Dentistry 3000

Vol 13, No 1 (2025)
ISSN 2167-8677 (online)
DOI 10.5195/d3000.2025.1004

Impact of Sinalized Silicon Carbide Nanoparticles on the Physical Characteristics of a Heat-Cured Acrylic Soft Liner

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Abstract

Objective: The purpose of this research was to examine how adding salinized silicon carbide Np to the soft denture lining material affected its thermal conductivity, water sorption, and solubility**. Material and Methods**: Silicon carbide NPs were added to the heat-cured soft lining material at quantities of 0.4%, and 0.6% by weight. The sixty specimens have been generated in compliance with the prescribed tests. **Results**: When compared to control specimens, soft lining material with 0.6% and 0.4% wt. sic NP had a highly significant decrease in solubility, a non-significant increase in thermal conductivity, and a non-significant decrease in water absorption. **Conclusion**: The addition of silicon carbide nanoparticles into heat cured acrylic denture soft liner material improved thermal conductivity and decrease water sorption and solubility.

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Citation: Amir MAA, et al. (2025) Impact of Sinalized Silicon Carbide Nanoparticles on the Physical Characteristics of a Heat-Cured Acrylic Soft Liner. Dentistry 3000. 1:a001 doi:10.5195/d3000.2025.1004
Received: July 28, 2025
Accepted: July 31, 2025
Published: September 9, 2025

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Introduction

Dentists have been using soft denture liners for almost a century, with natural rubber being the first [1].

Resilient denture liners can fix the problem of dentures becoming ill-fitting from residual ridge resorption, which causes discomfort and agony to the patient, while retention is necessary for effective dentures [2].

For complete dentures to be comfortable, flexible lining materials must be used. For example, if a patient has thin, non-pliable mucosal tissue covering their irregular alveolar margin, chewing forces applied through a solid acrylic base could be painful. By using soft lining materials, this pain could be alleviated, and the patient would be more likely to accept their dentures [3,4].

The soft lining materials consist of a variety of synthetic and natural substances, including hydrophilic polymers, silicone rubber, polyphosphazine fluoropolymers, fluoroethylene, and silicones added to polyvinyl siloxane. Silicone rubber and plasticized acrylics are the two most popular types of soft liners, and they are activated either by heat or chemicals [5].

To be ideal, soft denture liners should exhibit certain properties to ensure a maximum benefit for denture wearers; among these properties are the biocompatibility, dimensional stability, good resiliency, softness, proper wettability, color stability, low water solubility, sufficient bond strength with the underlying denture base and the ability to inhibit or reduce the microbial growth [6].

The patient's level of satisfaction with their dentures is affected by the soft denture liners' inability to adequately transfer heat from the denture base to the oral mucosa, Furthermore, the parotid gland's secretion and the health of the underlying supporting tissues are significantly impacted by the denture base's poor heat conductivity [7,8].

Soft lining materials have a lot of issues with water solubility and sorption. With time, the plasticizers and other important ingredients in the material will leach out, creating space for other particles and water to enter. This changes the material's chemical structure and physical properties [9].

Due to the gradual loss of plasticizer, the modulus of elasticity of soft-liner material would rise; consequently, its resilience, an essential property, will be compromised. In addition, the epithelial tissue may have a negative response to the release of some plasticizers, such phthalate ester [10].

Silicon carbide is a great material for structural and functional materials due to its high mechanical strength, minimal friction, chemical stability, and outstanding thermal conductivity [11].

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Nanoparticles' exceptional physical features, including high-flexibility, enhanced strength, and ease of form replication, have garnered a lot of interest for their incorporation into polymer-matrices [12].
Without using dispersing agent, inorganic particles are not easily distributed in polar organic matrix. For this reason, to produce stable chemical bonds with both inorganic and organic materials silane coupling agents are often used. So, the silane function as adhesion promoter that is to improve the binding of nanoparticles to the matrix of polymer [13].

