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RESEARCH ARTICLE – DENTISTRY (MISCELLANEOUS)

Evaluation of the Effect of Potassium Fluoride Addition on Surface Roughness and Surface Hardness of Acrylic Resin Material

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Abstract

Background: Acrylic is currently the most popular material for dental prosthesis fabrication. Fluoridated denture base resins have shown more stable properties such as decreased water sorption, good stain resistance, and solubility when compared to conventional ones. Fluoride addition may improve their properties.
Objective of study: Analyze how adding potassium fluoride (2% and 5%) affects the heat-cured acrylic resin material's surface roughness and hardness.

Materials and Methods: Testing on sixty heat-cured acrylic resin samples revealed that the samples were divided into two main groups: thirty samples were tested for surface roughness and thirty samples for surface hardness. Each group was divided into three groups: the control group, which included ten heat acrylic resin specimens in any combination, and the other two groups, which included ten heat acrylic resin specimens plus 2% potassium fluoride, and ten heat acrylic resin specimens combined with 5% potassium fluoride. The surface roughness and hardness specimens were prepared with the following dimensions: 65 mm x 10 mm x 2.5 mm, respectively. Elcometer (shore D, Germany) and profilometer tester (Time 3200/TR200, China) were employed for the evaluated hardness and surface roughness tests, respectively.

Results: The surface hardness test findings showed no statistically significant differences between the study groups; however, surface roughness test results revealed differences that were statistically significant across all study groups at $P< 0.05$.
Conclusion: The addition of 2% and 5% potassium fluoride to heat-cured acrylic resin materials produced no effect on surface hardness but it influenced the roughness test.

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Keywords: Acrylic Resin; Potassium Fluoride; Surface Hardness; Surface Roughness.

1. Introduction

For more than 50 years, acrylic resins have been utilized to create denture bases. Controlling oral hygiene is essential for patients who wear acrylic resin appliances all day (orthodontic retainers or removable appliances), especially for dental caries, in which bacteria is a pathogenic factor. Notwithstanding acrylic's benefits, particularly its simplicity in manufacturing with low-tech equipment, various restrictions have been noted in earlier studies that may affect their mechanical qualities [1, 2]. Furthermore, in addition to these limits, discoloration impairs the capacity of dental prosthesis to support and foster microbial adherence, which in turn impacts how aesthetically acceptable they are [2, 3]. While typical denture cleaning techniques cannot entirely remove bacteria from dentures, in addition to their potential resistance to microbial adhesion, some materials can circumvent some of these drawbacks of traditional denture base resins.

The usage of fluoride acrylic was one of these examples [4]. These fluoride denture base resins have shown more stable characteristics when compared to conventional ones, including reduced water sorption, greater stain resistance, and solubility. The percentage of senior patients using removable partial dentures grew at the same time that root caries and gingival recession were both on the rise [5, 6].

These approaches all successfully ward against root caries and inhibit recurrent caries [6, 7]. Fluoridated acrylic resin material can present more stable properties when compared with conventional ones. The most widely used fluoride –containing substance added to dental resin materials is sodium fluoride (Naf). This study evaluated the effect of Naf in different concentrations on the acrylic resin denture base material and its effect on tensile strength, and modules of elasticity with long –term water immersion (after 4 months of immersion in de-ionized water) [7]. Fluoride salt added to acrylic resin materials serves as a fluoride releaser for up to six months. Fluoride salt added to acrylic resin materials serves as a fluoride releaser for up to six months. This study aimed to evaluate the effect of the incorporation of (2% and 5%) potassium fluoride on surface hardness and surface roughness of heat cured acrylic resin material.

2. Materials and Methods

2.1. Grouping of samples

Based on the tests that were going to be used, sixty heat-cured acrylic resin samples (Vertex, Netherlands) were produced and split into two primary groups: thirty for the surface roughness test and thirty for the surface hardness test.10 heat-cured acrylic resin specimens from each group10 without any incorporation (control group), 10 with 2% potassium fluoride incorporation, and ten with 5% potassium fluoride combination were placed in each of the three smaller groups [8].

