Research Behind The Canary System®

The Canary System is an evidence-based caries detection system built upon a solid foundation of peer-reviewed lab and clinical research. This includes:

- 2 Health Canada approved clinical trials that met FDA 21 CFR standards for clinical trials.
- A clinical trial on accuracy of detecting interproximal lesions compared to x-ray radiographs.
- 60+ peer-reviewed primary journal publications.
- 50+ presentations at international dental conferences.
- 20+ publications in the "popular dental press", including Dentistry Today, Dentistry IQ, Oral Health and Dental Tribune.
- 8+ dental schools around the world conducting researching using Canary as a tool to detect and monitor caries.

Research has demonstrated that Canary's *energy conversion technology* (PTR-LUM) can be harnessed to help oral health professionals **detect, measure, monitor, record, and diagnose**:

- Lesions and defects ≤ 5 mm. below the enamel surface[1-4]
- Occlusal pit and fissure caries[4-7]
- Smooth surface caries[8, 9]
- Acid erosion lesions[10-15]
- Root caries[16, 17]
- Interproximal caries lesions[18-23]
- Caries beneath fissure sealants[24-27]
- Caries around margins of restorations and crowns[28-31]
- Caries beneath the intact margins of composite resins[32]
- Caries beneath intact margins of amalgam restorations[33, 34]
- Caries beneath the intact margins of resin modified glass ionomer & compomer restorations[35, 36]
- Demin- and remineralization of early caries lesions[17, 37-44]
- Caries beneath clear resin infiltrants[45]
- Caries Around orthodontic brackets[46, 47]

Clinical Trials

The Canary System has been investigated in three clinical trials. The first Health Canada-approved investigational study was completed in December 2009. The trial involved 50 patients using the first prototype in a number of clinical situations and found no safety issues.[48, 49] The second Health Canada clinical trial was a follow-on study designed primarily to help QDT define the Canary Scale and determine how to best integrate the system into a dental practice. The study involved 98 patients among four trial sites with 38 patients involved in multiple visits for monitoring the effects of remineralization therapy.[50-53] The third clinical study was performed in 2014 at the University of Texas to investigate interproximal caries detection. The investigators found Canary was able to detect 92% of the lesions while radiographs only found 62%.[23]

Canary Study Design Ensures Unbiased Results

Canary research at QDT is divided into two parts: 1) Canary scans are performed at the University of Toronto followed by visual ranking using ICDASII; and then 2) Polarized light microscopy (PLM) analyses are conducted in a blinded-fashion in the lab of Dr. Ben Amaechi at the University of Texas to measure the size and shape of the lesions.

