

Study the Laser Bleaching for Several Human Teeth and Their Structural Properties as a Model of Therapy

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ABSTRACT

In this study, the effect of teeth bleaching using infrared laser diode in the presence of a substance containing 35% hydrogen peroxide on the structural properties for teeth of different classes were studied. The x-ray diffraction measurements illustrate that the structure identical with hydroxide apatite (HAp) of hexagonal phase. No significant difference in the basic crystalline structure before and after treatment. Sample for a male of 24 years old appeared as the highest crystallized sample and increasing the age lead to a decrease in crystallization due to a decrease in the basic elements. Sample with highest magnesium ion (Mg^{+2}) content has the lowest degree of crystallization, and the lowest crystalline size. Also Mg ion substitution in HAp reduced its lattice constant(c) and correspondingly an increase

in the (a) constant. Comparing the FTIR spectra show that the PO_4^{3-} bands differ in their intensities from one sample to another, where the weakest one for the sample which has the lowest phosphate content and larger Mg content, as indicated by the XRF examinations.

Keywords: hydroxide apatite, structural properties, FTIR

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INTRODUCTION

Hydroxyapatite (HAp), of chemical formula $Ca_5(OH)(PO_4)_3$, is the primary building block for solid bone and tooth tissues in humans and vertebrates animals. HAp is characterized by two hexagonal and monoclinic crystalline structures but the most common is the hexagonal system of lattice constants ($a = 9.432 \text{ \AA}$, $c = 6.881 \text{ \AA}$; and $\gamma = 120^\circ$) [1]

The properties of bone based on minerals, such as density and strength, depend during the formation process of crystalline solid apatite not only through the availability of basic elements such as calcium or phosphorus, but in order to form a mineral apatite of good specifications, all other necessary elements must be available in appropriate proportions such as (Mg, Cl, F, OH) which are substituted ions within the apatite lattice [2]. Such ionic alternatives cause little change in the crystal structure, change in lattice parameters, and have clear effects on physical properties, such as solubility, hardness, thermal stability, and optical properties. In fact, the healthy body controls the ratio of these ions in apatite to the appropriate ratios. In this way, a slight difference in the apatite ions in the enamel from other bone types increases their solubility resistance[3]

Dental discoloration is a common clinical consequence. It may occur due to eating foods or drinks containing amounts of dyes, bacteria or dental fillings or due to some medicines. They differ in their appearance, composition and adherence. There are two types of tooth discoloration, that is, those related to intrinsic factors such as the congenital effect and that caused by external factors[4].

Teeth whitening substances contain hydrogen peroxide as an active substance in concentrations ranging from 3% to 40%. Bleaching mechanics using hydrogen peroxide perpendicular to peroxyoxyl (HO_2). Free radicals are formed by decomposing the O-H bond or the O-O bond in hydrogen peroxide. It has been proven that bleaching more efficient when exposed to lasers. The free radicals attack the double bonds of pigmented molecules in the enamel that lead to their disintegration into smaller and less pigmented components, as the absorption spectrum of the

chromophore molecules changes and teeth whitening occurs. Recently, calcium phosphate has been added to some teeth whitening products, to reduce sensitivity, remineralize teeth, and add shine to the teeth[5].

The thermal effects for dentin tissue ablation by 350fsec laser pulses of a ($1.05\mu m$) Ti:Sapphire as maximum temperature for tissue (T_{max}), thermal gradient, threshold ablative intensity (I), released thermal power per area (Q), vaporization energy per volume (Ee), thermal diffusivity (χ), effective thermal diffusivity length ($\ell\chi$), thermal relaxation time (τ), threshold ablative fluence (F1) and final ablative fluence (F2), as well as coefficients which specify ablation achievement success as ablation depth (d), ablation velocity (v), absorption coefficient (α), start ablation time (t1) and final ablation time (t2) had been calculated as tissue temperature variation in one time and at incident laser fluence variation in other [6].

The two different dental fillings as composite and amalgam, doped with SiO_2 nanoparticles, had been prepared. The optical properties as absorbance, absorption coefficient, transmittance, refractive index, reflectance, extinction coefficient and optical density, had been studied for studied dental fillings at different values of SiO_2 nanoparticles weight. the effects for both diode laser power and laser exposure time in the optical properties for such a studied dental fillings, had been studied [7].

In this work we study the effect of teeth bleaching using infrared laser diode in the presence of hydrogen peroxide on the structural properties, elemental analysis and chemical bands for teeth of different age, gender and smoking habit.

