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Comparative evaluation of wear resistance, surface roughness for three pit and fissure sealants with different filler content: An *in vitro* study

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Abstract:
Pit and fissure sealants clinical success depends on wear resistance and surface smoothness, yet optimal filler content balancing these properties remains unclear. Therefore, it is of interest to compare the unfilled (Clinpro), moderately filled (Helioseal F Plus, ~25% wt) and highly filled (Fissurit FX, ~55% wt) sealants using 24 disc samples (n=8/group) fabricated via STL printing and silicone molds. Wear resistance increased with filler content (Fissurit FX > Helioseal F Plus > Clinpro), while surface roughness showed inverse relationship (Clinpro smoothest, Fissurit FX roughest). Helioseal F Plus showed optimal balance with moderate roughness and improved wear resistance compared to extremes. Thus, data shows that filled sealants as a superior clinical compromise between durability and smoothness for long-term caries prevention.

Keywords: Pit and fissure sealants, filler content, wear resistance, surface roughness, preventive dentistry, *in vitro* study

Background:
Dental caries is one of the most common chronic diseases in the world, especially on the occlusal surfaces of the posterior teeth because of their complicated pit and fissure morphology **[1]**. These structural anomalies provide good niches where plaque and bacteria can thrive and hence, they are very prone to caries even with good oral health in people **[2]**. Pit and fissure sealants have become a viable preventive measure in that they create a physical barrier that prevents the entry of cariogenic microorganisms and fermentable substances **[3]**. The sealant materials have evolved greatly since their introduction with advancement in their physical, mechanical and handling properties. Traditional resin-based sealants may be broadly classified in terms of filler content as unfilled, moderately filled and highly filled materials **[4]**. Filler incorporation increases mechanical strength, abrasion resistance and longevity, but can also affect viscosity, penetration ability and surface properties **[5]**. Wear resistance is a vital characteristic of pit and fissure sealants, especially in stress-bearing occlusive where materials face masticatory forces and abrasive challenges **[6]**. Poorly wear-resistant materials can experience rapid degradation, causing loss of sealants and consequent risk of caries. Research has showed that the higher the filler content, the higher the wear resistance because of the reinforcement of the resin matrix and resistance to the occlusal stresses **[7]**. This is however usually achieved at the expense of higher viscosity which may affect the capacity of the sealant to penetrate deep fissures effectively **[8]**. Another parameter that affects the clinical performance of sealants is surface roughness. A smoother surface is preferable because it decreases the plaque formation, bacterial adhesion and secondary caries risk **[9]**. On the other hand, higher filler content can result in a rougher surface as a result of the protrusion of filler particles and the asymmetrical wear marks after abrasion **[10]**. This two-fold effect presents a clinical dilemma in choosing the best sealant material. Unfilled sealants are known for their low viscosity and superior penetration into narrow fissures, which enhances micromechanical retention and marginal adaptation **[11]**. They have however low wear resistance, which can restrict their long-term durability particularly in high-stress regions. Conversely, highly filled sealants have better mechanical strength and resistance to occlusal wear but can be difficult in terms of penetration and roughness of the surface **[12]**. To fill this gap, moderately filled sealants have been launched that provide a compromise between flowability and mechanical strength. The purpose of these materials is to attain sufficient penetration and at the same time, have a high degree of wear resistance and acceptable surface smoothness **[6]**. Although different sealant formulations are available, there is no consensus on the best filler content that guarantees durability and good surface properties. *In vitro* testing is important to test the properties of materials under controlled conditions and to enable a standardized comparison of various types of sealants. Objective measurements of parameters like wear resistance and surface roughness can be made, which can be useful in understanding the material performance prior to clinical use **[8]**. Therefore, it is of interest to compare the wear resistance and surface roughness of three popular pit and fissure sealants of different filler content and knowledge of the correlation between filler composition and material properties can help clinicians to choose the best sealant to prevent caries in the long term.

Materials and Methods:
Study design:
The present study was designed as an *in vitro* experimental study to comparatively evaluate the wear resistance and surface roughness of three commercially available pit and fissure sealants with varying filler content, conducted in Department of Preventive and Paediatric dentistry, New horizon dental college and research institute, Bilaspur, Chhattisgarh.

Sample size and grouping:
A total of 24 disc-shaped specimens were prepared and divided into three groups (n = 8 per group) based on the type of sealant used:
[1] Group A (Unfilled Sealant): 3M Clinpro Sealant
[2] Group B (Moderately Filled Sealant): Helioseal F Plus (≈25% filler by weight)

[3] Group C (Highly Filled Sealant): Fissurit FX (≈55% filler by weight)

Each group consisted of 8 samples, which were subjected to evaluation for surface roughness and wear resistance.