1. Jeon RJ, Mandelis A, Sanchez V, Abrams SH. Nonintrusive, noncontacting frequency-domain photothermal radiometry and luminescence depth profilometry of carious and artificial subsurface lesions in human teeth. J Biomed Opt 2004;9(4):804-19.
2. Wong B, Abrams, S.H., Sivagurunathan, K., Silvertown, J.D., Hellen, A., Mandelis, A., Hellen, W.M.P., Elman, G.I., Amaechi, B.T. Correlation with caries lesion depth of The Canary System, DIAGNOdent and ICDAS II. 60th Annual European Organization for Caries Research Conference Liverpool, UK: Caries Research 2013. p. 433-531.
3. Carey C, Coleman, S.S. PLM validation of WSL assessment by photothermal radiometry- modulated luminescence technology. Paper presented at: 2014 AADR/CADR Annual Meeting 2014; Charlotte, North Carolina
4. Abrams SH, Sivagurunathan, K., Silvertown, J. D., Wong, B., Hellen, A., Mandelis, A., Hellen, W. M. P., Elman, G. I., Mathew, S. K., Mensinkai, P. K., Amaechi, B. T. Correlation with Caries Lesion Depth of The Canary System, DIAGNOdent and ICDAS II. The Open Dentistry Journal 2017;11:679-89.
5. Jeon RJ, Han C, Mandelis A, Sanchez V, Abrams SH. Diagnosis of pit and fissure caries using frequency-domain infrared photothermal radiometry and modulated laser luminescence. Caries Res 2004;38(6):497-513.
6. Jeon RJ, Mandelis A, Sanchez V, Abrams SH. Dental depth profilometric diagnosis of pit & fissure caries using frequency-domain infrared photothermal radiometry and modulated laser luminescence. Journal de Physique IV (Proceedings) 2005;125:741-44.
7. Jeon RJ, Han, C., Mandelis, A., Sanchez, V., Abrams, S. Dental depth profilometric diagnosis of pit and fissure caries using frequency-domain infrared photothermal radiometry and modulated laser luminescence. In: Stookey GK, editor. Proceedings of the 6th Annual Indiana Conference Indiana School of Dentistry Indianapolis Indiana; 2003. p. 49-67.
8. Jeon RJ, Mandelis, A., Abrams, S. Depth profilometric case studies in caries diagnostics of human teeth using modulated laser radiometry and luminescence. Review of Scientific Instruments 2003;74(1):380.
9. Wong B, Sivagurunathan, K., Silvertown, J.D., Hellen, W.M., Elman, G., Okoye, L.O., Abrams, S.H., Amaechi, B.T. A comparison of methods for the detection of smooth caries. IADR/AADR/CADR General Session & Exhibition Boston Massachusetts Journal of Dental Research 2015. p. 0305.
10. Jeon RJ, Phan, T. D. T., Wu, A., Kulkarni, G., Abrams, S. H., Mandelis, A. Photothermal radiometric quantitative detection of the different degrees of demineralization of dental enamel by acid etching. J. Physique IV France 2005;125:721 – 72.
11. Sivagurunathan K, Hellen, A., Silvertown, J.D., Wong, B., Jeon, R.J., Amaechi, B.T., Abrams, S.H. Detection, monitoring and imaging dental erosion with The Canary Lab. International Association of Dental Research (IADR) 91st General Session. Seattle, WA.: J Dent Res; 2013. p. 2901.
12. Abrams SH, Matvienko, A., Ye, V., Mandelis, A., Ramalingam K., Amaechi, B. T. Detection and monitoring of dental erosion using PTR-LUM. IADR/AADR/CADR 89th General Session. San Diego, CA J. Dent. Res.; 2011. p. 238.
13. Matvienko A, Mandelis, A., Abrams, S. H., Amaechi, B. T. Study of Dental Erosion using the PTR-LUM Technique. Paper presented at: XVI International Conference on Photoacoustic and Photothermal Phenomena (ICPPP16), 2011.
14. Pier S, Carey, C.M. Detection of Surface Erosion: A Novel Application for PTR:LUM Technology. Paper presented at: AADR/CADR Annual Meeting 2016; Los Angeles California
15. Hellen A, Jeon, R., Matvienko, A., Mandelis, A., Abrams, S. H., Amaechi, B. T. Erosion Lesion Detection using Photothermal Radiometry and Modulated Luminescence. IADR/AADR/CADR 87th General Session. Miami Florida 2009 p. 70.
16. Jeon RJ, Hellen A, Matvienko A, et al. In vitro detection and quantification of enamel and root caries using infrared photothermal radiometry and modulated luminescence. J Biomed Opt 2008;13(3):034025.
17. Jeon RJ, Hellen, A., Matvienko, A., Mandelis, A., Abrams, S. H., Amaechi, B. T. Detection of demineralized-remineralized lesions on root and enamel of human teeth in vitro using infrared photothermal radiometry and modulated luminescence. Caries Research 2007;41:323.
18. Jeon RJ, Matvienko A, Mandelis A, et al. Interproximal dental caries detection using Photothermal Radiometry (PTR) and Modulated Luminescence (LUM). The European Physical Journal Special Topics 2008;153(1):467-69.
19. Jeon RJ, Matvienko A, Mandelis A, et al. Detection of interproximal demineralized lesions on human teeth in vitro using frequency-domain infrared photothermal radiometry and modulated luminescence. J Biomed Opt 2007;12(3):034028.
20. Mandelis A, Jeon R, Matvienko A, Abrams SH, Amaechi BT. Dental biothermophotonics: How photothermal methods are winning the race with X-rays

for dental caries diagnostic needs of clinical dentistry. The European Physical Journal Special Topics 2008;153(1):449-54.

