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The Structural Changes In The human Teeth During Their Calcination From 25 To 1200 °C by Electron Microscopy

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When teeth are submitted to calcination, structural changes are evidenced by color changes and fractures [1-3]. Sandholzer et al. [4] suggested that temperature produces a degree of perfection in the crystal structure of dentin but limited in enamel. Fereira et al. [5] observed that gradually heating produces minimal damage by fracture, but when the heating is fast, dentin and enamel are abruptly separated at the enamel-dentin junction and the fracture damage is severe. In addition, Reyes-Gasga et al. [6] reported a dielectric-conductive transition in human tooth enamel at around 300 °C. Recently there has been an increase use of laser radiation in dental surgeries. It is estimated that CO_2 lasers raise the temperature up to 800 °C at the application site [7], and erbium lasers produce temperatures above 300 °C [8]. The analysis of the effects of temperatures on the human dental piece play an important role in forensic research [9].

Bulk samples of human tooth enamel and dentin from molar teeth were calcined both in air and argon atmospheres from room temperature (25 °C) to 1200 °C to study the structural and crystallographic changes during heating. The morphological changes were analyzed by light microscopy and scanning (SEM) and transmission (TEM) electron microscopy. The coexistence of hydroxyapatite (HAP) and β tricalcium phosphate (β-TCP), was observed. Due to differences in expansivity, dentine is fracturing after 400 °C. In powder samples, the phase content was analyzed by x-ray diffraction (XRD) and their percentages were quantified by Rietveld method.

The color changes in enamel as a function of calcination temperature followed the sequence:

$$[Natural\ Color] \rightarrow [Light\ Gray] \rightarrow [Dark\ Gray] \rightarrow [Light\ Gray] \rightarrow [White]$$

In air, the dark gray in enamel is observed at 800 °C, while in argon it is observed at around 300 °C. The darkening is due to the removal of the organic material that occurs between 200 and 800 °C. The color changes in dentin followed the sequence:

$$[Natural\ Color] \rightarrow [Brown] \rightarrow [Gray] \rightarrow [Black] \rightarrow [Gray] \rightarrow [White]$$

Dentin is observed in black color at around 300 °C only under argon atmosphere. The color of dentin is lightening around 600 °C.

Figure 1 shows the SEM images of dentin (Figure 1A-C) and enamel (Figure 1D-E) at different calcination temperatures in air. In dentin, HAP crystals coalesce at 200 °C. At 800 °C the dentinal conducts disappear, and, above 1000 °C, an equiaxial granular structure is formed. These equiaxial grains grow considerably after 1000 °C. In enamel, at 200 °C in air the elongated HAP crystals coalesce (this occurs above 400 °C in argon), and above 600 °C form a molten structure, initially porous (1000 °C) and then continuous (1200 °C). The prismatic structure of the enamel is maintained up to 600 °C.

The coexistence of HAP and β-TCP in enamel was observed after 400 °C in air and after 800 °C in argon. For dentin, the coexistence of two phases is already observed at 600 °C in air and at 800 °C in argon. At 1200 °C, for dentin in air the percentage of these phases is 84% HAP and 15% β-TCP, respectively; in argon, the percentage is 72% HAP and 27% β-TCP. For enamel, the coexistence of two phases is already observed at 400 °C in air and at 600 °C in the argon. At 1200 °C, for dentin in air, the percentage of these phases is 94% HAP and 5% β-TCP, respectively; in argon, the percentage is 91% HAP and 8% β-TCP.

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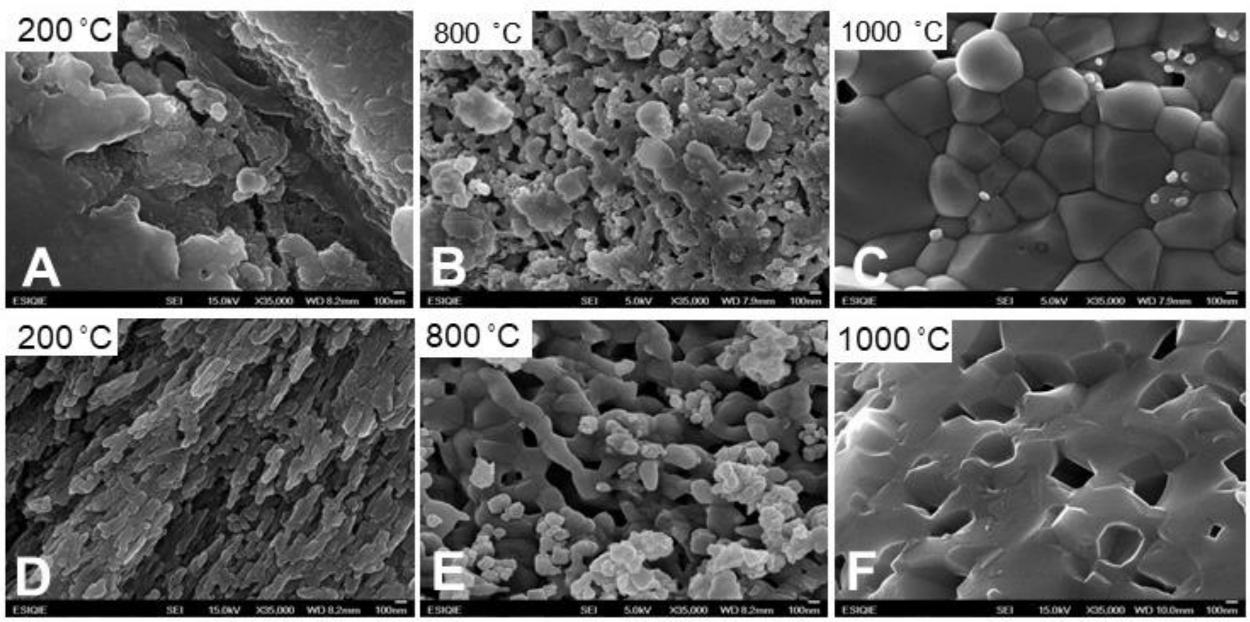

Figure 1. SEM images at same magnification of the structure changes observed in dentin (A-C) and in enamel (D-E) at different temperatures.

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