Evaluation of Iraqi Phosphorite from Akashat Mine as a Polishing and Whitening Material in Human Dentistry: A Study in Medical Geology

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Abstract: ***The aim of this study is to prepare and assess the phosphorite efficiency for removal extrinsic stains and debris from the human teeth and luster increasing via a set of laboratory experiments. The phosphorite is composed of carbonate-fluorapatite, while the human teeth are composed of hydroxyapatite. Polishing of the human teeth was conducted by using 68, 46, 30, and 18 µm grain sizes of phosphorite powder which are equivalent to 260, 325, 600, and 1200 mesh respectively. Buffing stage wesgently done later using diamond paste of 7 and 2.5 µm grain size. The surface roughness (Ra µm) of the target (human teeth) which was measured after each stage positively correlated to the grain size, while reflectance (R%) was of negative correlation. The reflectance values of the sharp human tooth are 0, 1.4, 2.8, 3.3, 3.6, 4.7, and 4.5%for the surface roughness values of 45.2, 39.8, 32.6, 25.6, 10.3, 7.5, and 4.0 µm. The reflectance values of the wide human tooth are 0, 1.1, 2.2, 2.7, 3.5, 4.2, and 4.6%for the surface roughness values of 40.2, 34.6, 27.7, 21.3, 9.0, 7.5, and 4.0 µm. The phosphorite powder of grain size 18 µmis the best abrasive for removal the extrinsic stain which is a deposition of chromogenic materials on the external surface (enamel and dentin) of the human teeth.***

Keywords: Phosphorite, Abrasive, Human teeth, Apatite, Akashat Formation.

1. Introduction

The natural and artificial abrasives used to grind, polish, and clean or otherwise remove solid substance, normally by rubbing effect [1].The most generally used abrasive substances are aluminium oxide and silicon carbide [2]; [3] and [4].Various materials such as pumice, marble, bone ash, coral and shells have been utilized for mechanical removal of tooth stains and debris [5]. Calcium pyrophosphate, silicates, calcium carbonate, alumina are basically known as mechanical abrasives.The grinding is used to remove surface irregularities and casting resin which covers the sample, preparing a smooth surface for further work[6].Polishing is used coated abrasives onto a cloth; that is, abrasive particles are attached in a water and can slide or roll across the specimen and cloth [7]; and [8]. Polishing creates a lined or brushed finish where buffing eliminates the lines and generates a bright luster finish.Calcium phosphate with some chemical agents (polyphosphates and pyrophosphate) have been introduced for polishing ability and abrasivity [9].The abrasivesrely on a variety of properties including crystal structure, chemical composition, hardness, cleavage, friability, concentration, size, shape distribution and surface features of particles[10]. The high enamel luster is significant for in contributing to the aesthetics of the teeth, and most highly polished enamel showsa whiter than duller enamel[11]. Several studies have revealed that unpolished andrough tooth surfaces facilitate the retention and formation of dental plaque and extrinsic stain[12] and[13]. Primary bacterial colonization beginsonthe irregularly tooth's surface[14]and [15].Abrasives should have ability to removing extrinsic stains practically without producing in unnecessary harmful abrasion for the teeth as well asinhibiting dental accumulations. In this study, phosphorite was used and assessed as an abrasive for polishing of the human teeth surfaces. The reason of the selection thephosphorite as a dental abrasive is matching of phosphorite mineralogy with the human teeth, the high cost of enhancing the dental luster in the dental clinic as well as the abundance of the phosphorite reserves in Iraq.

2. Materials and Methods

2.1 Sampling and abrasive sample preparation

Phosphortie samples were collected from the Akashat Formation (Early- Late Paleocene). The stratigraphic section of phosphorite in the Akashat Mine was divided into two layers depending on texture and color variation.Nine samples were collected from the mine depending on the fabric and color heterogeneity. One sample (3Ph) was collected from the bottom layer, while eight samples were collected from the top layer as they were later incorporated into a representative sample(4Ph) (Figure 1).The sample 3ph has a greater content of P_2O_5 than of sample 4pH.

Figure 1: Phosphorite sampling sites from the Akashat Mine

The dried friable samples are disaggregated gently by using the plastic rolling-pin, where the hard samples were crushed using agate mortar. For obtaining a representative sample, 100 g for each sample was mixed together. The total volume of the sample was coning and quartering into four equal parts. Then, one corner part was coning and quartering again. By repeating the procedure five times, a homogeneous and representative sample was obtained. The sample was sieved using the wet method to four grain sizes (68, 46, 30, and 18 µm) which are equivalent to 260, 325, 600, and 1200 mesh of grit size respectively. The procedures of abrasive preparation, grinding and polishing process had been done in the Department of Geology, College of Science, and University of Baghdad.