21. Wong B, Abrams, S.H., Tasevski, C., Sivagurunathan, K., Silvertown, J.D., Hellen, W.H., Elman, G., Amaechi, B.T. Detection of interproximal caries in vitro using The Canary System. J Dent Res 2014;93(Spec Iss A).
22. Jan J, Wan Bakar WZ, Mathews SM, et al. Proximal caries lesion detection using the Canary Caries Detection System: an in vitro study. J Investig Clin Dent 2016;7(4):383-90.
23. Uzamere EO, Jan, J., Bakar, W.W., Mathews, S.M., Amaechi, B. Clinical trial of the Canary System for proximal caries detection. J Dent Res 2015;94 (Spec Iss A).
24. Wong B, Abrams, S.H., Sivagurunathan, K., Jeon, R.J., Silvertown, J.D., Hellen, A., Mandelis, A., Hellen, W.M.P., Elman, G.I., Ramalingam, K., Ccahuana-Vasquez, R.A., Amaechi, B.T. In vitro detection of caries beneath dental sealant with The Canary System. 59th ORCA Congress. Cabo Frio, Brazil Caries Res; 2012. p. 268-338.
25. Abrams SH, Wong, B., Sivagurunathan, K.S., Jeon, R.J., Silvertown, J.D., Hellen, A., Mandelis, A., Hellen, W.M., Elman, G.I., Ramalingam, K., Ccahuana-Vasquez, R.A., Amaechi, B.T Effect of placing an opaque sealant on Canary Number readings. International Association of Dental Research 90th General Session. Iguaçu Falls, Brazil: J Dent Res; 2012. p. 7.
26. Wong B, Abrams, S., Abrams, T., Sivagurunathan, K., Jeon, R.J., Silvertown, J.D., Hellen, A., Mandelis, A, Hellen, W.M., Elman, G., Amaechi, B.T., Mensinkai, P.K., Mathews, S.M. Accuracy of The Canary System with opaque dental sealants. International Association of Dental Research (IADR) 91st General Session. Seattle, WA: J Dent Res; 2013. p. 7.
27. Silvertown JD, Wong BP, Abrams SH, et al. Comparison of The Canary System and DIAGNOdent for the in vitro detection of caries under opaque dental sealants. J Investig Clin Dent 2016.
28. Kim JM, A., Matvienko, A., Abrams, S., Amaechi, B. T. Detection of Dental Secondary Caries Using Frequency-Domain Infrared Photothermal Radiometry (PTR) and Modulated Luminescence (LUM). International Journal of Thermophysics 2012;33(10-11):1778-86.
29. Wong B, Abrams, S.H., Silvertown, J.D., Sivagurunathan, K., Klausz, R., Mandelis, A., Amaechi, B.T. Detection of caries around ceramic crown restorations with The Canary System and DIAGNOdent. 60th Annual ORCA Congress. Liverpool UK: Caries Res 2013. p. 433-531.
30. Carey CM, Coleman, S.S. Antatomy of secondary caries: the early stages. Dent Mat 2013;29(Suppl 1):e36.
31. Kim J. In vitro examination of secondary caries using infrared photothermal radiometry and modulated luminescence [Toronto Ontario Canada: University of Toronto (Canada); 2012.
32. Abrams SH, Silvertown, J.D., Wong, B., Sivagurunathan, K.S., Jeon, R.J., Mandelis, A., Hellen, W.M.P., Elman, G.I., Amaechi, B.T. Detection of caries around restorations with The Canary System. International Association of Dental Research 90th General Session. Iguaçu Falls, Brazil: J Dent Res; 2012. p. 1824.
33. Abrams TE, Silvertown, J.D., Sivagurunathan, K.S., Hellen, W.M.P., Elman, G.I.,Abrams, S.H.,Amaechi, B.T. Detection of Caries Around Amalgam Restorations Using Four Different Modalities. 63rd Annual ORCA Congress. Athens Greece Caries Research; 2016. p. 234-35.
34. Abrams TE, Abrams, S. H., Sivagurunathan, K., Silvertown, J. D., Hellen,W. M. P., Elman, G. I., Amaechi, B. T. In Vitro Detection of Caries Around Amalgam Restorations Using Four Different Modalities. The Open Dentistry Journal 2017;11:609-20.
35. Abrams TE, Abrams S. H., Sivagurunathan, K., Moravan, V., Hellen, W. M. P., Elman, G. I., Amaechi, B. T., . Detection of caries around Glass Ionomer and Compomer restorations using four different modalities. Journal of Dental Research 2018;97(Spec Iss B Abstract # 99).
36. Abrams T, Abrams S, Sivagurunathan K, et al. Detection of Caries Around Resin-Modified Glass Ionomer and Compomer Restorations Using Four Different Modalities In Vitro. Dentistry Journal 2018;6(3):47.
37. Matvienko A, Jeon J, Mandelis A, et al. Dental biothermophotonics: A quantitative photothermal analysis of early dental demineralization. The European Physical Journal Special Topics 2008;153(1):463-65.