1. Control Group: 10 specimens without any incorporation.
2. Experimental Group (2%): 10 specimens with incorporation of 2% by "weight of potassium fluoride" (KF).
3. Experimental Group (5%): 10 specimens with incorporation of 5% by "weight of potassium fluoride" (KF).

2.2. Incorporation of potassium fluoride into acrylic resin material

The weight of potassium fluoride(KF) was reduced from the weight of acrylic resin material to get the accurate P/L ratio [9], as shown in Table

Table 1. The percent of potassium fluoride (KF) mixed with the heat cure acrylic resin materials (powder + liquid) [10]

Type acrylic resin materials	Incorporation of potassium fluoride (KF) %	Amount of acrylic Powder (g)	Amount of acrylic Liquid (ml)	Quantity of potassium fluoride (gm.)
Heat cure acrylic resin materials	0%	100 g	40 ml	0 gm
	2% (KF)	98 g	40 ml	2 gm.
	5% (KF)	95 g	40 ml	5 gm.

The necessary quantity of potassium fluoride (KF) was thoroughly added to the liquid acrylic resin ingredients in a dry, clean glass jar. The mixture was then thoroughly stirred for three minutes using a 120 W and 60 KHz device to achieve total homogeneity. As a result, the heat-cure acrylic powder material was swiftly added to the prior mixture and combined with it by the acrylic resin material manufacturer's recommendations [11, 12].

2.3.1. Mold preparation for roughness and hardness test

The thirty specimens of metal patterns for roughness test were constructed with dimensions of millimeters (65mm x 10 mm x 2.5 mm), accordingly (length, breadth, and thickness), using a laser cutting machine (CNC), according to (ADA specification No.12, 1999), [12] as shown in Fig. 1.

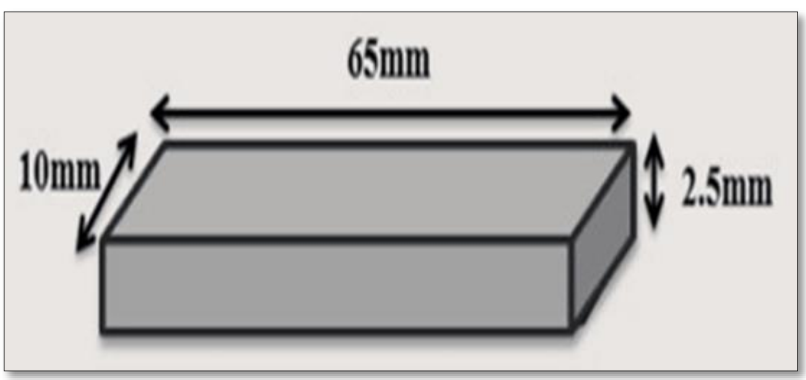

Fig. 1. Sample dimensions for surface roughness and hardness testing

2.3.2. Specimen preparation

After proportioning and mixing potassium fluoride" (KF) all specimens in the current investigation were packaged, cured, and deflasked. using heated acrylic resin materials. After completing each stage, to avoid overheating, the samples were cooled under running water. The additional specimen surface was finally eliminated without creating a polishing surface [13, 14]. All specimens of surface roughness test were immersed with artificial saliva for 2 months then starting testing [14].

2.3.3. Testing procedure for surface roughness

The surface roughness tests were measured by the profilometer Time 3200/TR200, a portable digital device with an accuracy of 0.001 µm. The devices come with a sensor needle (surface analyzer) fabricated from a diamond to track the rough surface. The specimens should be placed on fixed surfaces, and then the devices are adjusted in a manner that is placed just touches the surface of the specimen and moves along the (11mm) at three different points to get 3 readings from each specimen. The mean values of these three interpretations are represented as the roughness test value [14], as shown in Fig. 2.

