Danties struktūrinio vientisumo atskleidimas mikroįtrūkimo vietoje jungiant rentgeno spindulių kompiuterinę mikrotomografiją su fotoliuminescencine spektroskopija ir mašininiu mokymusi

Revelation of tooth structural integrity at the microcrack site by combining X-ray tomography with photoluminescence and machine learning

Irma Dumbryte[1], Maria Androulidaki[2], Donatas Narbutis[3], Elena Jasiuniene[4], Arturas Vailionis[5], Saulius Juodkazis[6], and Mangirdas Malinauskas[7]
[1]Vilnius University, Institute of Odontology, Zalgirio str. 117, 08217 Vilnius, Lithuania
[2]Foundation for Research and Technology FORTH-Hellas, Institute of Electronic Structure & Laser, Microelectronics Research Group, N. Plastira 100, 70013 Voutes, Heraklion, Crete, Greece
[3]Vilnius University, Institute of Theoretical Physics and Astronomy, Sauletekio Ave. 9, 10222 Vilnius, Lithuania
[4]Kaunas University of Technology, Ultrasound Research Institute, Barsausko str. 59-A423, 51423 Kaunas, Lithuania
[5]Stanford University, Stanford Nano Shared Facilities, 616 Serra Mall 200, CA 94305 Stanford, USA
[6]Swinburne University of Technology, School of Science, Optical Sciences Centre and ARC Training Centre in Surface Engineering for Advanced Materials (SEAM), VIC 3122, Hawthorn, Australia
[7]Vilnius University, Laser Research Center, Sauletekio Ave. 10, 10223 Vilnius, Lithuania
irma.dumbryte@mf.vu.lt

Although teeth microcracks (MCs) were recently characterized in three-dimensions (3D), it is still unknown whether there are changes in the tooth material within the MC compared to the enamel areas that are without cracks[1,2]. **The aim of the study** was to combine an X-ray micro-computed tomography (µCT) with photoluminescence (PL) and convolutional neural network (CNN) assisted voxel classification and volume segmentation for tooth structural integrity assessment at the MC site and verify this approach with extracted human teeth.

The samples were first examined using an X-ray µCT and segmented with CNN to identify enamel, dentin, and cracks (Fig. 1). A new CNN image segmentation model was trained based on "*Multiclass semantic segmentation using DeepLabV3+*" example and was implemented with "*TensorFlow*". Secondly, buccal and palatal teeth surfaces with MCs and sound areas were used to obtain fluorescence spectra illuminated with laser exposure wavelengths: 325 nm (CW) and 266 nm (0.5 ns pulsed).

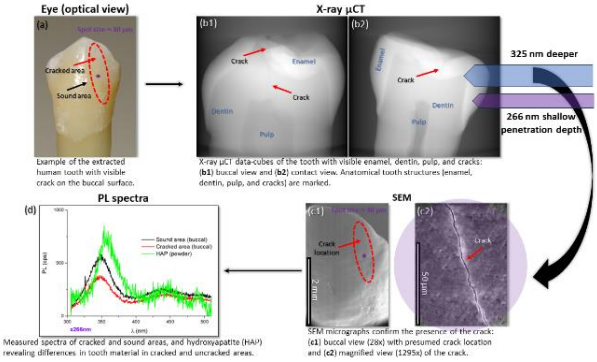

Fig. 1. Graphical abstract of the study.

X-ray µCT technique enhanced with CNN was employed allowed the recognition, detection, and 3D characterization of all tooth MCs, precisely identifying those cracks that were analyzed using PL (Fig. 2).

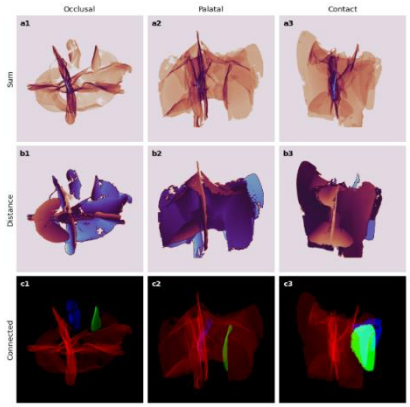

Fig. 2. Arrangement of microcracks inside the tooth.

With both excitation wavelengths, the fluorescence signal intensity associated with the crack was significantly reduced (by a factor of 1.5 for distinct wavelength peaks), while it was higher in the region of the sound tooth spectrum around the MC. The ability to assess the spectral changes in the tooth MC and compare them with the spectrum of the sound enamel revealed differences in the material elemental composition along the crack line, with a variation in the hydroxyapatite crystals at the cracked versus sound area. This suggests a possible loss of structural integrity at the MC site.

The proposed approach – using X-ray µCT in combination with PL and CNN assisted segmentation – reveals the possibilities for tooth structural integrity assessment at the crack area. It offers distinct precision and versatility and can be applied for all the teeth microstructure and surface mapping analysis.

Keywords: 3D imaging, artificial intelligence, enamel damage, spectroscopy.

Literature

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