2.2 Chemical and mineralogical analysis

Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) was used for analyzing the major oxides (SiO2, Al2O3, Fe2O3, CaO, MgO, Na2O, K2O, TiO2, MnO, P2O5, SrO, Cr2O3, BaO and L.O.I). The chemical analysis was carried out in the ALS Laboratory Group, Analytical Chemistry and Testing Services, Mineral Division-ALS Chemex at Dublin in Ireland. The adopted procedure is MEICP06 code, including a package of thirteen elements fused by lithium borate. 0.2g of the sample is added to 0.9g of lithium metaborate/lithium tetraborate flux, mixed well and fused in a furnace at 1000ºC. The resulting melt is then cooled and dissolved in 100 ml of 4% nitric acid, 2% hydrochloric acid solution [16] and [17]. This solution is then analyzed by ICP-AES and the results were corrected for spectral inter-element interferences. Oxide concentration is calculated from the determined elemental concentration. The mineralogical analyses are conducted by scanning electron microscope (SEM) and X-ray.The scanning electron microscope (SEM) wasperformed in AL-Nahrain University, College of Science, Department of Physics and X-ray diffraction (XRD) was performed in the Germany Lab, Department of Geology, College of Science, University of Baghdad.

2.3Preparation of targets

The human teeth which are used as targets (Figure 2A) were cleaned and the roots were removed, and then placed at 10% neutral formalin buffer to keep the chemical elements and mineral composition [18]. The teeth were longitudinal slices by using diamond saw parallels to the predictable vertical axis. The slice containing the enamel layer of teeth was then mounted in cold-setting epoxy resins for preparing the polished section (Figure 2B). A full procedure of [19] and [7]were followed to prepare the polished section. Lower jaw including twelve tooth was made at the dental clinic in Baghdad (Figure 2C) for the purpose of the final evaluation of the teeth polishing.

Figure 2: A: Human teeth; B: Polished section of human teeth; C: Artificial lower jaw of human teeth.

2.4 Polishing and buffing processes

The specimen sections of two human teeth arefirstly groundvery gently with 120 CaC for eliminating the remnant plastic of resin.Thereafter, paper coated with 68, 46, 30 and 18 µmand phosphate abrasive were used in polishing the human teeth. The distilled water was used as moisturize and cooling agent for each polishing stage that was done on arotating discof1000 rpm for 5 min. Cutting, polished sections, grinding and polishing processes were conducted at workshop ofthe Department of Geology, University of Baghdadusing devices shown in Figure 3.

Figure 3: Cutting, grinding, polishing devices used in this study, (A: cutting machine), (B: mounting preparation device), (C: grinding machine), (D: polishing and buffing machine)

2.5 Assessment of polishing methods

The surface roughness and reflectance were measured in attempt to evaluate the teeth polishing efficiency. The roughness measuring is performed by PosiTector Surface Profile Gage (Figure4), which gives reading in micron. It is a handheld electronic instrument that measures the peak- to-valley height along a profile cleaned surfaces. The device was normalized to zero before measuring using standardized smooth glass (Figure 4). This is done by applying slight pressure to the foot to ensure that it is perfectly flat on the glass. By loosening the locking screw, the bezel can now be moved easily in any direction. Still applying the slightest pressure, the bezel should be moved so that the zero on the gauge is immediately behind the needle, and then tighten the locking screw, the gauge is ready for use. It is normal to work to average readings. Several readings are taken, usually ten, in random positions on the surface, and the average was calculated. The reflectance at 546 nm in the air is performed by the Laser Beam System (Figure 5) which is composed from the laser beam, photoelectric cell and a galvanometer for measuring electric current. Laser beam invokes to receipt signals to the photoelectric cell that sending to measurement of electric current to give reading in microampere. Reflectance of the specimens was measured in the Optical Lab, Laser Branch, Applied Science Department at the University of Technology.

Figure 4: PosiTector device with standard plate and glass for the device normalization used for measuring the surface roughness.

