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Characterization Of Human Teeth By Laser-Induced Breakdown Spectroscopy

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Abstract. We present in this report the results of characterization of human teeth by Laser-Induced Breakdown Spectroscopy, LIBS (100 mJ, 7 ns, 1064 nm) in surrounding He gas of 55 mL/s. Measurements were carried out on human teeth on dentine and enamel (apical and buccal) until about of 45 μm depth from surface. The results showed that the Indonesian human teeth contain some elements such as Ca, F, Si, Zn, Na, Sn, Ar, Li, K, Ce, Fe, Mn, Ti, Al, Cr and P. In addition, based on line intensity ratio of ionic Ca II (396.84 nm) to neutral Ca I (422.67 nm), the apical enamel part is the hardest of all.

Keywords: human tooth, hardness, LIBS, He gas, dentin, and enamel.

1. Introduction

Elements tracing in human teeth is the best method to investigate individual’s nutritional and environmental status. Researchers [1–8], using different equipment and method, found human teeth contained different elements based on the person’s origin. For example, in Finland’s rural area, it was found that Zn and Mg were identified in human dentin which were connected with their concentration in the soil [8].

On the other hand, teeth have important role in food digestion. Teeth disorder will impair digestion. Certain teeth disorder can be caused by mistreatment or overused such as chewing hard things over the limit of teeth’s strength. Therefore, this experiment’s focus is to analyse the hardness of enamel and dentin using laser-induced breakdown spectroscopy (LIBS) through ionic calcium to neutral calcium line intensity ratio [9,10], until about of 27 μm depth from surface.

Some of LIBS’s advantages are its ability to be applied directly both qualitatively and quantitatively on solid, liquid and gas sample, almost without sample preparation, fast, accurate and categorized as non-destructive test.³¹ Sample which is analysed by LIBS can be either inorganic or organic. For organic sample, LIBS has been used successfully for qualitative and quantitative elemental analysis of the enamel and dentin of human teeth [12,13,14].
2. Experimental Procedure

2.1. Material
This experiment used premolar, molar and incisive. Each of them were 9 and taken randomly from sample ages ranged from 35 to 45 years old. Sample were taken from both male and female. Sample was collected from Indonesian people live near Surabaya, East Java. Figure 1, is an example of Premolar tooth that was cut cross sectioned horizontally to analyse its dentin (figure 1c).

![Figure 1. Photograph of Premolar human tooth. a) premolar tooth. b). enamel (buccal and apical). c) dentin](image)

2.2. Experimental Set-up
Commercial LIBS set-up shown in figure 2, was the same as used in the previous experiment[15]. LIBS consists of Nd-YAG laser (model CFR 200, 7 ns, 1064 nm, 200 mJ), spectrometer HR 2500 (14,336 CCD pixels, resolution 0.1 nm, spectra range 200-980 nm), sample site and computer with AddLIBS software [16,17]. Laser was operated on Q-switch mode, frequency of 5 Hz, energy of 100 mJ focused on tooth sample on apical, buccal and dentin, which produced plasma. Photon emission from plasma captured by spectrometer with accumulation 3, delay time detection of 0.5 μs was then displayed as intensity spectra as a function of wavelength in computer. Intensity and wavelength correlated with concentration and kind of elements, respectively. All experiments were done in surrounding gas of He with speed flow of 55 ml/s.

![Figure 2. Experimental Setup [15]](image)

3. Results And Discussion

3.1. Qualitative Analysis
Before determining teeth hardness, we took qualitative data from each tooth on apical enamel, buccal enamel and dentin for premolar, molar and incisive. Laser of 100 mJ was focused on teeth surface of enamel (apical and buccal part) and dentin until 21 shots. The spectra showed in figure 3.
Figure 3. Typical spectra of apical enamel of premolar on 21st shot

Figure 3, is a spectra of premolar tooth on 21st shot or about 45 μm from tooth surface. Data showed that the major elements found in apical enamel are Ca, F, Si, Zn, Na, Sn, Ar, Li, K, Ce, Mn, Ti, Al, Cr and P. It was also conducted on buccal enamel and dentin of premolar tooth, that was found the same elements. The same results appeared when administered on enamel and dentin of incisive. The major elements found in incisive, premolar and molar were the same. This supported the fact that these teeth were from the same place (Surabaya and surrounding). Beside the qualitative analysis of tooth, the tooth can be characterized from its hardness. So the next step was comparing teeth hardness of apical enamel, buccal enamel and dentin of incisive, premolar and molar using ionic calcium and neutral calcium line intensity ratio [9].

Figure 4. A spectra of ionic calcium Ca II 396.84 nm and neutral calcium Ca I 422.67 nm from premolar apical, buccal and dentin.
Figure 4, a spectra of ionic calcium Ca II 396.84 nm and neutral calcium Ca I 422.67 nm wavelength from premolar apical, buccal part and dentin analysed using LIBS. The data showed that calcium emission intensity for each part was different. It was caused by different quantity and calcification process that made impact to the hardness as shown in figure 5, 6 and 7.

Figure 5. Hardness of Molar human tooth

Figure 6. Hardness of Premolar human tooth

Figure 7. Hardness of incisive human tooth
Teeth are hard tissue that underwent mineralization or calcification. Calcification is tissue forming process by many elements and complex crystals. Calcium quantity are different in three parts as shown in figure 4. Based on ionic calcium Ca II 396.84 nm to neutral calcium Ca I 422.67 nm line intensity ratio[9], teeth hardness can be predicted. Another way of comparing hardness with LIBS is by comparing ionic calcium Ca II 373.69 nm to neutral calcium Ca I 428.9 nm line intensity ratio[10]. In this experiment, both methods produced the same trend. This experiment used the first method, because it has higher intensity and easier to read. Besides comparing calcium, there is another way by comparing ionic magnesium Mg II 280.26 nm to neutral magnesium Mg I 285.22 nm[10]. Unfortunately in this experiment, due to less sensitive equipment, this element could not be found clearly.

Figure 5, 6, and 7, showed that ionic calcium to neutral calcium line intensity ratio was higher in apical enamel compared to buccal enamel and dentin in all kinds of teeth (incisive, premolar, molar) until the depth of 27 μm. It means that apical part is the hardest as enamel contains about 60% of hydroxyl apatite crystal. These compounds bind very tightly with high crystallization. Another explanation is because apical part underwent layered formation process and received pressure during teeth usage. Therefore, apical part is dense and hard.

Enamel from buccal part had lower hardness than dentin. It is because it has no pressure during formation. Dentin has hardness between apical and buccal part of any teeth. During formation process, it has pressure but with less elements than enamel.

This experiment only discussed teeth hardness until depth to about of 27 μm (15th shot) as confinement effect happened on further shots. This experiment did not compare the hardness of incisive, premolar and molar because the teeth were not from the same person that could have different mineral composition.

4. Conclusion
The data show that the major elements on enamel and dentin are the same, and based on ionic calcium Ca II 396.84 nm to neutral calcium Ca I 422.67 nm line intensity ratio, the apical enamel is the hardest compared to buccal enamel and dentin parts.

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