Design and fabrication of samples:

The silicone molds of 13 mm diameter and 2 mm width is used to create disc-shaped specimens. According to the manufacturers' instruction, the fissure sealant materials were applied in equal amounts to silicone molds placed on flat glass plate. 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 according to manufactures instruction. The surfaces of samples were wet sanded with sandpapers and polished with polishing wheel and kept in distilled water. A total of 24 disc-shaped samples were prepared, with 8 samples in each of the three groups of different pit and fissure sealants. Each sample had a diameter of 13 mm and a thickness of 2 mm. The dimensions of the samples were verified using a Manha electronic digital caliper. The experimental samples were then divided into three different groups for the evaluation of surface roughness and wear. The disc-shaped specimens were thermocycled 500 times using electronic thermal cycling machine. They were put in water baths at 5 ± 2°C and 55 ± 2°C with 20 seconds dwell time in each bath. They were all stored in distilled water at 37°C. Thermocycling was done to simulate oral conditions before the samples were subjected to testing. The resin samples (diameter of 13 mm and width of 2 mm) of desired dimensions as mentioned above were designed using SketchUp software (Trimble Inc. year) and a Standard Tessellation Files (STL) were created and then the samples were printed. Thermoplastic silicone molds were then fabricated using soft thermoplastic sheet (durasoft) which was heated for 65 sec in a ministar (Scheu- Dental) machine at a temperature of 60 degree Celsius and then vacuum pressed for 110 sec over the resin samples. The experimental samples were then divided into three different groups for the evaluation of surface roughness and wear.

Group A: The unfilled pit and fissure sealant (3M Clinpro sealant) was packed inside the silicone mold and the excess sealant was removed. To create a smooth level surface and to prevent the formation of oxygen inhibiting layer the sealant was then covered with a clean glass slide. Finger pressure was then applied to achieve a smooth surface and good adaptation of the sealant. Curing was performed with blue phase light curing unit for 20 seconds overall in all the surfaces according to manufactures instructions. Total 8 discs were prepared for surface roughness and wear resistance using 3M Clinpro sealant.

Group B: Similarly, as mentioned above total 8 disc shaped sample were fabricated using moderately filled pit and fissure sealant (Helioseal F Plus) of dimension of 13 mm diameter and 2 mm width. Curing was followed according to manufactures instructions i.e. 20 sec.

Group C: Similarly, as mentioned above total 8 disc shaped sample were fabricated using highly filled pit and fissure sealant (Fissurit FX) of dimension of 13 mm diameter and 2 mm width. Curing was followed according to manufactures instructions i.e. 20 sec.

Finishing and polishing of samples:

The samples were smoothed using a micromotor handpiece (Marathon-4, Saeyang Microtech Co. Ltd. Korea) and a sandpaper mandrel (Indian Sand Paper Mandrel, India) at 5000 rpm for 15 sec. Then wet grinding was done with 400 and 600 grit silicon carbide paper using a micromotor handpiece (Marathon-4, Saeyang Microtech Co. Ltd. Korea) and a sandpaper mandrel (Indian Sand Paper Mandrel, India) at 5000rpm for 15sec. The finished samples were stored in distilled water at a temperature of 37+FC for 24 +2 hours before sending them to the laboratory for testing.

Surface roughness estimation using surface roughness tester, mitutoyo, japan. Model: Sj 210

The surface roughness of 12 specimens (four per each sealant) was measured using Surface Roughness Tester, Mitutoyo, Japan. Model: SJ 210 with Stylus Speed: 0.5mm/s, Cut off

Length: 4 mm. 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.

Wear resistance test using two body testing machine:

The wear resistance of 12 specimens (four per each sealant) will be taken in two body wear testing machine. After testing, The substance loss for specimens was determined by weighing before and after using two body wear testing machine. The wear resistance will be calculated by using formula:

Percentage wear:

$$\frac{Initial\ weight\ of\ disc - after\ weight\ of\ disc}{Initial\ weight\ of\ disc} \times 100$$

The surface roughness of specimens was measured using Surface Roughness Tester, Mitutoyo, Japan. Model: SJ 210. The average roughness for each specimen were then calculated and recorded.

Statistical analysis:

The collected data were tabulated and analyzed using appropriate statistical software. Mean and standard deviation were calculated for both surface roughness and wear resistance. Intergroup comparisons were performed using One-way Analysis of Variance (ANOVA). Post hoc analysis (Tukey's test) was applied for pairwise comparisons. A p-value < 0.05 was considered statistically significant.