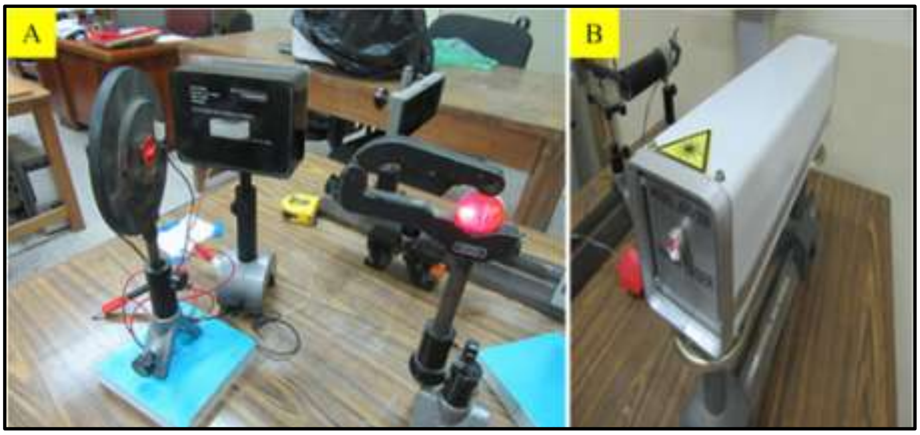

Figure 5: Laser beam system used for the reflectance measurements

3. Results and Discussion

3.1 Mineralogy and chemical composition

The X-ray revealed that the main constituent of the phosphorite used in this study is a carbonate-fluorapatite with minor amounts of calcite andquartz in both phosphoritesamples (3Ph and 4 Ph) (Figure 6).The human teeth represented by sample no. 6Ht is mainly formed from hydroxyapatite (Figure 7).The Energy Dispersive Spectroscopy (EDS) confirmed the crystal chemistry of carbonate-fluorapatite(Figure 8). The chemical composition results of the phosphorite samples are listed in Table 1.

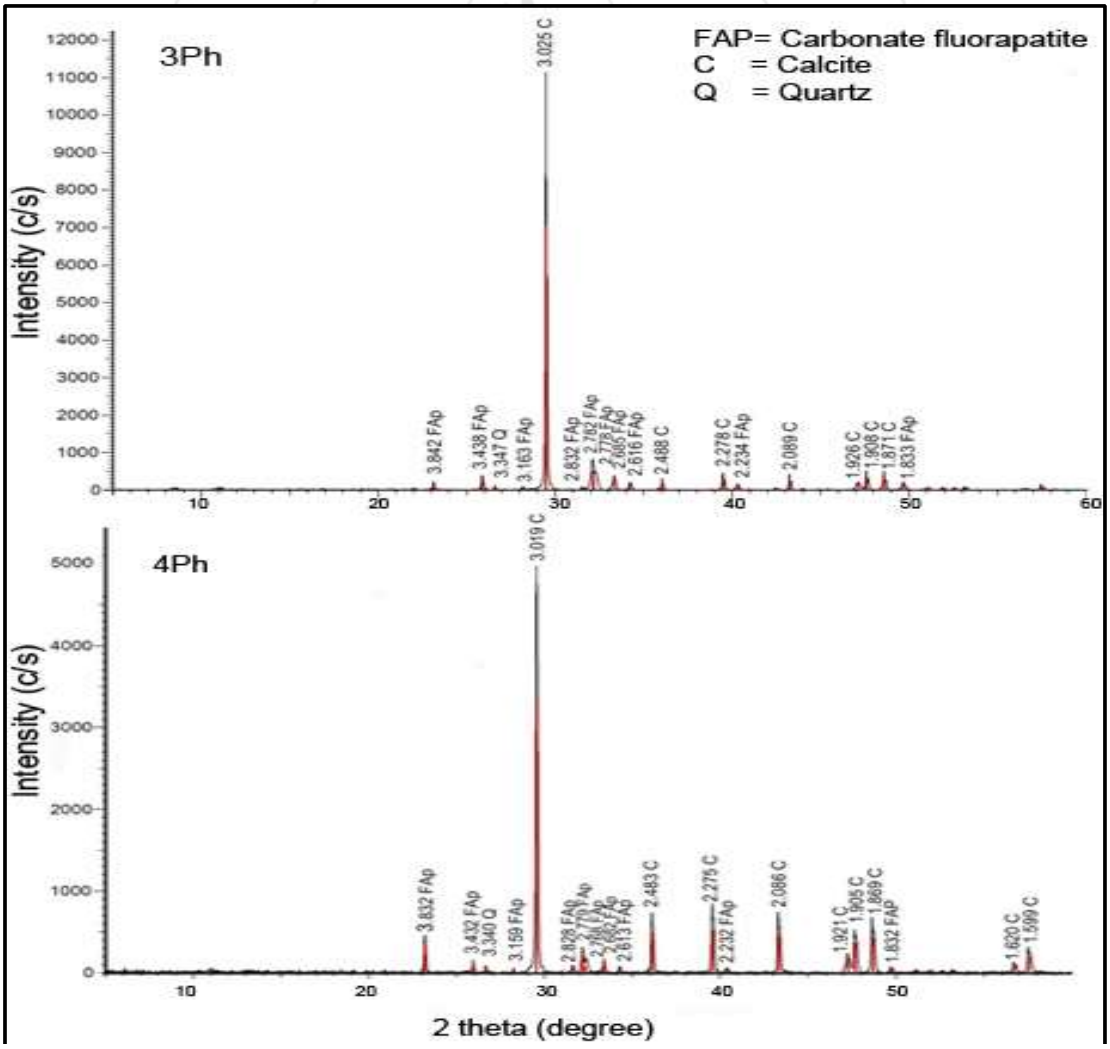

Figure 6: XRD diffractograms displaycarbonate fluorapatiteas a main constituent insamples 3Ph and 4Ph.

