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Evaluation of the Effect of Incorporation of Nano-fluorohydroxyapatite on Tensile Strength and Modulus of Elasticity of an Essix Plate

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Abstract

Background: Nano-fluorohydroxyapatite (nano-FHA) is a caries preventive agent that is applied in many fields of dentistry and has the potential of being added to Essix retainers to create antibacterial properties.
Objectives: The purpose of this study was to investigate the effect of nano-fluorohydroxyapatite addition on the tensile strength and modulus of elasticity of an Essix plate.
Methods: The nano-fluorohydroxyapatite was synthesized and added to an Essix plate in various weight percentages: 0% (group 1), 0.1% (group 2) and 0.5% (group 3). We performed the measuring of flexural strength and modulus of elasticity for the experimented three groups using a universal testing machine. The data were analyzed through one-way ANOVA and Tukey's test at the significance level of 0.05.
Results: Accordingly, the obtained results were indicative of significant differences between the groups (P-value = 0.003); however, the difference between group 2 and control group was not statistically notable (P-value = 0.427). Furthermore, the tensile strength of group 3 significantly decreased (P-value = 0.04). In regards to the modulus of elasticity, the data were suggestive of significant differences between the groups (P-value = 0.002). Apparently, the modulus of elasticity of group 2 and group 3 decreased significantly compared to that of the control group (group 1).
Conclusions: We can conclude that nano-FHA can be incorporated into Essix plates in concentrations of up to 0.1 wt% in order to create some caries preventing effects with no negative effects on tensile strength; however, adding nano-FHA to Essix plate will decrease modulus of elasticity.

Keywords: Essix, Nano-flourohydroxy Apatite, Tensile Strength, Modulus of Elasticity

1. Background

Prevention of relapse and maintaining the corrected positions of teeth after treatment stand as the final and essential steps in orthodontic treatment. Teeth have a tendency to return toward their pretreatment positions as a result of periodontal, gingival, occlusal, and growth related factors (1). To overcome this problem, two different retainer systems are used in orthodontic treatments (2) that include fixed and removable retainers. Fixed retainers hold several advantages, including superior aesthetics, not requiring patient cooperation, and suitability for long-term retention. However, fragility and weakening of oral hygiene, as well as the tendency to cause periodontal problems are considered as the disadvantages of this routine (2).

Despite the increasing popularity of fixed retainers, the most common appliances for the retention phase are removable retainers due to their considerable benefits (3). In addition to being clear and invisible, Essix retainers are rapidly manufactured, comfortable, fitting, and aesthetic (4). Nevertheless, one of the challenges of applying these retainers is their susceptibility to caries since they prevent the salivary flow over the tooth surface and consequently cause microorganisms to accumulate (5). In recent years, researchers have focused on preventive methods that would not require the cooperation of patients to

overcome the inducement of caries and white spot lesions (WSL) (6). The incorporation of antimicrobial agents into orthodontic dental materials is an effective strategy to improve their antimicrobial activity. Nonetheless, it is important to ensure that this modification does not result in any significant deleterious impacts on the mechanical or physical properties of materials (6-8).

In recent years, different nanomaterials such as chitosan, silver, zinc oxide (ZnO), titanium dioxide (TiO_2), and copper oxide (CuO) NPs have been incorporated into orthodontic dental materials (7, 9-12).

Nano-fluorohydroxyapatite (nano-FHA) is a caries preventive agent that is applied in many fields of dentistry and has the potential of being added to Essix retainers in order to create some antibacterial properties. However, it is necessary to investigate the effects of nano-FHA addition on the mechanical properties of Essix plates, which has not yet been evaluated to the best of our knowledge.

2. Objectives

Therefore, the present study aimed to evaluate the effects of nano-FHA addition to Essix plate tensile strength and its modulus of elasticity.

