Detection of Surface Erosion:

A Novel Application for PTR-LUM Technology

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Abstract

A caries detection system based on photothermal radiometry - modulated luminescence (PTR-LUM) technology has become available from Quantum Dental Technologies, Inc. called the Canary System. This non-destructive caries detector uses an infrared laser that penetrates 5mm into the tooth creating a fluorescence signal which is related to mineral integrity. This information is converted into a "Canary Number" which has been interpreted for early caries detection. Because the caries detector responds to bulk tooth structure, it has been assumed that this technology may not be useful for detecting surface erosion. However, because the surface is the first layer encountered by the laser and the last surface registered by the fluorescence detector, it's possible the mineralization status of the surface layer may exert a measurable effect on the Canary Number.

Objective: Determine if PTR-LUM technology is effective for detecting surface erosion.

Methods: The circular areas of human premolars extracted for orthodontic purposes were protected with nail polish, leaving 6mm circular windows of uncoated tooth surface to define experimental zones. An orthodontic bracket was bonded to each exposed tooth surface using either Transbond XT leaving an unprotected halo around the bracket (T-XT), Fuji Ortho (FO) or an experimental fluoride-containing bonding resin (expF) covering the whole exposed surface around the bracket; n=8 for each treatment group. Canary Numbers were recorded at the incisal and gingival regions (above and below) each bracket, and the teeth were treated with 1 % citric acid, pH 3.6 for four hours to induce surface erosion. Canary Numbers were taken again. The teeth were sectioned into four sagittal slices through the brackets (and thus through the incisal and gingival zones). Digitized micrographs of the cross-sections were analyzed for surface loss using Image-J software.

Results: The correlation between the change in the Canary Number (ΔCN) and the surface lost (μm) was linear for the treatments that resulted in surface loss.

Treatment Group*	Gingival Loss (μm)	R^2 Gingival	Incisal Loss (μm)	R^2 Incisal
T-XT (Halo)	19±17	0.73, p≤0.01	35±22	0.82, p≤0.01
FO (whole surface)	12±9	0.81, p≤0.01	14±7	0.91, p≤0.01
Exp-F (whole surface)	2±4	0.37, p≥0.05	3±7	0.60, p≤0.05

*n=8 for each gingival and incisal group, significance determined by Pearson's r.

The incisal zones tended to erode more than the gingival zones. There were no false positives found for the group that did not show surfaces loss.

Conclusion: There were significant linear correlations between ΔCN and the two groups of orthodontic treatment that allowed surface loss and very few false positive responses where there was no surface loss. The Canary System may be useful for monitoring early erosion.

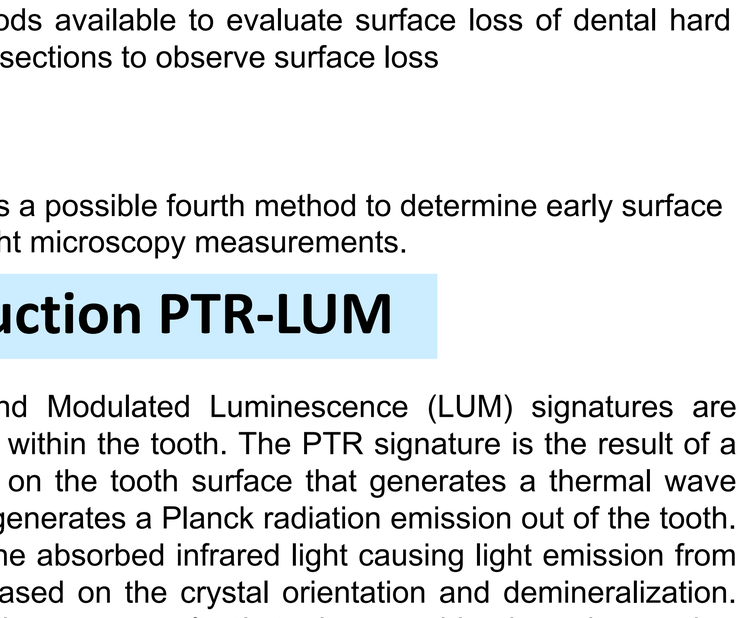
Introduction

- Dental erosion is the loss of tooth structure by acid dissolution without the involvement of bacteria.
- At this time there are three methods available to evaluate surface loss of dental hard tissues. They all assess the cross sections to observe surface loss
  1. Light microscopy
  2. X-ray microradiography
  3. Profilometry
- We tested PTR-LUM technology as a possible fourth method to determine early surface loss (erosion) by comparison to light microscopy measurements.