EXPERIMENTAL

Five dental models were prepared by a dentist, taking information about the patient in terms of age, gender, and smoking habit, and keeping them in separate small packages in formalin. A dental bleaching system was used Model No. WLL 1595 from DMC USA Corp., which works within the infrared wavelength. The teeth have been coated with a medicinal substance of a commercial name, (biodinamica) contains 35% of the hydrogen peroxide substance before

laser exposed of 10 W power. The teeth color were compared visually with standard kit. The crystal structure of teeth is studied before and after the bleaching process using x-ray diffraction technique for a range of angles 2θ from 10° to 80° using (XRD Xpert Pro Panalytical). X-ray fluorescence technique (model XRF Panalytical) was used to atomic analysis of teeth of different groups in the apparatus. FTIR spectrometer (ZTIUM) was used to study the molecular bonds before and after treatment.

RESULTS AND DISCUSSIONS

Figure 1 show the photograph of the five dental samples installed on a waxy base before and after treatment for 30 minutes. We notice the difference in the amount of pigmentations and calcifications accumulated on the teeth from one sample to another, due to the difference in the type of foods that a person eats or maintains dental cleaning or other habits. We notice effective dental whiteness after exposed to the laser for 30 minutes for all samples.



Figure 1: Pictures of dental samples after treatment for 30 minutes

Samples were compared standard teeth kit to know the efficiency of the color change as listed in Table 1. We notice the variation in the teeth colors due to the difference in the amount of calcareous material on the teeth from one person

to another. It can be seen that the whiteness efficiency of some teeth, such as the S5 sample, was very high, while others were less efficient as the S1 sample.

Table 1: Change in the color tone of dental samples before and after treatment for 15 and 30 minutes

Sample	S1	S2	S3	S4	S5
Gender	Female	Female	Male	Male	Male
Age	18	35	38	24	35
Smoking	-	-	-	-	Smoker
Before treatment	2M3	2M3	2M3	2M3	3R2
30 min treatment	1M2	0M3	0M3	1M2	0M1

The structural properties of the teeth samples have been studied to know the difference in crystal structure, degree of crystallization, and crystal size, which are considered as an indication of dental integrity, for different groups according to age, gender, and smoking habit. As well as the effect of laser treatment on the structural properties of the teeth.

Figure 2 illustrates the x-ray diffraction pattern from the S1 sample before and after treatment and its conformity with the standard lines (red lines) for the crystal structure of hydroxide apatite (HAP) of hexagonal structure of lattice constants ($a = 9.4212 \text{ \AA}$ $c = 6.8927 \text{ \AA}$) in the standard card number 96-901-3628. The figure shows a healthy structural structure in terms of complete crystallization well for the tooth. HAP is the main material for building tooth tissue in

addition to some organic materials and other trace elements that substituted within lattice without significantly affecting its crystal structure that give the enamel strength.

Many peaks appeared in the figure due to crystalline levels, i.e. the polycrystalline structure. The most prominent of these peaks, which are more intense at the diffraction angles 31.74° , 32.18° and 32.87° , corresponding to crystalline planes (211), (112) and (300), respectively.

It appears from the two curves that there is no significant difference in the crystal structure before and after treatment, which indicates that there is no negative effect of treatment in this way on the structure of the basic structure of the tooth.