3. Methods

The synthesis of nano-FHA was performed through a sol-gel method (13). $(NH_4)H_2PO_4$ and NaF were added to the solution of $Ca(NO_3)_2.4H_2O$ and stirred for 24 hours. Subsequently, the obtained product was kept in room temperature in order for the gel to be centrifuged, dried, and calcinated under 450°C for one hour. An Essix plate (Duran, Germany) was dissolved in a suitable solvent (dichloromethane) with a volume ratio of 1:2, and the nano-FHA was incorporated into the solution using a magnetic stirrer in the weight percentages of 0.1% (group 2) and 0.5% (group 3). Thereafter, a thin film was injected by a 10 cc syringe on a mirror surface through a solvent-casting method (14). Every half an hour, a layer was injected in the same way on the previous layer to achieve a composite thickness of 1mm. After 24 hours, the modified Essix plate was removed from the mirror surface. To investigate the homogeneous distribution of nano-FHA in the Essix plate, the sample was examined through a scanning electron microscope (SEM) (Figure 1).

Ten rectangular strips (65 mm × 4 mm × 1 mm) were fabricated for the control group (group 1), group 2 (0.5% nano-FHA), and group 3 (1% nano-FHA). The tensile strength of the specimens was measured in accordance with the ISO 527-4, which required the application of a universal testing machine (STM20, SANTAM, Tehran, Iran) at a cross head speed of 5 mm/min. The force that caused the fracture of the specimen was recorded; while the tensile strength and modulus of elasticity were also calculated.

We conducted the statistical analysis through the usage of SPSS software version 22 (SPSS Inc., Chicago, IL, USA). All the gathered data were analyzed through one-way ANOVA and Tukey's test at the significance level of 0.05.

4. Results

Normal distribution of the data was confirmed using the Kolmogorov-Smirnov test. The existence of significant differences between the tensile strengths of the groups was revealed by the results of One-way ANOVA test (Table 1) (P-value = 0.003). However, the observed difference between group 2 and the control group (P-value = 0.427) was not statistically significant, while the tensile strength of group 3 was reported to be significantly lower than that of the control group (P-value = 0.04). In addition, group 3 had lower tensile strength than group 2 (P-value = 0.002).

Table 1. Comparison of the Mean and Standard Deviation of the Tensile Strength in the Three Groups (P-Value = 0.003)

Groups	Numbers[a]	Mean ± SD (MPa)
Group 1 (Essix)	10	14.89 ± 2.22
Group 2 (Essix + 0.1% nano-FHA)	10	16.19 ± 1.51
Group 3 (Essix + 0.5% nano-FHA)	10	12.31 ± 2.94

[a]Number of specimens per group.

In regards to the modulus of elasticity, the results of ANOVA test (Table 2) and Tukey's test (P-value = 0.002) were suggestive of significant differences between the groups. Apparently, the modulus of elasticity had significantly decreased in group 2 (P-value = 0.002) and group 3 compared to the control group (P-value = 0.001). However, there was no significant difference between group 2 and group 3 (P-value = 0.704).

Table 2. Comparison of the Mean and Standard Deviation of the Modulus of Elasticity in the Three Groups (P-Value = 0.002)

Groups	Numbers[a]	Mean ± SD (MPa)
Group 1 (Essix)	10	336.05 ± 108.91
Group 2 (Essix+0.1%nano-FHA)	10	188.34 ± 96.87
Group 3 (Essix+0.5%nano-FHA)	10	220.03 ± 45.98

[a]Number of specimens per group.

5. Discussion

Tensile stress is an important factor in the mechanical and clinical aspects of dental materials. In this study,

