NOVEL NANOCOMPUTED TOMOGRAPHY (nanoCT) TECHNIQUES APPLIED TO DENTAL RESEARCH

HÅVARD J. HAUGEN*

DEPARTMENT OF BIOMATERIALS,
FACULTY OF DENTISTRY,
UNIVERSITY OF OSLO
*E-MAIL: H.J.HAUGEN@ODONT.UIO.NO

[ENGINEERING OF BIOMATERIALS 158 (2020) 5]

Introduction

X-ray computed tomography (CT) has developed rapidly over the last decade, and the technological advances and user friendliness have made the technique applicable to virtually all branches of the natural sciences and manufacturing industries. The unique advantages of X-ray imaging reside in the combination of high resolution, the penetrating ability of looking inside materials even through complex sample environments, and the relative ease with which the resulting images can be interpreted. Still, X-ray imaging keeps progressing and near-future breakthroughs will include ultrafast measurements, computer-assisted image interpretation and lower-dose measurements. 3D images are easy to grasp, and CT is quite literally an eye-opener to internal processes in living and functional objects. With demand for higher resolutions in laboratory-based X-ray CT imaging in the submicrometer range, the fields of microcomputed tomography (microCT) and nanocomputed tomography (nanoCT) imaging have been established (within this work microCT refers to voxel sizes >1 μm and nanoCT refers to voxel sizes from >100 nm to <1 μm). Also for the general public and popular dissemination, CT images are easily digested and of invaluable importance when it comes to visualizing complex internal structures. CT has become an invaluable tool for the nondestructive investigation of objects in many fields such as material science, industrial testing, or medical diagnostics.
Technically, a range of different contrast mechanisms can be employed (diffraction, scattering, and absorption) where the spatial resolution may reach a few nanometres, while temporal resolutions can be below one microsecond. To become almost comparable to conventional histology with regard to resulting contrast, nanoCT imaging makes use very small focal spot sizes. The application of microCT and nanoCT for biological sample screening, however, remains limited due to very low intrinsic contrast of soft tissue, which means that soft tissues does not appear on regular X-ray. However, the utilization of different contrast agents can aid in visualize such soft tissue structures. Here we will present some recent advances in X-ray enhancement agents used on teeth and hydrogels, which has enabled us to visualize and quantify both soft and cellular tissues. The presentation will show that with our protocols it is possible to visualize cells alongside with mineralised tissues.to minimal speculation about the significance of the work.

Methodology

PTA in various concentrations and immersion time was tested and scanned with high resolution nano-CT. The method was applied to freshly extracted teeth where we examined both cementum and pulpal region.

Results

Three-dimensional nano-CT imaging of dental cementum and periodontium as well as interior components, such as odontoblasts and predentine, with high resolutions was made visible when using PTA staining. The optimal staining protocol differed in different segment of the tooth. The thickness of the cementum could be computed over the height of the tooth made possible by the PTA-enhanced contrast, and the attached soft tissue components of the interior of the tooth could be shown on the dentine-pulp interface in great detail. Three-dimensional illustrations allowed a histology-like visualization of the sections in all orientations with a single scan and easy sample preparation. Furthermore, the dentinal tubules, with the characteristic sigmoid curvature, could be visualized. The segmentation of the tubules and the surrounding dentine allowed a three-dimensional investigation of the dentine composition, such as tubular lumen or ratio of tubular lumen area to dentinal surface

Conclusion

The developed methodology show that it is possible to visualise hard tissue along with cellular structure and soft tissues using laboratory based nano-CT technique. The staining protocol depended on both tissue type and size. The methodology offers new possibilities for the visualisation of structures at the interphases between soft and hard dental tissue, particularly related to endodontic and periodontal research.

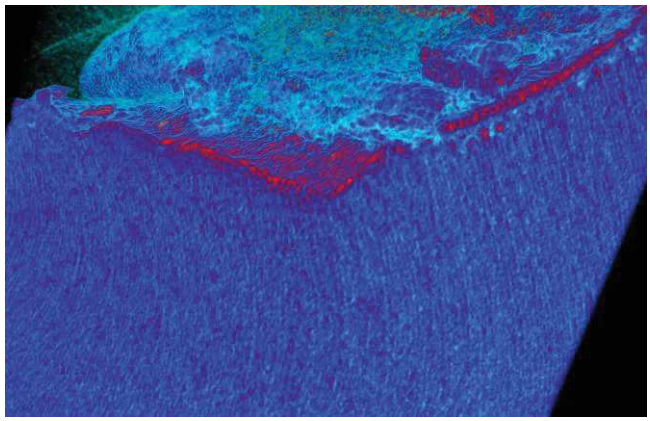

FIG. 1. Odontoblast inside the pulpal chamber from a freshly extracted tooth.

Acknowledgements

Author would like to thank colleagues that participated in this study Torben Hildebrand, Liebert Nogueira, Pia Titterud Sunde, Dag Ørstavik, University of Oslo