Gullu A. Evaluation of surface roughness and hardness of different glass ionomer cements. *European Journal of Dentistry*. 2012; 6: 79–86.
- [44] Moreira K, Kantovitz K, Bueno T, Agulhari M, Rizzante F, Aguiar J, *et al.* Indirect evaluation of pit and fissure sealants: a 3D-based method validation. *Journal of Clinical and Experimental Dentistry*. 2020; 12: e852–e856.

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