38. Hellen A, Mandelis A, Finer Y, Amaechi BT. Quantitative evaluation of the kinetics of human enamel simulated caries using photothermal radiometry and modulated luminescence. J Biomed Opt 2011;16(7):071406.
39. Hellen A, Mandelis A, Finer Y, Amaechi BT. Quantitative remineralization evolution kinetics of artificially demineralized human enamel using photothermal radiometry and modulated luminescence. J Biophotonics 2011;4(11-12):788-804.
40. Wong B, Silvertown, J.D., Abrams, S.H., Sivagurunathan, K., Amaechi, B.T Detection of remineralization of early caries with The Canary System. Paper presented at: 2014 AADR/CADR Annual Meeting 2014; Charlotte, North Carolina
41. Silvertown JD, Wong BP, Sivagurunathan KS, et al. Remineralization of natural early caries lesions in vitro by P11 -4 monitored with photothermal radiometry and luminescence. J Investig Clin Dent 2017.
42. Hellen A. Quantitative Evaluation of Simulated Enamel Demineralization and Remineralization Using Photothermal Radiometry and Modulated Luminescence [University of Toronto T Space University of Toronto 2010.
43. Hellen A, Mandelis A, Finer Y. Photothermal Radiometry and Modulated Luminescence Examination of Demineralized and Remineralized Lesions. J Phys Conf Ser 2010;2014(1):012024.
44. Hellen A, Matvienko, A., Mandelis, A., Finer, Y., Amaechi, B. T. Optothermophysical properties of demineralized human dental enamel determined using photothermally generated diffuse photon density and thermal-wave fields. Appl Opt 2010;49(36):6938-51.
45. Wong B, Abrams, S., Silvertown, J., Sivagurunathan, K., Amaechi, B.T., Hohnk, H.D. Using the Canary System to evaluate the resistance of resin infiltration to demineralization. European Organization for Caries Research 62nd Annual Conference. Brussels Belgium Caries Research 2015. p. 297 - 369.
46. Dorfman J, Boston, D.,. Godel, J., Jeffries, S., . Cement composition effects on enamel demineralization adjacent to orthodontic brackets. Journal of Dental Research 2017;IADR/AADR/CADR 95th General Session Volume 96(Special Issue A).
47. Dorfman JM. Cement composition effects on enamel demineralization adjacent to orthodontic brackets: An in vitro study using the canary system [Dissertation/Thesis]. ProQuest Dissertations & Theses Global. (1951782587): Temple University 2017
48. Sivagurunathan K, Abrams, SH., Garcia, J., Mandelis, A., Amaechi, B. T., Finer, Y., Hellen, W. M. P., and Elman, G. . Using PTR-LUM ('The Canary System') for in vivo Detection of Dental Caries: Clinical Trial Results. Caries Res 2010;44:171-247.
49. Sivagurunathan K, Abrams, S. H., Garcia, J., Mandelis, A., Amaechi, B. T., Finer, Y., Hellen, W. M. P., and Elman, G. PTR-LUM ("The Canary System") Clinical Trial Results for Caries Detection. IADR General Session (July 14-17, 2010) Barcelona, Spain J Dent Res; 2010. p. 3745.
50. Abrams SH, Sivagurunathan, K., Jeon, R.J., Mandelis, A., Silvertown, J.D., Hellen, A., Hellen, W.M.P., Elman, G.I., Ehrlich, R., Chouljian, R., Finer, Y., Amaechi, B.T Multi-center clinical study to evaluate the safety and effectiveness of the Canary System (PTR-LUM Technology). 58th Annual ORCA Congress Kaunas, Lithuania: Karger; 2011. p. 174 – 242.
51. Abrams SH, Sivagurunathan, K., Jeon, R.J., Silvertown, J.D., Hellen, A., Mandelis, A., Hellen, W.M.P., Elman, G.I., Amaechi, B.T., Finer, Y Multi-center study evaluating safety and effectiveness of The Canary System. IADR/AADR/CADR 89th General Session. San Diego, CA: J Dent Res; 2011. p. 2920.
52. Silvertown JD, Sivagurunathan, K., Hellen, A., Kennedy, J., Hellen, W.M., Elman, G.I., Chouljian, R., Ehrlich, R., Amaechi, B.T., Finer, Y., Abrams, S.H. Clinical Detection and Monitoring of Caries Using The Canary System. IADR/AADR/CADR Seattle, Washington Journal of Dental Research 2013. p. 2026.
53. Silvertown JD, Abrams, S. H., Sivagurunathana, K. S., Kennedy, J., Jeon, J., Mandelis, A., Hellen, A., Hellen, W., Elman, G., Ehrlich, R., Chouljian, R., Finer, Y., Amaechi, B. T., . Multi-centre clinical evaluation of photothermal radiometry and luminescence correlated with international benchmarks for caries detection. The Open Dentistry Journal 2017;11:636–47.