Fig. 2. Specimen is subjected to surface roughness test

2.3.4. Testing procedure for surface hardness

The surface hardness tests were measured by the Digital Shore D dourmeter. This equipment is made up of a blunt –point indenter with a diameter of 0.08 mm that tapers to a 1.6mm diameter cylinder. A digital scale is attached to the indenter with a 0-100 unit graduation The digital scale reading was used to take measurements each specimen was indented five times. The mean values of these five interpretations are represented as the hardness test value [15], as shown in Fig. 3.

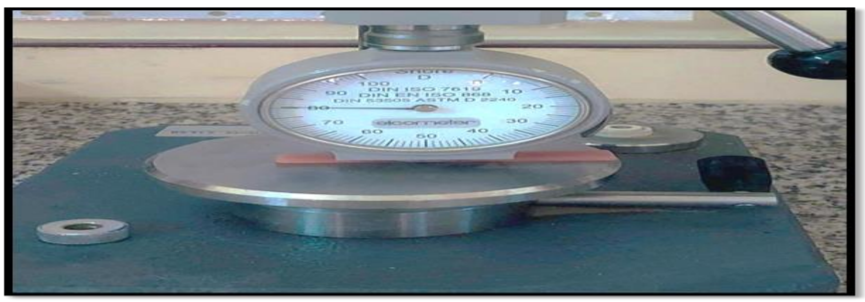

Fig. 3. Shore D dourmeter tester device for measuring the surface hardness of the heat acrylic resin specimen

2.4. Statistical analysis

SPSS V 0.28 for Windows and Microsoft Office Excel V 16 were used to enter and evaluate the data. Frequency, mean and standard deviation were used as descriptive statistics in tables and graphs. Shapiro-Wilk test for normality, ANOVA, As inferential statistics, the Post-hoc Bonferroni test was employed. Statistical significance is defined as a P-value less than 0.05.

3. Results

3.1. Surface roughness test

The descriptive statistics of the surface roughness tests included the mean values, standard deviation, standard error, and the two extreme values (minimum and maximum) of the investigated data. As illustrated in Table 2 and Fig. 4, the results indicated that the material group for acrylic resin with the highest mean value of 5% potassium fluoride incorporation was (1.756 ± 0.016) µm, while the integration-free control group had the lowest mean value (1.068 ± 0.147) µm. The average value of the 2% potassium fluoride incorporation to the acrylic resin material group was (1.359 ± 0.006) µm. ANOVA test and Post-hoc Pairwise were applied to comparisons between all surface roughness of studied groups, shown in Table 3 as well as Table 4. The pairwise test revealed significantly different results at $P < 0.05$ across all study groups.

3.2. Surface Hardness test

According to the findings, the control group without integration had the greatest mean value. (81.22±0.49), the average rate of 2%. The material group for acrylic resin was added potassium fluoride (80.42 ± 0.65), and the materials collection of 5% potassium fluoride integration into acrylic resin, which was equivalent to the lowest mean rate (81.08 ± 0.71) as shown in Table 5 and Figure 5. ANOVA test was applied and post-hoc pairwise comparisons between all surface hardness of studied groups, shown in Table 6 as well as Table 7. The extremely significant differences were shown by the ANOVA test at $P < 0.05$ in all study groups.