Material and Methods

Silicon Carbide Surface Modification

The nanoparticles of silicon carbide (SiC, Beta, 99.9% purity, less than 80 nm, cubic, Nanoshel, USA) were treated with a silane coupling agent (trimethoxysilylprpoyl methacrylate TMSPM Cheng du micxy chemical co. ltd. 2530-86-0. China) to enhance their binding to the polymer matrix and to introduce reactive groups into the nanoparticles.
Typical process as followed, 30g of nanoparticles and 200 milliliters pure toluene were placed into a flask then sonicated at ambient temperature for 20 minutes. The standard procedure involved adding 30 grams of nanoparticles to 200 milliliters of pure toluene in a flask and sonicating the mixture at room temperature for 20 minutes.
Twenty hours were spent drying the modified nano filler in a vacuum oven set at 60°C. The nanofiller is thereafter left at room temperature until it is needed [14,15].
By examining the distinctive vibrations of functional groups, the FTIR spectrophotometer can identify if MPS functional groups are bonded to nanoparticles [16].

Preparation of Specimens

The soft denture liner material was made of heat-cured acrylic and was sourced from Moonstar in Turkey. Nanoparticles of silicon carbide were included into the soft liner's liquid component.
Results from the pilot investigation indicated that concentrations of silicon carbide NPs between 0.4% and 0.6% produced the best shear bond strength and hardness increases. The monomer was combined with the measured amount of nano SiC to form the dough with the correct quantity of nanofiller. The nanoparticles were then uniformly dispersed throughout the monomer by use of a probe sonication equipment operating at 120 W and 60 KHz for a duration of three minutes [17].
The manufacturer's instructions required the creation of acrylic specimens; thus, a new plastic design was made. The mold was then constructed following the standard procedure for making full dentures.

Experimental Groups

- control group without addition of nanoparticles (n=10, for each test).
- experimental group with 0.4 % wt. Sci nanoparticles (n=10, for each test).
- experimental group with 0.6 % wt. Sci nanoparticles (n=10, for each test).

Evaluation of Thermal Conductivity

Disks with 40 mm diameters and 5 mm thicknesses have been manufactured for thermal property testing in accordance with instrument standards ISO 22007-2. The specimens were subjected to thermal conductivity testing using the hot disk thermal analyzer (Tps 500, Kiteley, Sweden), which uses a double spiral design that extends from a thick sheet of nickel foil. Once the polymer parameter is selected, the system may be tested with a thermal conductivity value 15 minutes after the hot disk is turned on, which should be done around 1 hour before to the testing.

Evaluation of Water Sorption and Solubility

The dissecator was used to dry the specimens using recently dried silica gel. After being incubated at 37°C ±2 °C for 24 hours, the specimens were allowed to cool to ambient temperature for an additional hour. Afterwards, they were precisely weighed using a digital scale, which had an accuracy of (0.000lg). After five days of this, we obtained a constant mass "conditioned mass" (M1), which indicates that the weight loss from each disc was less than 0.2 mg in 24 hours (ADA Specification NO.12, 2000). Following a 7-day immersion in distilled water at 370C ± 2.0C, the specimens were taken out of the water using tweezers and dried with a clean, dry hand towel for 30 seconds. After that, they were permitted to air for 15 seconds before being weighed; the resulting value represents M2. As was done before for the sorption test, the discs were reconditioned to a constant mass in the desiccators at 37°C ±2 °C to get the solubility value; this time, the reconditioned mass was recorded as (M3). Within five days, the entire group arrived at M3. The following equations were used to calculate the solubility and water sorption:
Water sorption = (M2 – M1) / S
Water solubility= (M1- M3) / S
M1=initial weight of specimen
M2=weight after specimen immersion in water
M3=weigh after specimen placed in desiccators
S=surface area

Atomic Force Microscopy (AFM) Analysis

The surface topography and morphology of specimens with 0%, 0.4%, and 0.6% concentrations were examined using atomic force microscopy. The prepared specimens were identical to the hardness test specimens in terms of dimensions (35 mm wide and 6 mm deep).