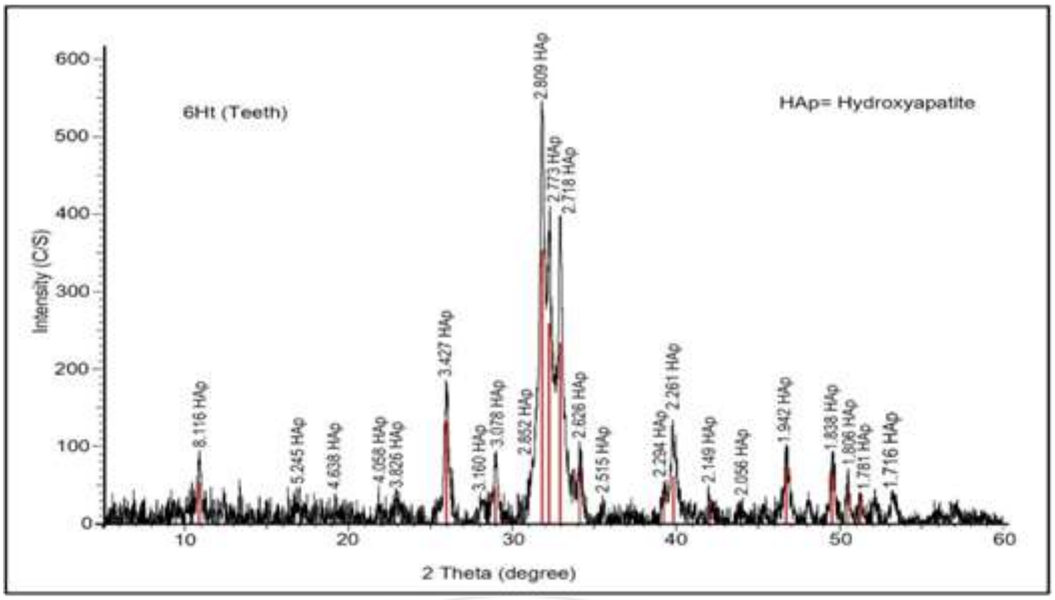

Figure 7: XRD diffractogram of the human teeth; sample no. 6Ht.

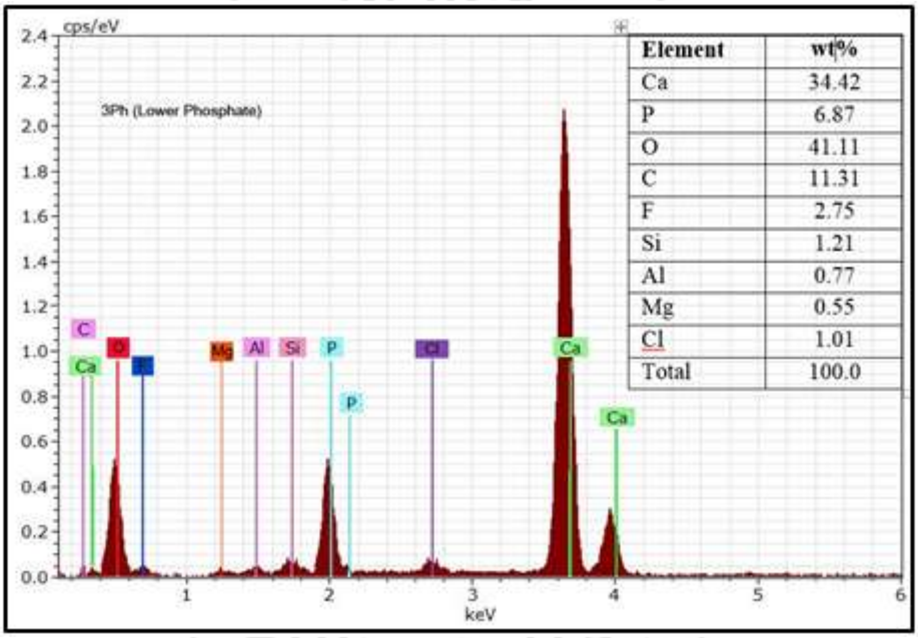

Figure 8: Energy Despersion spectra (EDS)of phosphorite showing the chemical composition of sample number 3Ph.

