J. Phys. IV France **125** (2005) 721-723

DOI: 10.1051/jp4:2005125165

Photothermal radiometric quantitative detection of the different degrees of demineralization of dental enamel by acid etching

R.J. Jeon[1], T.D.T. Phan[2], A. Wu[1], G. Kulkarni[2], S.H. Abrams[3] and A. Mandelis[1]

[1]*Center for Advanced Diffusion Wave Technologies, Dept. of Mechanical and Industrial Engineering, University of Toronto, 5 King's College Road, Toronto, Ontario, Canada M5S 3G8, Canada*
[2]*Faculty of Dentistry, University of Toronto, Toronto, Ontario, Canada*
[3]*Four Cell Consulting, 748 Briar Hill Ave., Toronto, Ontario, Canada M6B 1L3, Canada*

Abstracts. Photothermal radiometric (FD-PTR or PTR) signals from human teeth have been used toward detecting an artificial surface demineralization. The aim of the study is to characterize PTR signals by using controlled mineral loss from human enamel to mimic surface and subsurface dental caries. At a fixed modulation frequency, an Ar^+ ion laser was used as a light source to scan across the tooth surface, and an MCT infrared detector was used for measuring the PTR signals. Several human molar teeth were etched using 37% phosphoric acid etching gel and scanned across the etched region at 30 Hz. PTR amplitude from the etched region shows that the signal decreases with increasing etching time. The PTR phase also shows the same behavior with the amplitude and better contrast between different etching times. The PTR technique could thus be used to detect early surface demineralization and may give the examiner quantitative information of the degree of demineralization in dental caries.

1. INTRODUCTION

In this era, the aim of dentists is to preserve tooth structure to prevent the patient being trapped in the cycle of restoration. However, it is important to note that since grooves on the surface of teeth are not removed at an early age anymore, the potential risk of developing caries in those deep fissures is increased as the patient ages. To counteract that situation, an accurate diagnosis of the presence, extent and activity of the lesion is fundamental. For many decades, the diagnosis of dental caries was based on visual, tactile and radiographic assessment. The validity of each diagnostic method (visual and radiographic), used separately and together, was investigated and found to have a sensitivity of 75% and a high specificity of 90% [1]. With only a sensitivity of 75%, it means that there remains a significant risk of missing early dentinal lesions in teeth with non-overt disease [2]. New diagnostic instruments have been developed to better assess dental caries: electrical conductance methods (ECM) [3], quantitative laser fluorescence (QLF) [4], laser fluorescence (DIAGNODent system) [5], tuned-aperture computed tomography (TACT)[6] and optical coherence tomography(OCT) [7]. For most of those new diagnostics tools, studies were done *in-vitro* and the evidence of their effectiveness in detecting early dental caries is still weak. Recently, a new methodology has emerged in an attempt to create an improved diagnostic tool for early caries detection: Photothermal radiometric (FD-PTR or PTR) signals from human teeth have been used toward detecting an artificial surface demineralization. It is possible that the PTR technique could be used to detect early surface demineralization and may give the examiner quantitative information of the degree of demineralization in dental caries. The next step to the realization of the new system based on that finding is the characterization of the dental PTR signals.

2. MATERIAL AND METHODS

For the experiments, extracted unerupted healthy third molars stored in distilled water have been used because those teeth are usually free of caries since they did not erupted in the oral cavity yet and moreover, they have flat surfaces allowing laser scanning without to have to adjust the focal point more than once. During the preliminaries set of experiments, scans were performed with various laser wavelengths and frequencies in search of the best combination. It was found that using 488nm and 30Hz respectively, showed the best resolved results for linear smooth surface scanning. The following experiments have been scanned with those settings.

2.1 Sequential etching

This first stage of experiment is to evaluate the behavior of the PTR signals on demineralized human enamel by an acid gel. The etch duration of 0 s, 20 s, 40 s and 60 s was determined arbitrarily. Since the acid gel has a high viscosity allowing it to stay firmly in place, it was deemed unnecessary to delimit the area with nail polish or tape, thus preventing any disturbances during scanning caused by the use of those products. On the flat surface of a molar, a length of 6mm of enamel has been scanned with the laser for baseline assessment. Three areas were then etched sequentially with 37% phosphoric acid (Scotchbond, 3M) for 60 s, 40 s and 20 s respectively. The fourth area was not etched and was used as a control. The etchant was then removed with a dry cotton swab followed by a cotton swab impregnated with distilled water. The lesion was scanned again with the same laser.

2.2 Artificial caries

For this stage of experiments, a demineralization solution capable of inducing subsurface dental caries without softening the enamel surface has been prepared. This type of lesion is similar to the incipient caries found in the oral cavity. The demineralization solution has been prepared according to Ten Cate et al study [8]: 2.2 mM potassium phosphate, monobasic, 50 mM acetic acid, 2.2 mM of 1M calcium chloride, 0.5 ppm fluoride. The pH was set at 4.5 with potassium hydroxide. The solution was applied to a molar using an agarose pellet to prevent it from leaking on the surface of the molar. Radiographs of the area were taken everyday until signs of a subsurface dental caries was noticeable on the film. At the same time, PTR scanning was performed at different intervals until the lesion was detected by the radiograph.