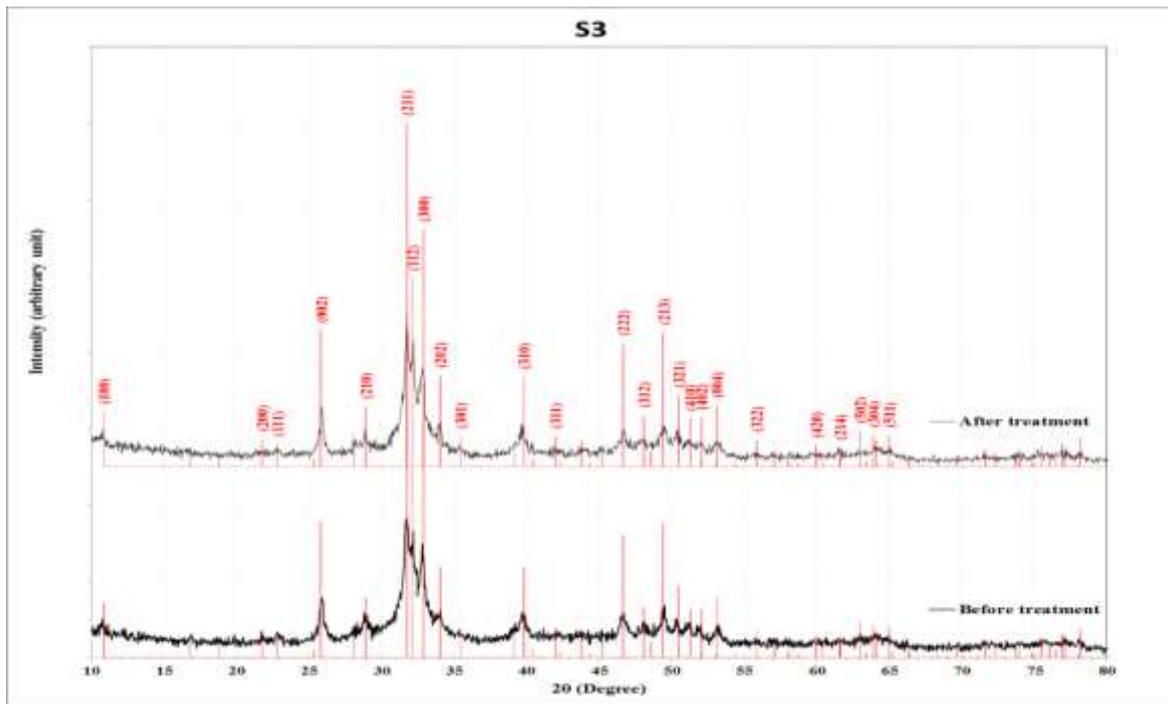


Figure 4: Comparing the x-ray diffraction of the S3sample before and after the treatment

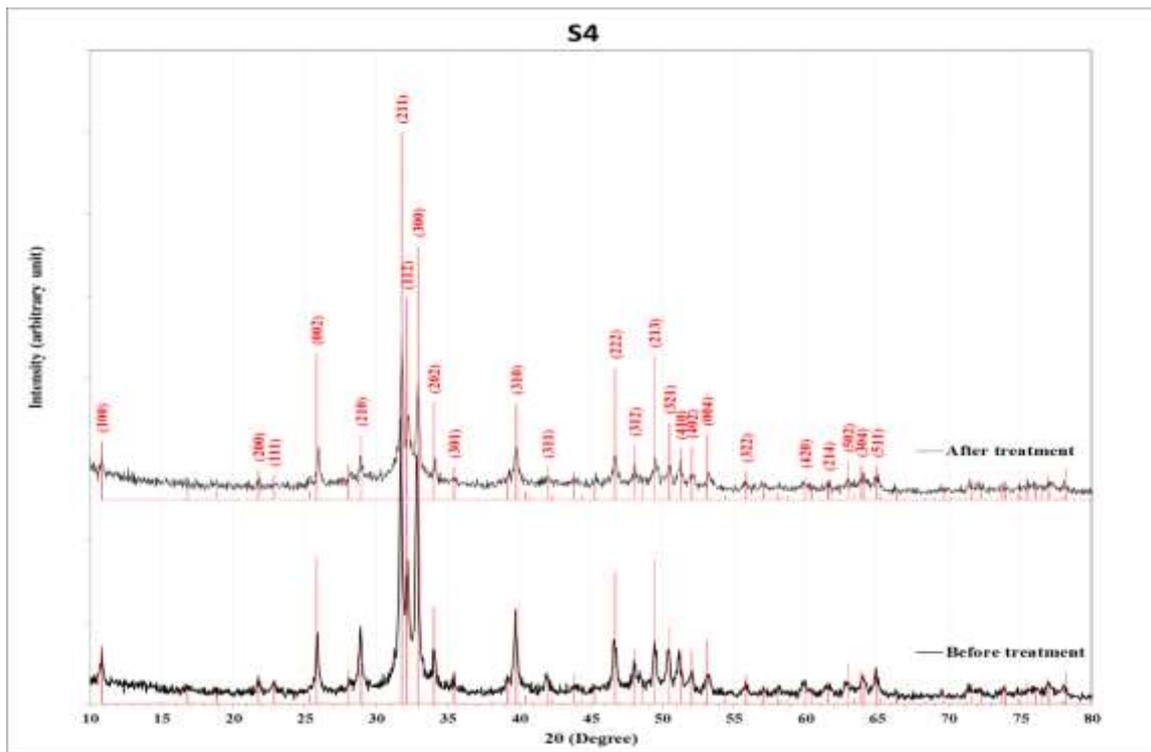


Figure 5: Comparison of x-ray diffraction of the S4sample before and after the treatment