Table 1: Chemical composition (%) of the phosphorite samples

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	SrO	Cr_2O_3	BaO	L.O.I	Total
3Ph	2.10	0.35	0.13	52.8	0.67	0.62	0.02	0.02	18.5	<0.01	0.15	0.03	<0.01	23.2	98.59
4Ph	1.59	0.33	0.20	55.2	0.57	0.17	0.01	0.02	4.61	<0.01	0.05	0.01	0.01	38.2	100.97
Av.	1.85	0.34	0.17	54.0	0.62	0.40	0.015	0.02	11.6	<0.01	0.10	0.02	<0.01	30.7	99.9

Phosphorite is a medium hard material and has a 5 hardness on the moh's scale involving microcrystalline apatite, teeth, pellets, oolites, avoids, bone fragments, coprolite and other uncharacterized phosphorite fragments(Figure 9 A, B,C, D and E).Their morphology shows irregular forms with other particles are concerned with the presence of organic remain particles. Sometimes, apatite occur in interstitial cement between the other phosphatic particles, and in a substitution of carbonate detritus. Matrix consists from ovoid-shape apatite microparticles (Figure 9E, F), and micron-size globules (Figure 9D). Greatly, ovoid-type apatite grains of flattened or are rosettes on surfaces of skeletal grains (Figure 9D, F). At light-brown particles, both the cortex and nucleus are heterogeneous and porous, involved of micron-sized apatite (Figure 9B, C).The irregular shape is clear in Figure 9 G and H.

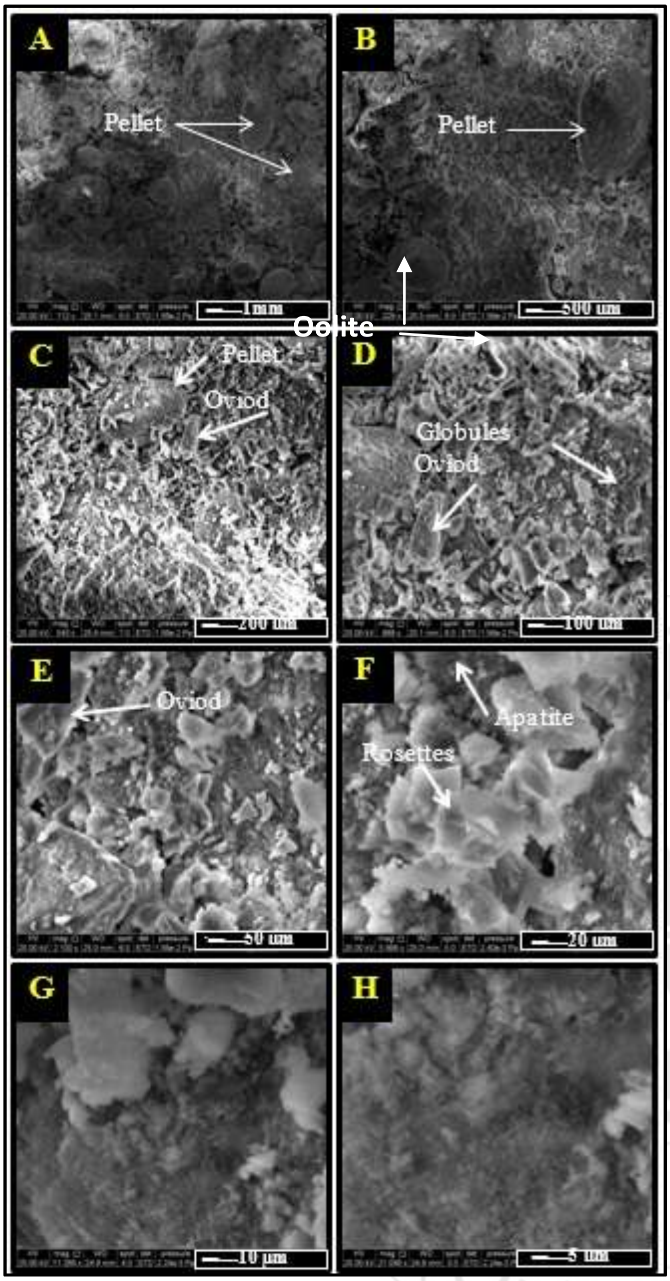

Figure 9: SEM photomicrograph of the phosphorite surface morphology; sample no. 3Ph.

3.2 Abrasion evaluation

The abrasion resistance of phosphorite can be evaluated through its pits loss and surface smoothness, after a certain period about five minutes for each abrasion stage. The tooth rough surfaces participate to increase the plaque retention and the staining. The surface roughness averages have statistically significant decrease in their roughness after an abrasion process in positive relationship with this grain size (Table 2 and Figure 10).The light reflectance shows negative relationship with the grain sizes 120, 68, 46, 30, 18, 7 and 2.5 μm. The reflectance value of the sharp human tooth were 0, 1.4, 2.8, 3.3, 3.6, 4.7, and 4.5% with surface roughness of 45.2, 39.8, 32.6, 25.6, 10.3, 7.5, and 4.0 μm, whilst the reflectance for wide human tooth were 0, 1.1, 2.2, 2.7, 3.5, 4.2, and 4.6% with surface roughness of 40.2, 34.6, 27.7, 21.3, 9.0, 7.5, and 4.0 μm for grain sizes of phosphorite abrasives 120, 68, 46, 30, 18, 7 and 2.5 μm respectively. The abrasion rate increased significantly with increasing the abrasive size.