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Results:

The study comprised a total of 24 samples, which were equally distributed into three groups based on the filler content of the pit and fissure sealants. Each group contained 8 specimens, ensuring uniform sample size and comparability. Group A included the unfilled sealant (3M Clinpro), representing materials with minimal viscosity and no filler particles. Group B consisted of the moderately filled sealant (Helioseal F Plus), providing an intermediate filler composition. Group C comprised the highly filled sealant (Fissurit FX), representing materials with maximum filler loading. This equal distribution allows for a balanced comparative evaluation, minimizing sampling bias and enabling reliable assessment of how varying filler content influences wear resistance and surface roughness **(Table 1)**. Surface roughness showed a statistically significant overall difference among groups (p = 0.019), increasing with filler content, with Group C showing the highest roughness. However, pairwise comparisons revealed significance only between Group A and Group C. Wear resistance demonstrated a highly significant difference (p < 0.001), with values increasing progressively from Group A to Group C, indicating that higher filler content enhances resistance to wear **(Table 2)**. Inter-group comparison for surface roughness of pit and fissure sealant showed that there was statistically significant difference between 3M Clinpro sealant and Fissurit FX (p=0.014) except between Fissurit FX and Helioseal F Plus (p=0.199), Helioseal F Plus and Fissurit FX (p=0.403) **(Table 3)**. Inter-group comparison for wear resistance of pit and fissure sealant showed that there is highly significant difference between 3M Clinpro, Fissurit FX and Helioseal F Plus (p<0.001). The mean value was highest for Fissurit FX in comparison with 3M Clinpro and Helioseal F Plus (p<0.001) **(Table 4)**.

Table 1: Showing distribution of total sample size according to type of pit and fissure sealants

Groups	Pit and fissure sealants	No. of samples
Group A	Unfilled (3M clinpro)	08
Group B	Moderately filled (Healioseal f plus)	08
Group C	Highly filled (Fissurit FX)	08

Table 2: Surface roughness, wear resistance and intergroup comparison

Parameter	Group	Sealant Type	Mean	SD	Overall P value
Surface Roughness (µm)	Group A	3M Clinpro (Unfilled)	0.039	0.015	0.019*
	Group B	Helioseal F Plus (Moderately filled)	0.064	0.019	
	Group C	Fissurit FX (Highly filled)	0.083	0.042	
Wear Resistance (%)	Group A	3M Clinpro (Unfilled)	0.32	0.13	<0.001*
	Group B	Helioseal F Plus (Moderately filled)	0.75	0.21	
	Group C	Fissurit FX (Highly filled)	1.14	0.12	

Table 3: Inter-group comparison of Surface Roughness

Group	Mean	SD	P value
Group A (3M Clinpro sealant) vs.	0.039	0.015	0.199
Group B (Helioseal F Plus)	0.064	0.019	
Group B (Helioseal F Plus) vs.	0.064	0.019	0.403
Group C (Fissurit FX)	0.083	0.042	
Group A (3M Clinpro sealant) vs.	0.039	0.015	0.014*
Group C (Fissurit FX)	0.083	0.042	

Table 4: Inter-group comparison of Wear resistance

Group	Mean	SD	P value
Group A (3M Clinpro sealant) vs.	0.32	0.13	<0.001*
Group B (Helioseal F Plus)	0.75	0.21	
Group B (Helioseal F Plus) vs.	0.75	0.21	<0.001*
Group C (Fissurit FX)	1.14	0.12	
Group A (3M Clinpro sealant) vs.	0.32	0.13	<0.001*
Group C (Fissurit FX)	1.14	0.12	

Discussion:

