Photothermal Evaluation of Demineralization Kinetics of Human Enamel

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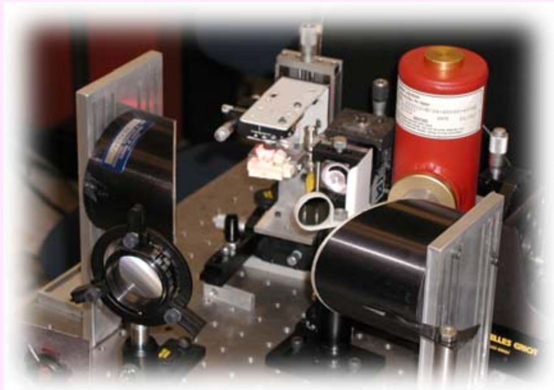
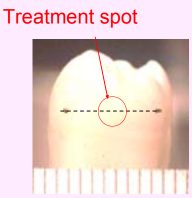
- *Tooth demineralization is very difficult to detect or monitor at early stages with either x-rays or visual examination.*
- *Photothermal Radiomety (PTR) applied as a safe and highly-sensitive tool for the early detection of dental demineralization.*
- *Theoretical model based on diffuse-photon-density and thermal-wave analysis was developed to quantify the properties of the demineralized enamel and analyze the kinetics of demineralization process.*

Experimental setup

- A semiconductor laser emitting at 659 nm was the source of PTR signal.
- Modulated laser light generated infrared blackbody radiation from a tooth.
- The modulated PTR signal from the sample was collected and focused onto a mercury cadmium telluride (MCT) detector.
- The scanning was done over the range of frequencies. High frequencies create thermal field near the surface, whereas low frequencies allow laser energy to move deeper into tooth.

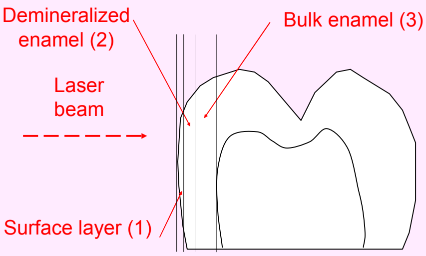




- Tooth sample was demineralized with artificial demineralization gel: 0.1M lactic acid, 0.1M NaOH to raise pH to 4.5, 6%w/v hydroxyethylcellulose.
- Scanning was done before treatment and after 1 min, 3, 7 and 14 days of demineralization treatment.
- After 14 days of treatment, TMR was done to measure the thickness of the layers. It demonstrated the creation of an artificial carious lesion.

Theoretical model and results

- Theoretical 3-Layer diffuse-photon-density-wave and thermal-wave model describes the frequency dependence of the PTR signal, which is proportional to the modulated temperature of a tooth sample.
- The PTR amplitude and phase first decrease due to the changes in the properties of the surface layer. After 3 days of treatment the signal increases due to significant increase in the scattering coefficient of the demineralized enamel.

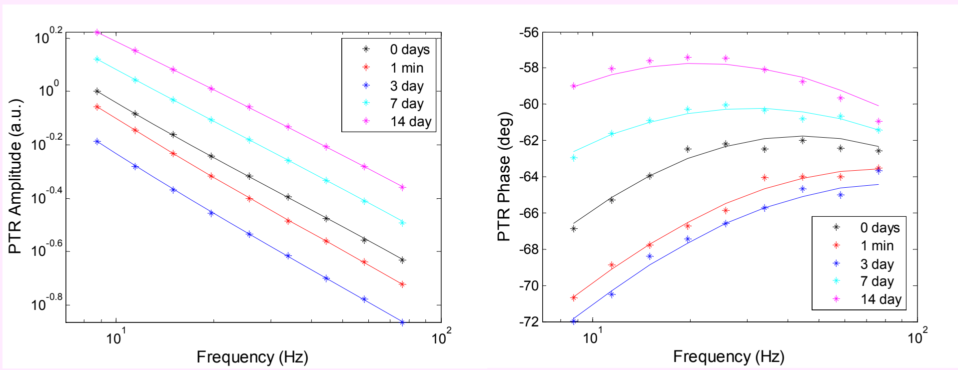


$$V_{PTR} = V_{PTR}\left(\mu_{a_n}, \mu_{s_n}, \alpha_n, k_n, L_n\right)$$

n = 1,2,3 - the layer index

$$V_{PTR} = Amp_{PTR} \exp\left[iPhase_{PTR}\right]$$

The theoretical PTR signal was fitted to the 14-days treatment experimental curve with the TMR-measured thickness of the demineralized layer L_2 = 14.9 μm (TMR). As a result, optical and thermal properties were obtained.



	Surface layer	Demineralized enamel	Bulk enamel
Absorption coefficient, μ_{a}, m^{-1}	87	148	74
Scattering coefficient, μ_{s}, m^{-1}	4576	40484	4588
Thermal diffusivity, α, m^2/s	6.1×10^{-7}	5.6×10^{-7}	4.3×10^{-7}
Thermal conductivity, k, W/mK	0.9	1.0	0.9

Conclusions

- PTR was shown to be a promising tool for the early detection of enamel demineralization.
- Theoretical model allows quantitative analysis of thermal and optical properties of enamel. The long-term objective is the estimation of the thickness of the demineralized layer based on the fitting results.

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