Table 2: Results of roughness (μm) and reflectance (%) values of the human teeth surface for the different grain sizes of abrasive

Abrasive (Phosphorite)			Measurement	n	Target material	
Stage	Grain size (μm)	Approximate Mesh (grit size)			Sharp human tooth	Wide human tooth
Grinding by SiC	120	100	Roughness Av. μm	10	45.2	40.2
			Reflectance %	1	0	0
Polishing by phosphorite	68	200	Roughness Av. μm	10	39.8	34.6
			Reflectance %	1	1.4	1.1
	46	325	Roughness Av. μm	10	32.6	27.7
			Reflectance %	1	2.8	2.2
	30	600	Roughness Av. μm	10	25.6	21.3
			Reflectance %	1	3.3	2.7
	18	1200	Roughness Av. μm	10	10.3	9.0
			Reflectance %	1	3.6	3.5
Buffing by diamond paste	7	3000	Roughness Av. μm	10	7.5	7.5
			Reflectance %	1	4.7	4.2
	2.5	8000	Roughness Av. μm	10	4.0	4.0
			Reflectance %	1	4.5	4.6

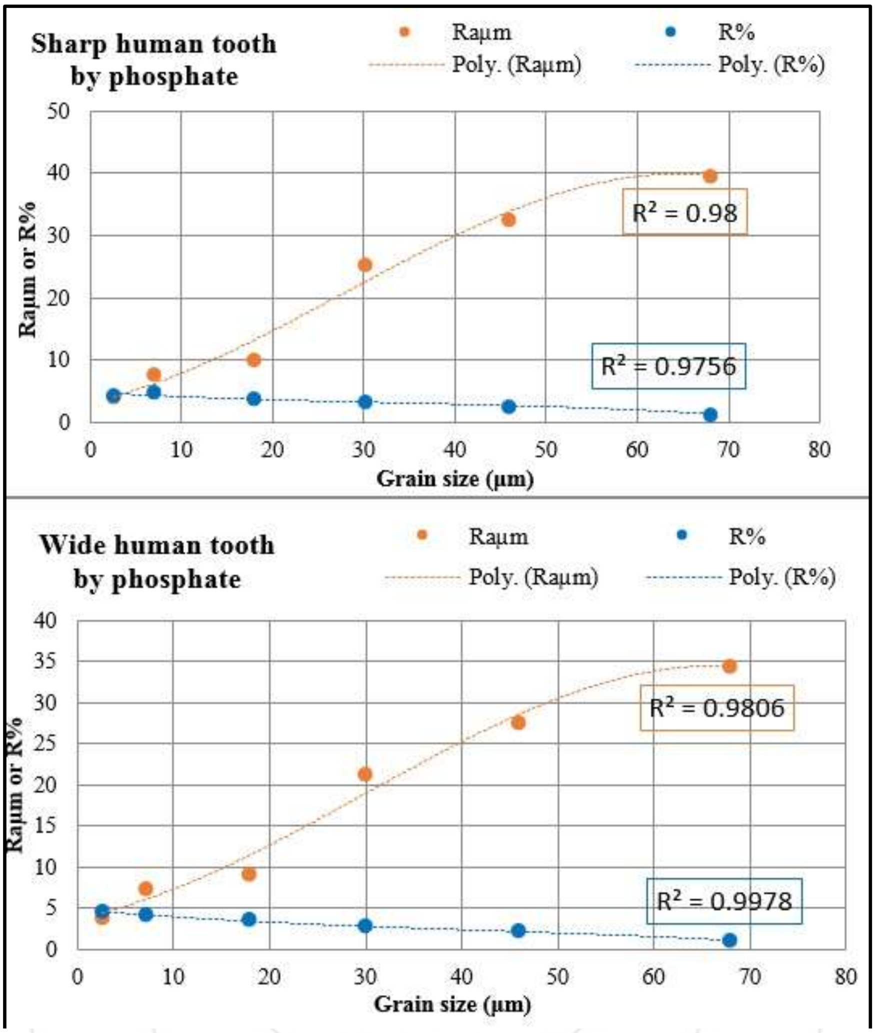

Figure 10: The relationship between grain size of phosphorite abrasive and each of the roughness (Ra µm) and reflectance (R%) values; A positive proportional with the R%, but proportionally negative with Ra.

Each stage of grinding, polishing and buffing has been examined, and then the surface regularity of human teeth is gradually improved with decrease theabrasive grain size. Micro-images for the human teeth surface were taken under the reflected light microscope for each grinding, polishing and buffing stages (Figures11 and 12).The identification of the texture of each of sharp and wide tooth showed that theenamel layer did not scratch. After selecting the preferred grain size of phosphorite abrasive (18 µm) to clean and bleach the teeth based on the results of the reflectivity and smoothness of the surface; an experiment was conducted on the artificial lower jaw that was manufactured by this study and the results were successful. The phosphorites with grain size of 18 µmcan removalthe teeth stain without causing deleterious, and it will be better if the abrasives are used with therapeutic agents such as fluoride.

