

Characterization of Human Teeth using Vibrational Spectroscopies

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ABSTRACT. Dentin and enamel are the two main constituents of human teeth, and the detailed characterization of their biochemical properties is of fundamental relevance in many fields of dentistry research. Vibrational spectroscopies such as Fourier-Transform Infrared (FT-IR) and Raman spectroscopy can be adopted to obtain precise information before and after chemical or physical teeth treatments. We have used the two above-mentioned spectroscopic techniques for investigating dentin and enamel powders and few-mm thick disks cut from human molar teeth. FT-IR and Raman spectra clearly show the contributions of different sample components. The spectra obtained from dentin and enamel powders evidence the differences due to their chemical composition. The spectra from human tooth disks present different characteristics depending on the region of the samples from which they were collected, thus enabling a spatial characterization of the samples themselves on different scales. These results confirm that vibrational spectroscopies allow a detailed characterization of hard dental tissues at the microscopic level.

MATERIALS

Few-mm thick slices were cut from human molar teeth. The teeth were sectioned vertically with a diamond saw (Buehler, Lake Bluff, IL, USA) (see Figure 1). After preparation, the samples were stored in a dry state. Before laser processing, they were rehydrated with distilled water for 24 hours to restore the normal fully hydrated state.

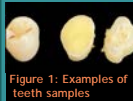


Figure 1: Examples of tooth samples

The teeth powder was obtained with angle handpiece blue ring 40000 r/m (Kavo Biberach, Germany) using a flame red ring diamond bur Fine-Grit Diamond Milling Cutters FG314 (30 µm) (Komet, Verona Italy). After preparation, the powder samples of enamel and dentin were stored separately in a dry state for the spectroscopic measurements.

METHODS

FT-IR spectra of powder samples were obtained by using small amount of the samples and the Universal ATR (Attenuated Total Reflectance) accessory of a Perkin Elmer Spectrum One spectrometer equipped with a MIR TGS detector. The spectra were acquired in the range. To analyze tooth disk the microscope stage of the spectrometer was used to record micro-ATR spectra by using a 0.6 mm radius germanium hemispherical internal reflection element (IRE). In both the cases, the FT-IR spectra were acquired using 64 scans in the 4000–650 cm⁻¹ with a 4 cm⁻¹ spectral resolution

Raman measurements were carried on by a Horiba Xplora Raman micro-spectroscopy system equipped with a Peltier cooled CCD detector, a 785-nm laser with a maximum power of 100 mW. A 1200 lines/mm grating and a 50X objective were used. Spectra were acquired in the 600–3300 cm⁻¹ range.

RESULTS: Dentin and enamel powder samples

In Figure 1 the average FT-IR spectrum collected from dentin powder samples is reported in the two panels (a) and (b) related to the high wavenumber spectral range (3700–2000cm⁻¹) and fingerprint region (1800–800 cm⁻¹), respectively. Representative Raman spectrum of dentin powder is instead shown in Figure 3. In both the spectra Different contributions from organic and inorganic dentin components are evident. Similar results are obtained for enamel powder.

RESULTS: human molar disk samples

In Figure 4 left-panel the FT-IR spectra acquired from different regions in a human molar disks are reported. In this case, the use of the germanium IRE allows the characterization of small areas of the samples with a spatial resolution of tens of µm². In this way, the changes induced in the chemical composition of small areas of teeth by treatments with physical and chemical external agents can be easily investigated. Some Raman spectra obtained from different positions of molar disk samples are shown in Figure 4 right-panel. The contributes due to the two main components of the teeth are observed, the relative intensity of the various peaks being highly dependent on the investigated positions. This confirmed the ability of Raman spectroscopy to investigate micrometric regions of teeth samples also by taking advantage of its higher spatial resolution.

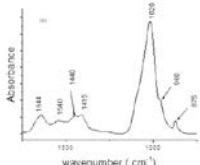
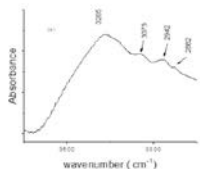


Figure 2. Average FT-IR spectrum of dentin powder.

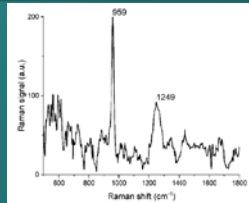


Figure 3. Representative Raman spectrum of dentin powder.

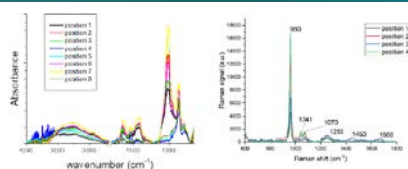


Figure 4. Representative FT-IR (left panel) and Raman spectrum (right panel) of human teeth.

CONCLUSIONS. The present investigation allowed us to optimize the measurement procedures for spectra acquisition and confirmed that FT-IR and Raman spectroscopies represent useful tools for characterizing the chemical composition of hard dental tissues. The two above-mentioned techniques are demonstrated to give complementary information that can be particularly valuable when teeth undergo different chemical and physical treatments. In these cases, the high sensitivity of FT-IR spectroscopy and the excellent spatial resolution of Raman spectroscopy can jointly contribute to obtain a precise and detailed description of the changes induced and the processes occurring during the treatments.