Results

Investigating the Properties of Nanofillers Made of Silanized Silicon Carbide (SiC)

As shown in Figure 1, it is demonstrated that the FTIR result of Sic after silanization displays the same absorption peaks as Sic before salinization.
This indicates that the Sic nanoparticles and the silane coupling agent do not form a chemical connection.
Figure 2 displays the two- and three-dimensional pictures captured by the AFM investigation. The two- and three-dimensional images of all have shown unevenly distributed granular films with large diameters of protuberances. Grain number and average roughness have increased after nanoparticles addition when compared to untreated specimens.
Results for both the untreated and treated samples were compared in terms of thermal conductivity, water sorption, and water solubility.
To establish the importance of adding Sci NPs to acrylic soft-liner specimens, descriptive statistics and one-way ANOVA were used to conduct comparative analysis for each group.
Table 1 displays the results of the thermal conductivity test, which showed a high mean value in the 0.6% wt. Sci NP group and a statistically non-significant rise in the one-way ANOVA across all groups ($p>0.05$). Water sorption test results reveal a non-significant decrease in water sorption when comparing all groups in a one-way ANOVA with a p-value of more than 0.05.
The water solubility showed a statistically significant reduction in water solubility when comparing all groups in a one-way ANOVA with a significance level of $p<0.05$.

Discussion

The use of denture lining materials has grown in significance in the field of dental prosthetics due to the following reasons: increased patient comfort, more uniform force distribution, less localized pressure, and better denture retention for patients whose numbers are projected to rise over the next 20 years [18].
Results from integrating sic NP into PEMA were assessed in this study. A study was

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conducted to examine the physical features of the soft liner, including its heat conductivity, water sorption, and solubility.

A material's thermal conductivity may be defined as its capacity to evaluate the rate of heat transfer over a certain period in a specific cross-sectional area of the material samples [19].

Poor thermal conductivity is a major concern with poly ethyl methacrylate (PEMA) resin, which impacts both the patient's acceptance of the prosthesis and the health of the tissues supporting the denture [19].

The thermal conductivity reveals a non-significant increase of 0.4% and 0.6% with the introduction of sic NPs into PEMA. This may happen because of particles coming into touch with one another over time, creating a network like a structure known as thermal pathways.

These routes facilitate the transfer of heat from one area of the sample to another, effectively bridging the insulating effect of the polymer.

Solubility and water sorption were assessed concurrently by measuring the amount of water gained or lost by soluble components [20].

The bonding strength of the liner-denture base contact weakens because the water sorption by the lining material causes changes in dimension and stress concentration. How much water a polymer absorbs depends on the filler and how it bonds to the polymer.

Incorporating silicon carbide NPs into soft denture liner at the concentrations of 0.4% and 0.6% utilized in this research reduced the water sorption mean value, while the effect was not statistically significant. Adding sci NPs may have reduced the number of PEMA molecules on the specimen's surface, which in turn reduced water diffusion.

The hydrophobic property of Sci aids in minimizing the infiltration of water into the polymer.

Another possibility is that the microporosity that forms during polymerization makes it easier for the polymer to absorb fluids. Because of their filler properties, the inclusion of Sci NPs reduced the water sorption by decreasing the size of these spaces.

This study found that adding 0.4%, 0.6% Sic NPs significantly reduced water solubility compared to the control group. This might be because the soft lining material's water sorption characteristics decreased as the amount of Sci NPs increased. Because of this restriction in the dispersed water, molecular flexibility and the extraction of soluble components from the polymer mass are less likely to occur.

Another possible explanation is that the solubility in this study was measured by the loss of specimen weight. Since Sci NPs are insoluble in water, they added mass to the specimens and acted as impurities, reducing their solubility mean value. This could explain why there was a decrease in solubility mean value as the amount of Sic NPs increased.

Conclusion

According to the study's criteria, adding sci NPS to soft liner material can improve its heat conductivity, minimize water sorption, and make it less soluble.

Funding

No specific grant was given to this research by funding organizations in the public, private, or not-for-profit sectors.

Author's Contributions

Each author agreed to be accountable for every part of this work and contributed to data analysis, writing, and revision of the article.

Conflict of Interest

According to the author, there is no conflict of interest.

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Table 1. Thermal conductivity, water sorption and solubility.