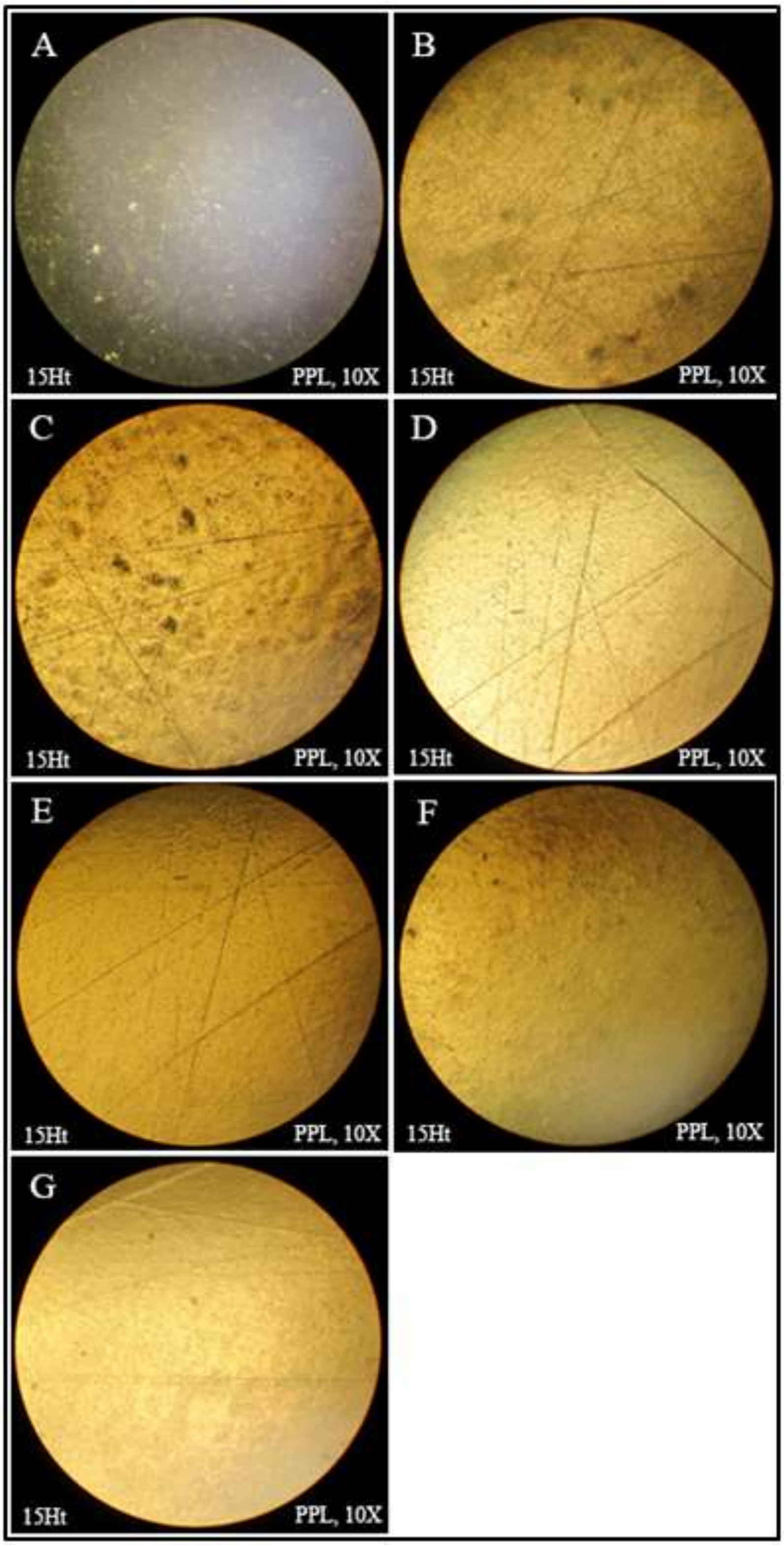

Figure 11: Micro-photos under reflected microscope shows the polishing stages of the sharp molar tooth at different abrasive grain sizes; A: 120 µm; B: 68µm; C: 46µm; D: 30µm; E: 18µm; F: 7µm diamond paste; G: 2.5µm diamond paste.