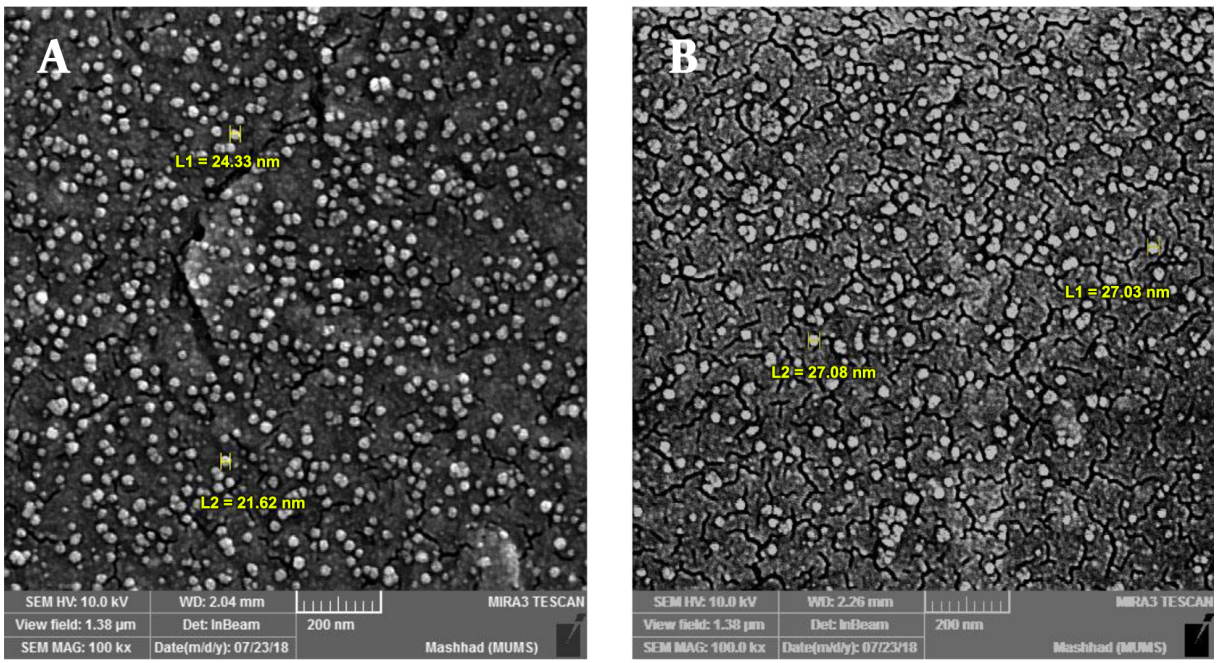

Figure 1. Distribution of nano-FHA in the Essix plate: A, Essix + 0.1% nano-FHA; B, Essix+ 0.5% nano-FHA

two mechanical properties of an Essix plate that contained nano-FHA were evaluated, which included the tensile strength and the modulus of elasticity. According to our results, the addition of up to 0.1 wt% nano-FHA to Essix plate did not lead to any significant negative effects on its tensile strength, while the incorporation of 0.5 wt% nano-FHA caused a decrease in this parameter. It is possible that the nanoparticles function as impurities in the Essix structure and consequently cause a decrease in the tensile strength. There are no investigative reports on the effect of the addition of nano particles on the mechanical properties of Essix plates.

Barandehfard et al. (15) investigated the influence of hydroxyapatite (HA) and fluorapatite (FA) nanoparticles incorporation on the mechanical characteristics of glass-ionomer cements (GICs). According to their results, the GICs that contained HA and FA nanoparticles were able to provide enhanced mechanical properties for restorative dental materials.

The work of Khaghani et al. (16) stated based on their discoveries that the addition of synthesized nano-fluoroapatite to glass ionomer cement resulted in the enhancement of the compressive strength and induced the nucleation of a calcium phosphate layer on the surface of composite.

Moshaverinia et al. (17) investigated the effects of hydroxyapatite and fluoroapatite nanobioceramics incorporation in conventional glass ionomer cements. Apparently, the glass ionomer cements containing nanobioceramics can stand as promising restorative dental materials with both improved mechanical properties and improved bond strength to dentin.

In the present study, there was a significant increase in the modulus of elasticity in regards to Essix plate that contained 0.5% nano-FHA. According to the work of Arcis et al. (18), the addition of 50 - 60 wt% of hydroxyapatite particles to dental composites led to the increase of both modulus of elasticity and surface hardness of materials, while the flexural strength was decreased.

Considering the limitations of this in vitro study, it can be concluded that the addition of nano-FHA up to 0.1 wt% does not lead to any significant negative effects on tensile strength. However, further research is required to investigate other important aspects of modified Essix plates.

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Footnotes

Authors' Contribution: Study concept and design: HS, HA, and HB. Analysis and interpretation of data: HA, HB, and AR. Drafting of the manuscript: BY and FM. Critical revision of the manuscript for important intellectual content: AR. Statistical analysis: HE.

Conflict of Interests: The authors declare no conflict of interest.

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