Thermal conductivity	Test groups	N	Mean	Std. Deviation	p-value
	0%	10	0.1909	0.01296	
	0.4%	10	0.1915	0.04040	
	0.6%	10	0.1987	0.03562	
	total	30	0.5811	0.08898	0.833
Water sorption	0%	10	2.09	11.72	
	0.4%	10	1.63	4.12	
	0.6%	10	0.31	5.40	
	total	30	4.03	21.24	0.082
Water solubility	0%	10	16.35	24.40	
	0.4%	10	10.39	35.21	
	0.6%	10	6.22	22.82	
	total	30	32.96	82.43	0.021

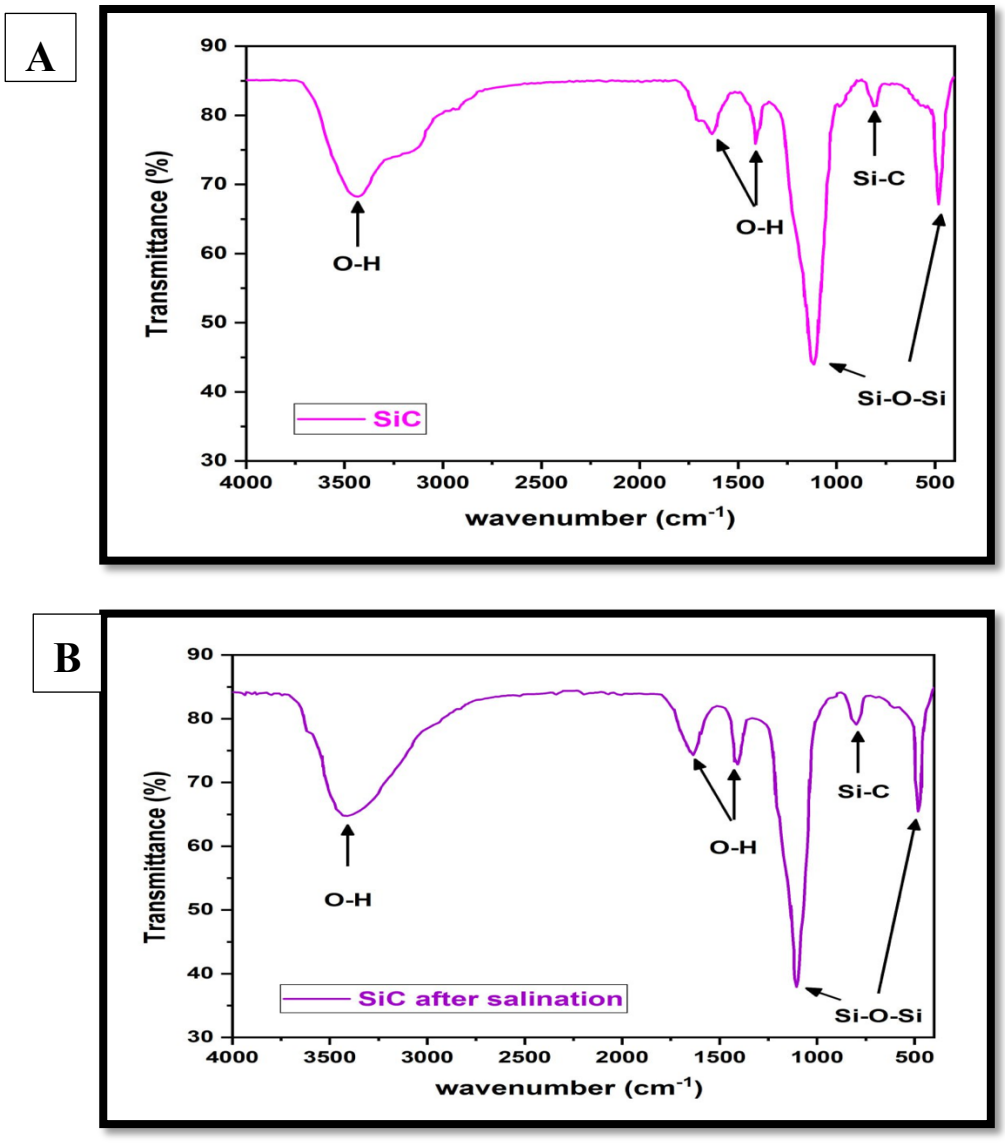

Figure 1. FTIR spectrum of silicon carbide nanoparticles (A) before surface modification and (B) after surface modification.