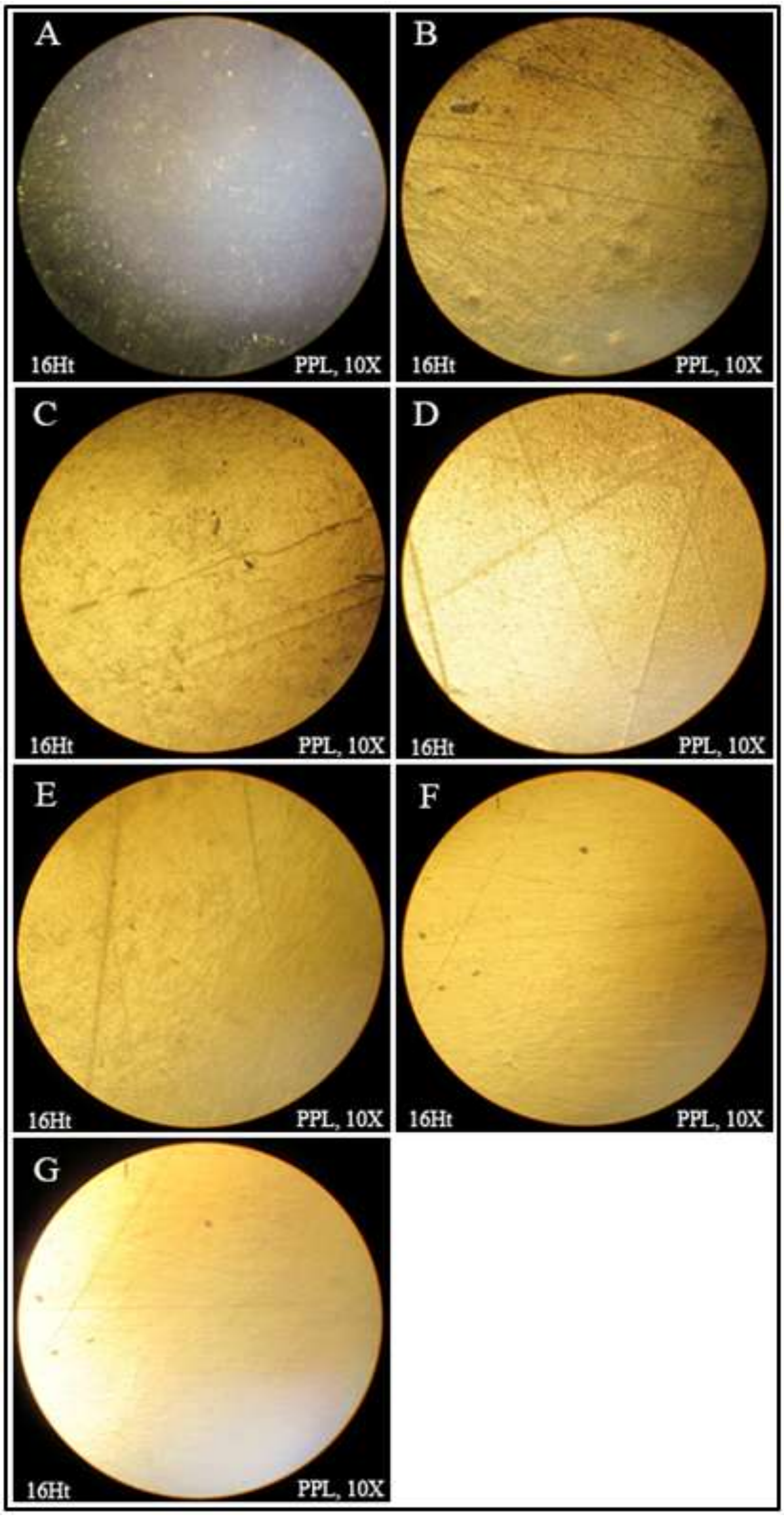

Figure 12: Micro-photos under reflected microscope shows the polishing stages of the wide molar tooth at different abrasive grain sizes; A: 120 µm; B: 68µm; C: 46µm; D: 30µm; E: 18µm; F: 7µm diamond paste; G: 2.5µm diamond paste

4. Conclusions

Polishing by phosphorite abrasive is a technique has been used for removing stain and cleansing the teeth, whereas at the same time conserving tooth structure and surface smoothness. The phosphorite that preparing in the present study is valid for polishing and somewhat whiting the teeth, due to its mineralogical composition that composed of carbonate fluorapatite as main constituent, which is similar to the tooth mineral. Polishing by the phosphorite abrasive mixed with a distilled water form a paste easy to deal with the teeth. The surface roughness of the human teeth decreased from 45.2 to10.3 µm and from 40.2 to and 9.0 µm for sharp and wide human teeth respectively, while the reflectance increased from 0 to 3.6% and from 0 to 3.5%. The diamond paste of grain size 7 and 2.5 µmwas used very gently as the final buffing stage.It reduced the roughness tooth surface to4.0 µm, whist the reflectance upgraded to 4.5 and 4.6% for sharp and wide molar teeth respectively. Accordingly, the best polished surface of human teeth obtained is by using an 18 µm grain sized abrasive which is equivalent to 1200 mesh which gives a good bright luster adding more aesthetics to the teeth. It should be noted that time is an effective factor in the teeth abrasion efficiency.

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