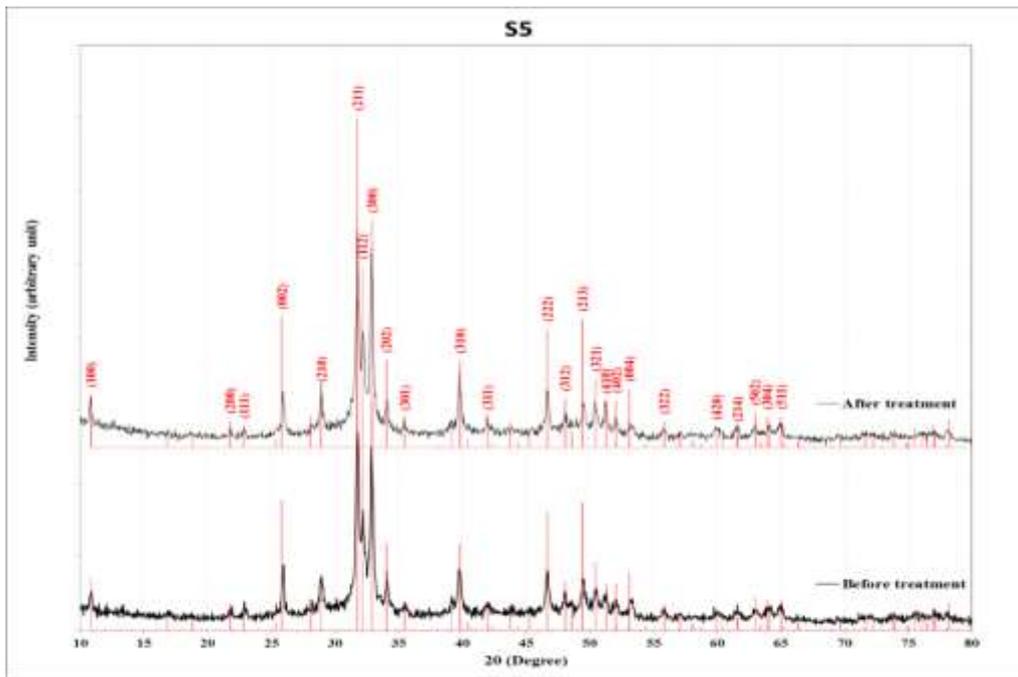


Figure 6: Comparison of x-ray diffraction of the S5sample before and after the treatment

Figure 7 shows the change in the average of calculated crystalline size according to Sherrer's formula for the biological apatite. Mg ion substitution in crystalline HAP reduced its degree of crystallization. Furthermore, the results clearly showed that the average crystalline size of

HAP had decreased due to magnesium substitution. The Mg substituted within HAP structure made the grain irregular and the remaining Mg was absorbed onto the HAP surface which prevents the growth of crystals[8].

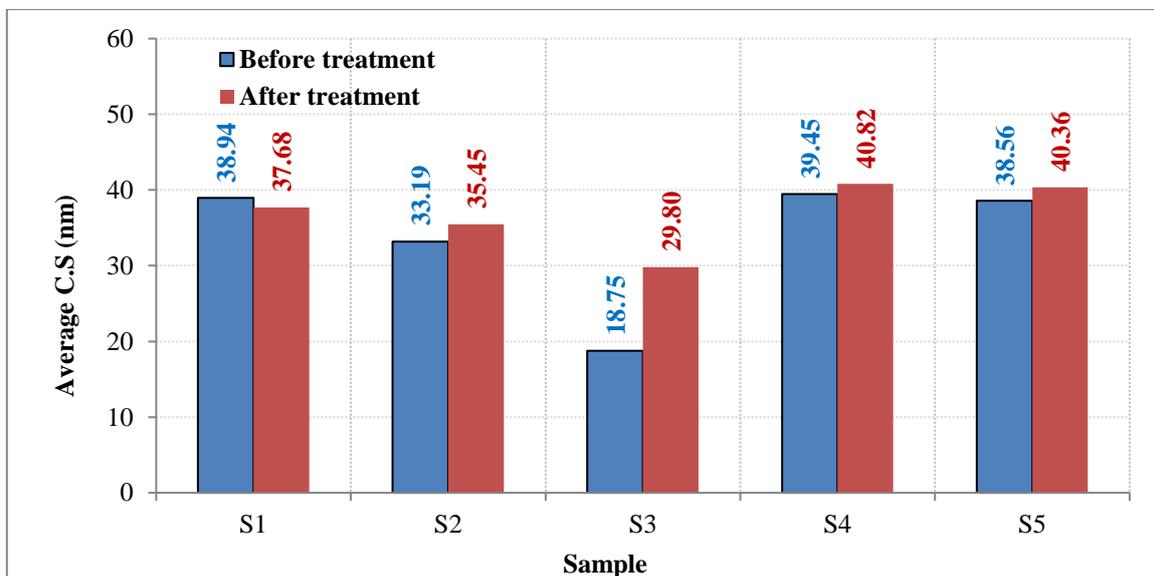


Figure 7: The average crystalline size of the dental samples before and after treatment