Table 2. Descriptive statistics for the surface roughness for different groups

Groups	NO	Mean	SD	SE	Min	Maxi
Control	10	1.068	0.147	.004655	1.06	1.10
Acrylic resin with 2 % incorporation of potassium fluoride	10	1.359	0.006	.002035	1.35	1.37
Acrylic resin with 5 % incorporation of potassium fluoride	10	1.756	0.016	.004947	1.73	1.79

SD: Standard deviation
SE: standard error

Table 3. ANOVA analysis for groups for roughness testing

ANOVA for roughness	Sum of squares	df	Mean square	F	Sig.
Between groups	2.388	2	1.194	7123.654	P<0.05 P=0.001

Table 4. Pairwise comparison test of roughness between groups

Pairwise* comparison	Control	2% KF
2% KF	0.033**	
5% KF	<0.001	0.033

* Bonferroni test, ** P-value

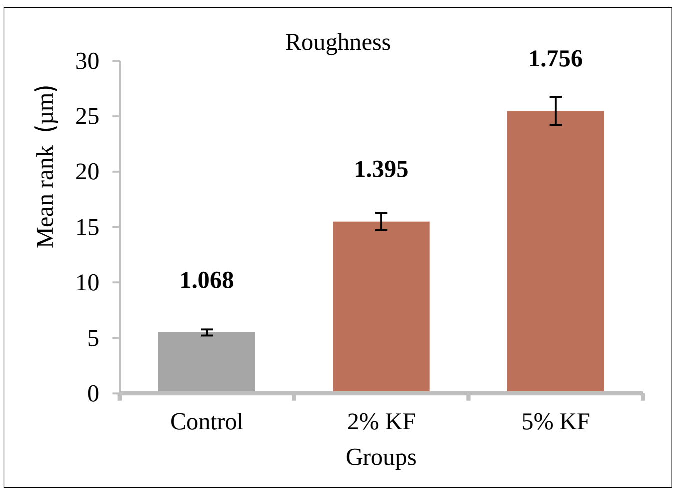

Fig. 4. Bar chart for surface roughness (µɱ) test of the studied groups

Table 5. Descriptive statistics for surface hardness testing for different groups

Groups	NO	Mean	SD	SE	Min	Maxi
Control	10	81.22	0.49	.1562	80.6	82.0
Acrylic resin with 2 % incorporation of potassium fluoride	10	80.42	0.65	.2054	79.6	81.8
Acrylic resin with 5 % incorporation of potassium fluoride	10	81.08	0.71	.2255	80.4	82.6

SD: Standard deviation, SE: standard error

Table 6. ANOVA analysis for groups for hardness testing

ANOVA for hardness	Sum of squares	df	Mean square	F	Sig.
Between groups	3.651	2	1.825	4.668	0.08

Table 7. Pairwise comparison of hardness between groups

Pairwise* comparison	Control	2% KF
2% KF	0.80 (0.024)**	
5% KF	0.14 (1.000)	-0.66 (0.077)

* Bonferroni test
** Mean difference (p-value)

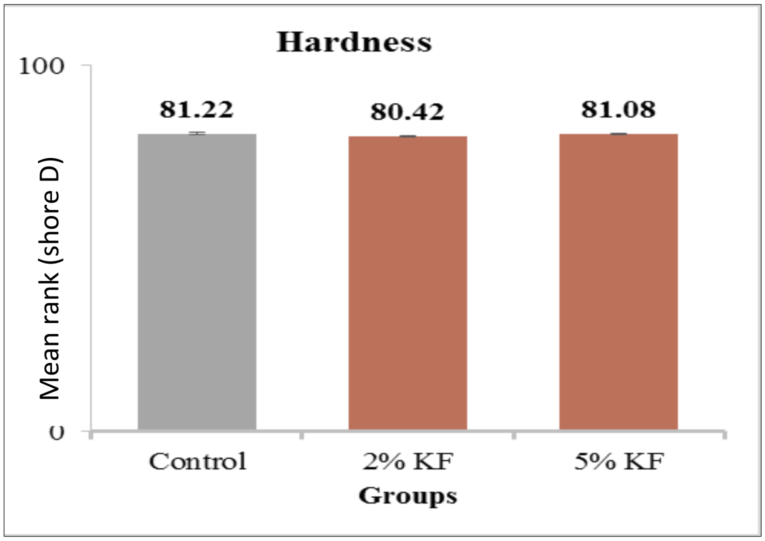

Fig. 5. Bar chart for the mean value of surface hardness test (shore D) of studied groups