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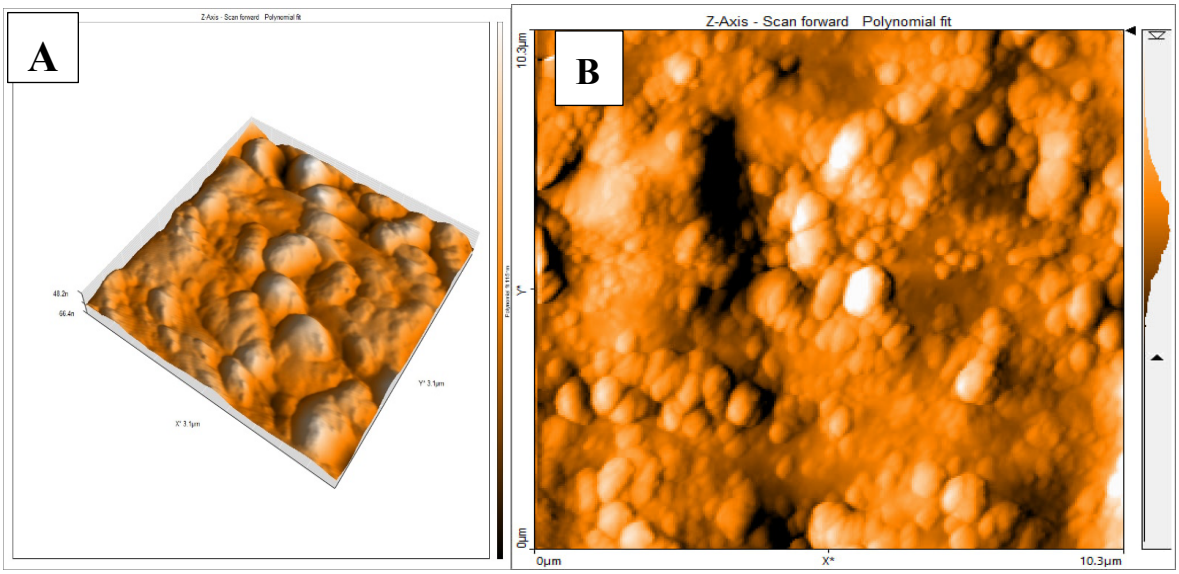