The lattice constants (a and c) have been calculated using the (300) and (004) directions respectively. Figures 8 and 9 indicate the change of the lattice constants of the dental samples before and after treatment. It is shown that (c) increases in S3 sample. The variation in lattice constants maybe due to variation in magnesium ion (Mg^{+2}) content

which leads to a decrease (c) as shown in previous research [9],[10] due to the radius of Mg^{+2} (0.069 nm), smaller than the radius of Ca^{+2} (0.099 nm) [11] and correspondingly an increase in the (a). These results agree with Udhaya kumar et al[12].

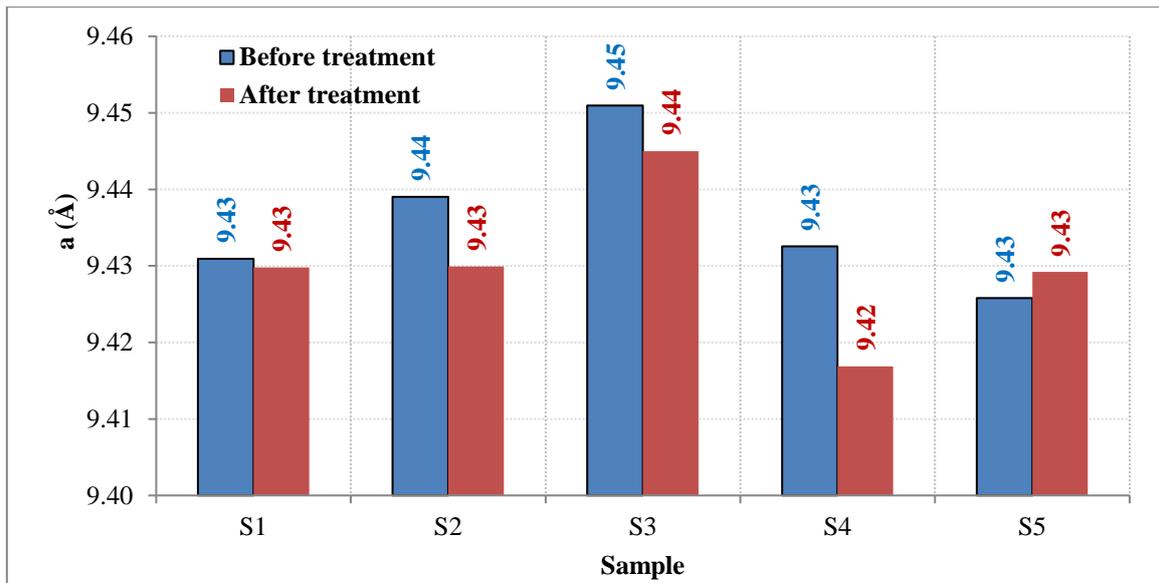


Figure 8: Variation of lattice constant (a) for the dental samples before and after treatment