3. PRELIMINARY RESULTS AND DISCUSSION

3.1 Sequential etching

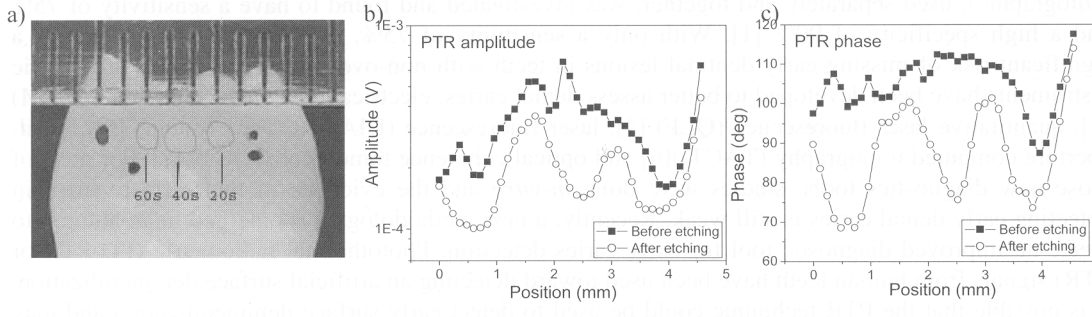

Figure 1. Photographs and experimental results of sample tooth T4. (a) Sample T4 showing 3 etched areas of 60 s, 40 s, and 20s respectively. (b) and (c) PTR amplitude and phase signals across the scanned line at 30Hz.

In Figure 1(a), on the enamel surface of the tooth, three areas of demineralization can be easily distinguished from the rest of the surface. PTR amplitude signals in Figure 1(b) from the etched areas show that the signal decreases and exhibits an oscillatory behavior with increasing etching time. The PTR phase also shows the same behavior.

3.2 Artificial caries

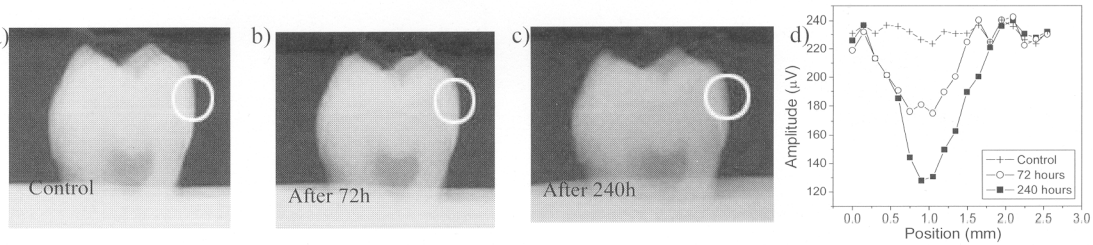

Figure 2. Radiographs and experimental results of sample C1. (a) Sample C1 prior to etching. (b) Sample C1 after 72h of etching. (c) Sample C1 after 240h of etching and starting to show evidence of enamel demineralization. (d) PTR amplitude across the scanned line at 30Hz.

To take the radiographs in Figure 2(a) to 2(c), the molar has been rotated by 90° to assess the depth of the lesion. The PTR amplitude signals resulting from the scan of dental enamel etched with an artificial caries solution decreased with an increased etching time. It is important to note that an evidence of demineralization was clear radiographically (formation of a radiolucent/black area) only after 240h of etching time while the PTR signals started to decrease a long time before showing then its sensitivity to enamel lesion.

4. OUTCOMES AND SIGNIFICANCE

These experiments will provide sets of standardized radiometry signals, which can be directly related to different degrees of demineralization and moisture content. These data will provide the basis for the early detection of dental caries using laser radiometry.

References

[1] C. E. Ketley and R. D. Holt, British Dental Journal **174** (1993), 364-370.
[2] D. McComb and L. E. Tam, *Diagnosis of occlusal caries: Part I. Conventional methods*, Journal (Canadian Dental Association). **67** (2001), 454-457.
[3] Y. L. Ie, E. H. Verdonschot, M. J. Schaeken and M. A. van't Hof, Caries Research **29** (1995), 94-99.
[4] M. Ando, A. F. Hall, G. J. Eckert, B. R. Schemehorn, M. Analoui and G. K. Stookey, Caries Research **31** (1997), 125-131.
[5] A. Sanchez-Figueras, Jr., Compendium of Continuing Education in Dentistry **24** (2003), 3-11.
[6] X. Q. Shi, P. Han, U. Welander and B. Angmar-Mansson, Dento-Maxillo-Facial Radiology **30** (2001), 45-49.
[7] B. T. Amaechi, S. M. Higham, A. G. Podoleanu, J. A. Rogers and D. A. Jackson, Journal of Oral Rehabilitation **28** (2001), 1092-1093.
[8] J. D. Featherstone, J. M. ten Cate, M. Shariati and J. Arends, Caries Research., **17** (1983), 385-91.