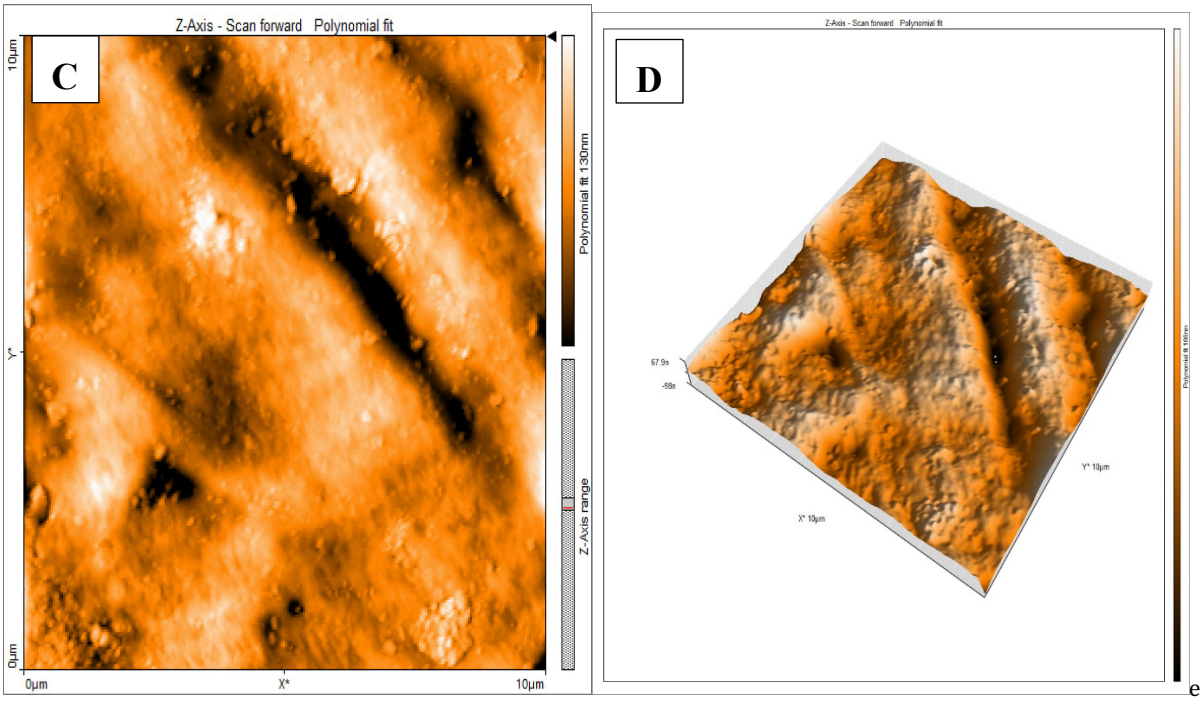

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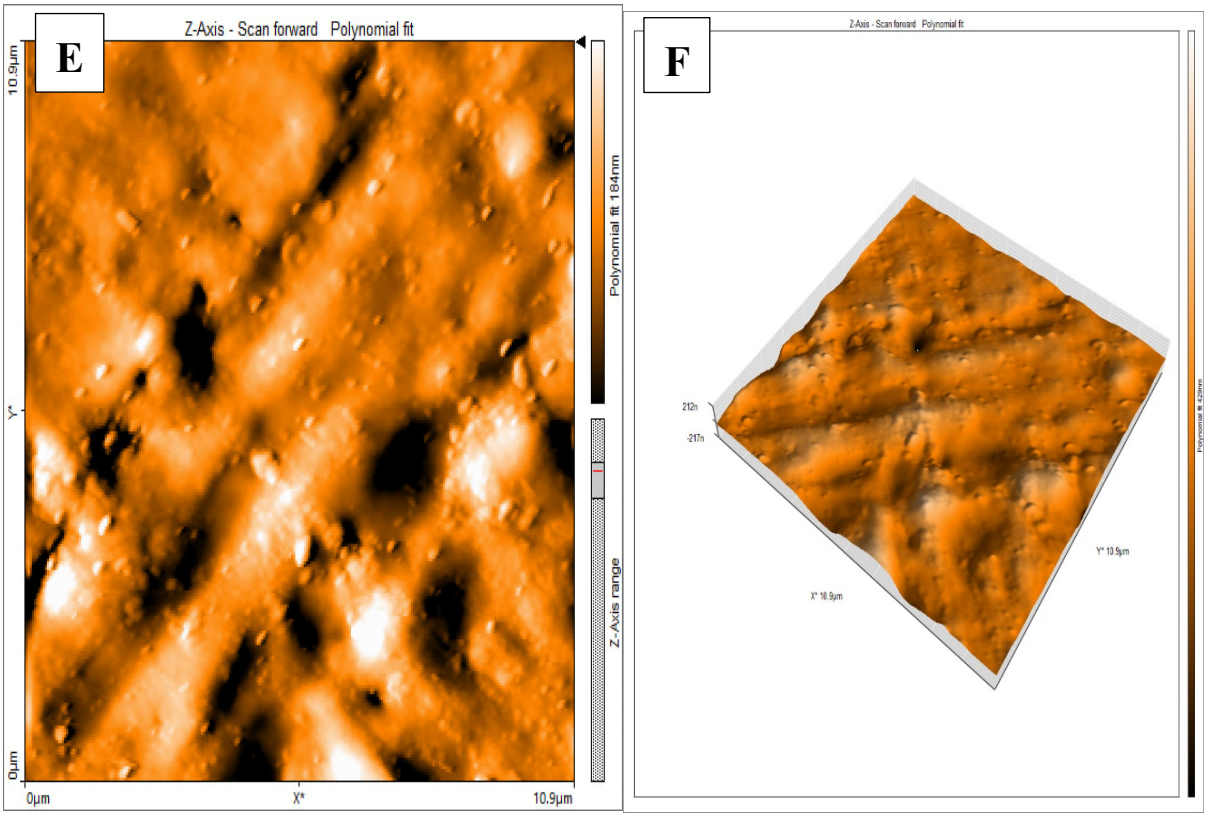

Figure 2. AFM (atomic force microscopy) and three-dimensional images of (A+B) control specimens, (C+D) 0.4% specimens, and (E+F) 0.6% specimens.