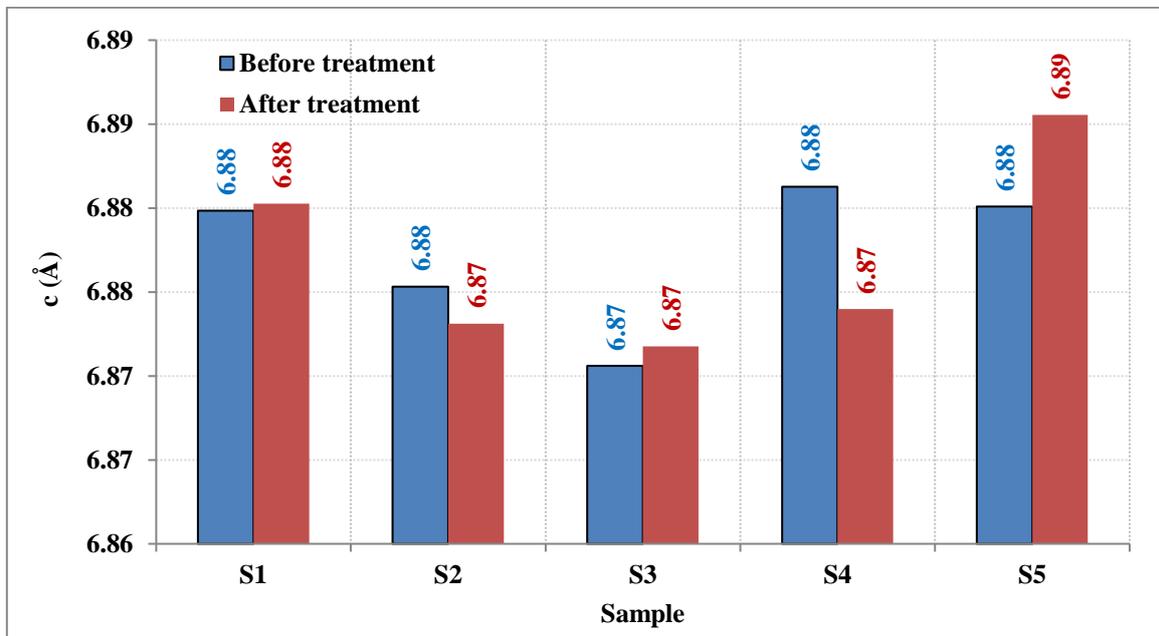


Figure 9: Variation of lattice constant (c) for the dental samples before and after treatment

Figure 10 shows the change in the average lattice strain δ calculated from the following equation [13].

$$\delta = \frac{|d-d_0|}{d_0}$$
 , where d and d_0 represent the inter-plane distance values for the standard and calculated values respectively. It appears that the high values were for the S3

sample due to its smaller crystalline size or because it contained greater amounts of magnesium ions as would be demonstrated by XRF measurement. There is no significant difference in values before and after treatment.

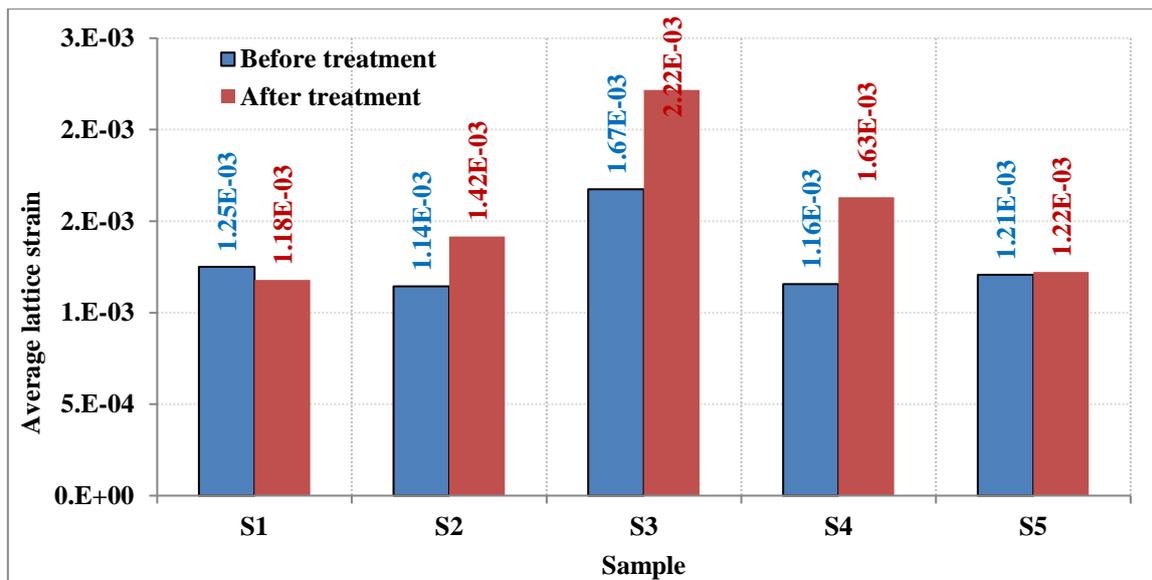


Figure 10: lattice strain for the dental samples before and after treatment

Table 2 displays the x-ray fluorescence result for the dental samples before and after treatment. Almost all samples show the same ratio of phosphate/calcium, which is about 1.3 for the apatite, and they differ from those for the standard hydroxide apatite stoichiometry (1.67) due to the presence of a variety of alternatives and vacancies within the biological apatite [14]. In addition to the presence of small amounts of other minerals, most of which are sodium, magnesium and calcium. The presence of small quantities of trace elements leads to a difference in the arrangement and size of the apatite crystals in the enamel as well as affecting its hardness and optical properties [15]. Trace elements are of low concentration but have an important role to maintain healthy teeth. The source of trace elements in the human

body is through eating or due to exposed to the environment, and incorporated into the structure of apatite in the enamel [15]. There is a slight increase in the concentrations of magnesium after treatment. The presence of sodium indicates the sodium silicate phosphate compounds. A recent clinical study indicated that sodium silicate phosphate and chlorine compounds lead to a significant reduction in tooth sensitivity [16]. Early laboratory studies showed that sodium silicate phosphate forms a mineral layer and prevents exposed enamel surfaces [17]. The tests show a slight increase in both sodium and chlorine compounds.