Pit and fissure sealants are still considered to be one of the most effective preventive measures against occlusal caries, especially in high-risk patients. Mechanical durability and surface properties of these materials are highly reliant on their filler content and determine their long-term success. The *in vitro* experiment was carried out to compare and contrast the wear resistance and surface roughness of three popular sealants with different filler percentages. The results of this paper have shown that filler content is an important factor in the wear resistance and surface roughness and hence, the clinical performance of pit and fissure sealants. The findings indicated that the surface roughness of the groups was statistically different (p = 0.019) and the roughness was higher with an increase in filler content. Likewise, the difference in wear resistance (p < 0.001) was also very significant, with an increased filler content leading to a better resistance to material loss. The high wear resistance of the highly filled sealant (Fissurit FX) can be explained by the fact that the resin contains a greater percentage of inorganic filler particles in the resin matrix. These fillers are used to improve the mechanical properties of the material by increasing resistance to abrasion and occlusal forces. The result is in line with other research by Gurbuz *et al.* **[1]** and Kumar *et al.* **[2],** who established that the higher the filler loading the greater the resistance of resin-based materials to mechanical degradation under masticatory stress. The reinforcing effect of fillers minimizes the deformation of the matrix and minimizes the loss of the material in the two-body abrasion. Conversely, the unfilled sealant (3M Clinpro) had the lowest wear resistance, possibly because of the lack of reinforcing filler particles. The resin matrix is more prone to wear when subjected to repeat mechanical loading and thus degrades more rapidly. Priscilla *et al.* **[3]** also made similar observations and concluded that unfilled sealants, despite their benefits in terms of penetration, exhibit poorer resistance to occlusal wear. The present study conducted surface roughness analysis where the opposite was found in relation to wear resistance. The sealant with the lowest values of Ra (unfilled) showed the smoothest surface, whereas the roughest surface was observed with the highly filled sealant. This is attributed to the fact that there are filler particles that are likely to stick out of the resin matrix after polymerization or wear, thus augmenting surface irregularities. Zheng *et al.* **[4]** emphasized that surface roughness depends on the filler size, distribution and bonding between the matrix and fillers and the fillers that are not well integrated lead to a higher roughness. The clinical implication of rougher surfaces is very important because rough surfaces favor the growth of plaque and adhesion of bacteria, which may enhance the chances of secondary caries

[5]. Hence, although highly filled sealants have better wear resistance, their roughness can negatively affect their long-term preventive effectiveness. This two-fold effect highlights the significance of the balance between mechanical strength and surface smoothness. These findings are also supported by intergroup comparisons in the current study. The statistically significant difference in the surface roughness was found between Group A (Clinpro) and Group C (Fissurit FX) only ($p = 0.014$), which means that the effect of filler content is more pronounced at higher concentrations. Nevertheless, there was no significant difference between Group A and Group B or Group B and Group C, which indicates that moderate filler levels might not have a drastic effect on surface texture. In terms of wear resistance, there was a very significant difference between all groups ($p < 0.001$), with Fissurit FX showing the highest mean values. These results are consistent with the findings of de Jesus *et al.* **[6],** who found that the higher the filler loading, the better the resistance to abrasive wear. In the same manner, Naaman *et al.* **[7]** highlighted that filled sealants have better retention because of increased resistance to occlusal forces. The sealant with medium fill (Helioseal F Plus) showed moderate values of surface roughness and wear resistance, indicating a balanced performance. This is clinically pertinent, because it suggests that moderate filler content can offer a good trade-off between durability and surface smoothness. Sivavong *et al.* **[8]** also suggested that materials with balanced properties are more suitable for long-term clinical success, as they combine adequate penetration with sufficient mechanical strength. Viscosity of sealant materials is another factor to consider. Low viscosity sealants (unfilled) have better penetration into deep and narrow fissures leading to better micromechanical retention **[9]**. Nevertheless, they might have a short life due to their reduced wear resistance. Conversely, highly filled sealants, although mechanically superior, can be less flowable, which can influence their capability to effectively seal complex fissure patterns **[10]**. The results of the current research are consistent with those of Ifzah and Kumar **[11]**, who stressed the importance of optimal balance between the flowability and mechanical properties in the choice of sealant. Too viscous materials cannot penetrate sufficiently and too fluid materials can be not durable. It should be mentioned that the study was carried out in in-vitro conditions, which might not completely simulate the complicated oral environment. Saliva, changes in pH, thermal cycling and masticatory dynamics are some of the factors that may affect the clinical performance of sealants **[12-14]**. Consistent with the present findings, resin-based and glass ionomer sealants coated with a nanofilled resin exhibited distinct mechanical advantages, with glass ionomer sealants showing greater wear resistance and resin-based sealants showing superior compressive strength **[15]**. Thus, the findings are useful in understanding the behavior of materials, but clinical research is required to confirm the findings. In spite of these shortcomings, the current research offers valuable information on the effect of filler content on the performance of sealants. The findings indicate that moderately filled sealants, including Helioseal F Plus, can provide a good balance between wear resistance and surface smoothness and thus, be more appropriate to use in clinical practice than unfilled or highly filled ones.

Conclusion:

Filler content significantly affects wear resistance and surface roughness of pit and fissure sealants, with higher filler content improving durability but increasing roughness that may promote plaque retention. Highly filled sealants (Fissurit FX) excel in mechanical performance while unfilled sealants (Clinpro) provide smoothest surfaces; Helioseal F Plus offers optimal balance. Moderately filled sealants emerge as clinically superior compromise for long-term caries prevention, warranting validation through prospective clinical trials.

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