Introduction PTR-LUM

Photothermal Radiometry (PTR) and Modulated Luminescence (LUM) signatures are combined to detect demineralization within the tooth. The PTR signature is the result of a pulsed infrared laser beam focused on the tooth surface that generates a thermal wave absorbed by the tooth which in turn generates a Planck radiation emission out of the tooth. The LUM signature is the result of the absorbed infrared light causing light emission from the tooth at different wavelengths based on the crystal orientation and demineralization. These two signatures provide complimentary results that when combined can be used to detect very small changes in the mineral and specifically demineralization. The Canary System (Quantum Dental Technologies, Inc.) uses the PRT-LUM methods that have been refined to pulse the infrared light such that the resulting signatures have probed to a depth of 5 mm into the tooth.

The resulting signatures are combined in a mathematical formula developed from repeated scans of teeth to generate a single number called the Canary Number which is diagnostic of mineral quality where the larger the number the more likely there is demineralization. What is not known is how the Canary Number relates to white spot lesion depth, or what features may alter the resulting Canary Number.



*Information about the Canary System can be found at Quantum Dental Technologies, Toronto CN, www.thecanarysystem.com

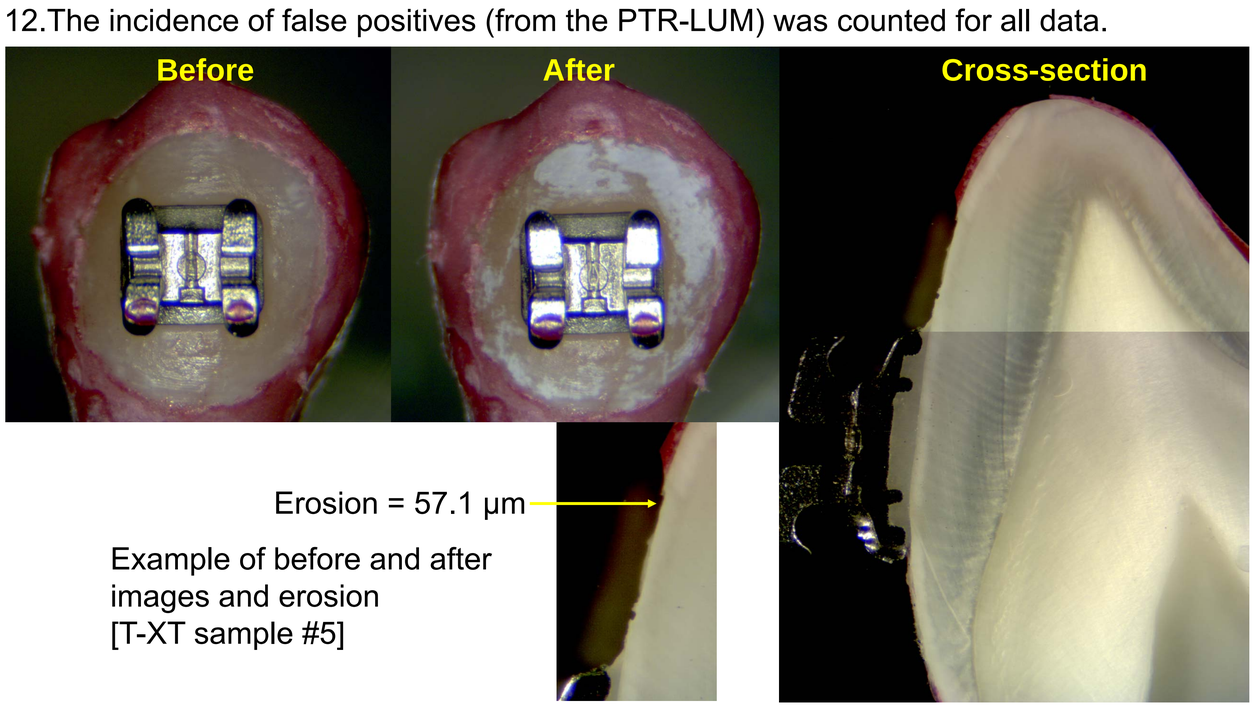
The authors have no financial or research relationship with Quantum Dental Technologies.