Table 3: Weight percentage of elements in the dental samples

Sample		Wt %				
		CaO	P ₂ O ₅	Na ₂ O	MgO	Cl
S1	Before	54.142	42.000	2.485	0.764	0.345
	After	53.975	41.749	2.905	0.917	0.454
S2	Before	53.697	41.974	3.074	0.871	0.383
	After	53.766	42.757	2.469	1.009	0.412
S3	Before	54.926	40.609	2.554	1.597	0.313
	After	54.247	40.828	2.304	1.621	0.466
S4	Before	54.334	41.578	2.443	0.934	0.501
	After	53.793	42.207	2.570	0.927	0.503
S5	Before	54.218	42.139	2.286	0.885	0.472
	After	54.166	41.874	2.662	0.802	0.496

Teeth contain hydroxyapatite (HAP) crystals of chemical formula Ca₁₀(PO₄)₅(OH)₂, in addition to bicarbonate ions, organic collagen and water. These components absorb strongly in the infrared spectrum. The precise determination of the chemical components of tooth synthesis depends on several variables such as a person's age, but despite these variables the values remain very similar to all samples as they appeared in Figure 11.

Two bands of phosphate ions appeared, each divided into three peaks at about 604, 563, and 473 cm⁻¹, and another at 1090, 1038, and 959 cm⁻¹, which date back to the crystals [18] HAP, [19]. Phosphate ions have four multiple vibrational patterns due to the multiple degrees of freedom. All of these patterns appear at the infrared spectrum of enamel and ivory tissues [20].

FTIR spectra also confirmed the presence of Collagen proteins, Amide I at 1646 cm^{-1} which is due to the expansion vibration $\text{C}=\text{O}$, and Amide II for the $\text{C}-\text{N}$ band at 1548 cm^{-1} , where the organic matrix of the bones is mainly collagen. Whereas the Amide III was weak at about 1250 cm^{-1} [21].

Tests also confirmed that the dental samples contained carbonate ions with the appearance of the two bands at 1417 and 873 cm^{-1} carbonate ions, in addition to the OH band at 1460 cm^{-1} indicating the presence of water within the crystal structure of teeth [22]. Carbon substitution rate for

phosphate varies, which determines solubility. The ratio of inorganic to organic contents also varies from sample to sample.

Comparing the FTIR spectrum curves for the five samples before treatment shows that the spectral bands, especially PO_4^{3-} , differ in intensity from one sample to another as the weakest was the intensity of the S3 sample which had the lowest phosphate content more Mg content, as indicated by the XRF examinations.

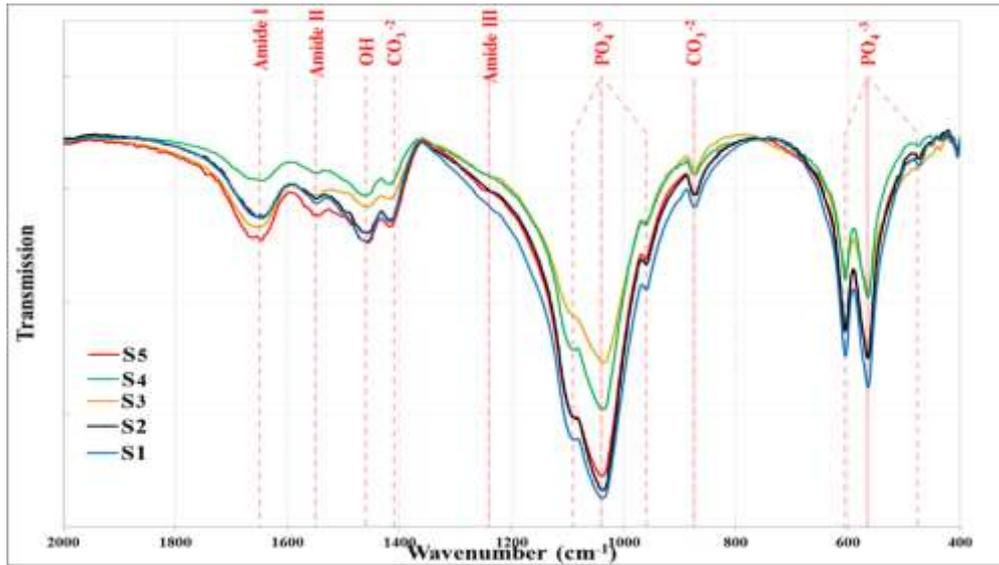


Figure 11: Comparison of FTIR curves for S1, S2, S6, S9, and S10 models before processing

The comparison between untreated sample treated sample shows no variation in the characteristic band of apatite structure as shown in Figure 12.