4. Discussion

4.1. Surface roughness

Surface roughness is a crucial characteristic of clinical significance for acrylic resin materials because it influences microbial adherence and the development of diseases like denture stomatitis, all of which are uncomfortable for patients. These components must be flawless and have flat surfaces [14, 15, 16]. Table 2 displays the surface roughness test findings. The control group had the lowest mean value of 1.068μm, while the 5% potassium fluoride incorporation to acrylic resin material group had the highest mean value of 1.756μm. Furthermore, comparisons between the groups of acrylic resin with 2% potassium fluoride incorporation and the group of acrylic resin with 5% "potassium fluoride" incorporation revealed increase significant difference between the groups of acrylic resin with 2% potassium fluoride incorporation and the group of acrylic resin with 5% "potassium fluoride" incorporation in comparison to the control group.

The result of the current study revealed that the surface roughness of the acrylic resin was significantly affected after incorporation with fluoride salts in comparison to control in 2% of salts (KF) also results showed the post-hoc pairwise comparison indicated statistically significant differences of roughness mean rank values when an increase in percentage 5% (KF and AlF_3) in compassion to control groups, this result was pertinent because roughness was a crucial factor for microorganism adhesion on the acrylic resin surfaces [15]. Roughness test high fluoride percentage groups could be caused by fluoride particles being incorporated, which would impact the roughness test increase. This finding is consistent with [16] that reported higher roughness after fluoroalkyl methacrylate incorporation would be a possible result. Alternatively, it could be owing to the presence of fluoride particles in the polymerization. This would occur through the exposure of polymer beads, as indicated by Axe et al. 2016 [17].

4.2. Surface hardness

Resistance to piercing the persistent surface indentation is a measure of hardness [18]. The present study's findings indicate that the control group, which did not add potassium fluoride, exhibited the highest mean values for the surface hardness test. Additionally, the control group's mean values for the 2% and 5% potassium fluoride incorporation groups were the lowest and highest, respectively, based on the statistical sensitivity of the results, as presented in Table 2. Roughness, [19]. The opposite set of results could be caused by variations in the methods used to add fluoride [19] inclusion using polymer instead of monomer; also, the same fluoride concentration was employed, but a different type of fluoride was used. Furthermore, the results contradict those of Ali, 2014, who demonstrated that adding sodium fluoride to acrylic resin material results in a modest increase in surface hardness [19]. The reasons for the variation in the results could be due to different types of fluoride added at different concentrations, integration with polymer instead of monomer, and variations in the fluoride addition procedures, as shown by [19].

The modest amounts of fluoride added to the acrylic resin without altering the polymer's chain arrangement may have caused a slight increase in mean values with a larger fluoride %, which in turn did not affect hardness. Moreover, a fluoride and polymer reaction might not occur. The results of the hardness test showed no discernible variations across the groups. This result could be explained by an increase in the proportion of fluoride in the acrylic resin, which would lead to more crystals per unit area. Thus, the findings could be attributed to fluoride crystals being more resistant to indenter penetration than acrylic polymer due to their higher hardness.

5. Conclusion

The addition of 2% and 5% potassium fluoride (KF) to heat-cured acrylic resin materials produced no effect on surface hardness but it influenced the roughness test. The mean value of the surface hardness test was varied with concentrations of fluoride salts (KF) addition, however there were no significant differences between all groups for the hardness test with a control group and with each other. The mean value of the surface roughness test was varied according to the concentration of (KF) in comparison with the control group and there were significant differences between all groups even with control and with each other.

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Nomenclature & Symbols			
KF	Potassium fluoride	SPSS	Statistical Package for the Social Sciences
P/L ratio	Powder /Liquid ratio	ANOVA	Analysis of Variance
SD	Standard Deviation	ADA	American Dental Association

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