Purpose

To establish the reliability of PTR-LUM based technology to quantitatively evaluate surface loss from human enamel after exposure to erosion standard of 1.0 % citric acid at pH 3.60. This was established by use of light microscopy, an established reference method, and correlation analysis between the quantities determined from both analyses.

Methods

1. We used an orthodontic model for the erosion,
   a. Circular areas of human premolars extracted for orthodontic purposes were protected with nail polish, leaving 6mm circular windows of uncoated tooth surface to define experimental zones,
   b. orthodontic brackets were bonded to the buccal surface of each tooth by use of on of three adhesives, n=8 for each treatment group:
      i. Transbond XT (T-XT) leaving an unprotected halo around the bracket,
      ii. Fuji Ortho (FO) covering the whole exposed surface around the bracket,
      iii. Experimental fluoride-containing bonding resin (exp-F) covering the whole exposed surface around the bracket.
2. Note that there was an exposed (unprotected) portion of the surface for the T-XT samples (control) verses completely covered surfaces for the exp-F and FO samples.
3. Digital images were taken and PTR-LUM (Canary Numbers) were determined at the incisal and gingival regions (above and below) the bracket before the erosion,
4. The teeth were exposed to 1 % citric acid (pH 3.60) erosion standard for 4 hours stirred @ 250 rpm.
5. Digital images were taken and PTR-LUM (Canary Numbers) were determined at the incisal and gingival regions (above and below) the bracket after the erosion,
6. The teeth were sagittally sectioned to create two 1 mm thick cross-sections through the bracket and thus through the incisal and gingival zones.
7. Digitized light microscopy images were taken of the cross-section samples, see figures below,
8. The digital images were analyzed with ImageJ software to determine the maximum amount of surface loss (μm) in each zone (incisal or gingival).
9. The change in Canary Number (ΔCN) was calculated by subtraction,
10. The incisal and gingival surface loss was plotted against the ΔCN and the linear correlation was calculated.
11. The statistical significance of the correlation coefficient (r) was determined by Pearson's r statistic.
12. The incidence of false positives (from the PTR-LUM) was counted for all data.



Example of before and after images and erosion [T-XT sample #5]

Results

Treatment Group*	Gingival Loss (μm)	R^2 Gingival	Incisal Loss (μm)	R^2 Incisal
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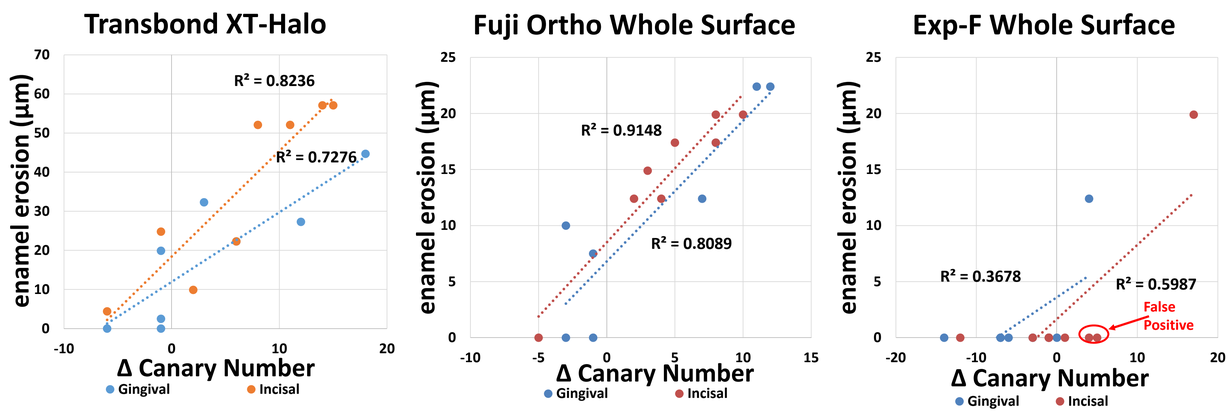

Discussion

- The correlation between the change in the Canary Number (ΔCN) and the surface lost (μm) was linear for the treatments that resulted in surface loss.
- Two false positive responses where observed where there was no surface loss
- The incisal zones tended to erode more than the gingival zones. There were no false positives found for the group that did not show surfaces loss.

Conclusions

- There was significant linear correlation between ΔCN and the two groups of orthodontic treatment that allowed surface loss and very few false positive responses where there was no surface loss.
- The Canary System may be useful for monitoring early erosion.

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