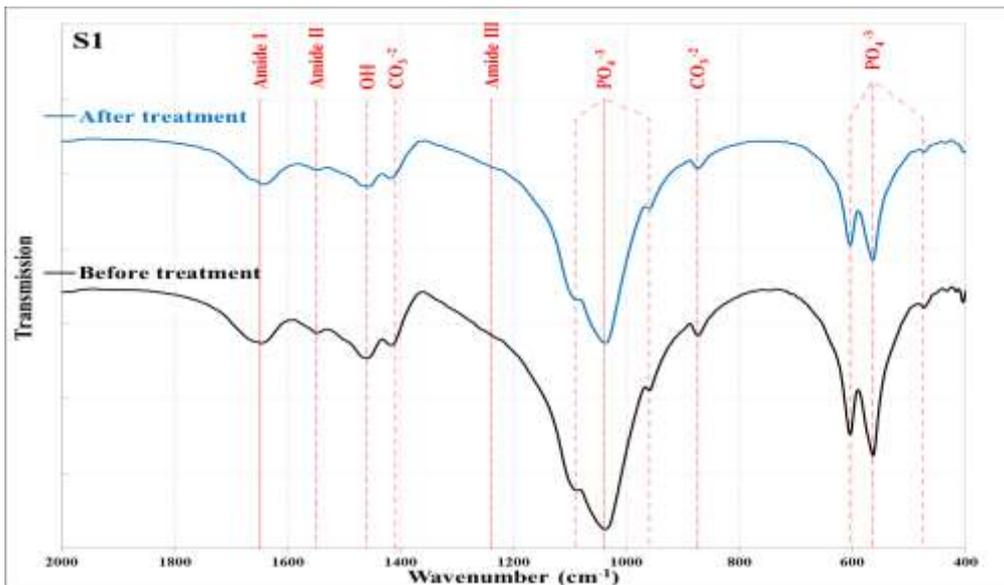


Figure 12: Comparison of the FTIR curves for the S1 model before and after 30-minute treatment

Table 4: FTIR bands for the five samples before and after treatment

Sample		Band type										
		Amide I	Amide II	OH	CO ₃ ²⁻	PO ₄ ³⁻						
S1	Before	1646.90	1548.24	1460.08	1417.48	1090.58	1038.10	959.82	873.25	604.24	563.75	473.55
	After	1646.90	1548.24	1457.83	1413.39	1090.58	1037.67	959.82	874.51	604.29	564.06	469.47
S2	Before	1643.69	1552.33	1456.46	1417.48	1094.67	1036.97	955.73	872.83	604.21	564.10	473.55
	After	1649.95	1548.24	1456.47	1417.48	1094.67	1038.70	955.73	873.84	604.24	564.10	471.55
S6	Before	1654.01	1544.15	1456.44	1421.57	1098.75	1035.40	951.65	872.82	603.84	563.19	477.64
	After	1662.31	1556.41	1456.41	1413.39	1098.71	1036.38	959.82	871.73	604.47	563.78	477.64
S9	Before	1646.62	1548.24	1460.66	1417.48	1090.58	1036.47	959.82	871.70	604.25	563.76	473.55
	After	1646.11	1544.15	1459.70	1417.48	1094.67	1037.67	959.82	873.29	604.74	564.44	473.55
S10	Before	1647.04	1548.24	1456.82	1413.39	1094.67	1038.63	959.82	873.90	604.65	564.54	474.65
	After	1664.22	1552.33	1457.70	1417.48	1090.58	1036.13	955.73	871.84	604.71	563.59	473.51

CONCLUSIONS

The teeth bleaching using infrared laser diode in the presence of hydrogen peroxide has no significant difference in the basic crystalline structure of HAp.

Sample with highest content of magnesium ion has the lowest degree of crystallization, and the lowest crystalline size. Also increase the Mg ion substitution reduced c lattice constant and increase the lattice strain.

The comparing between the FTIR spectral patterns show that the PO₄³⁻ bands intensities decrease with decreasing the P/Mg ratio.

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