The origin of teeth and tooth replacement revealed by 3D synchrotron virtual palaeohistology

D. Chen[1], S. Sanchez[1,2], P. Tafforeau[3], V. Vaškaninová[1,4], T. Märss[5], H. Blom[1], P.E. Ahlberg[1]

[1]Department of Organismal Biology, and [2]SciLifeLab, Uppsala University, Uppsala, Sweden, [3]European Synchrotron Radiation Facility, Grenoble, France, [4]Institute of Geology and Palaeontology, Faculty of Science, Charles University, Prague, Czech Republic, [5]Estonian Marine Institute, University of Tartu, Estonia
donglei.chen@ebc.uu.se

The origin and evolution of vertebrate dentitions has long been a cardinal question for comparative morphologists. To understand the organisation and development of fossil dentitions it is essential to examine their histology (microscopic tissue structure). This has traditionally been done by cutting thin sections that can be examined under the light microscope. However, while teeth are generally abundant in the fossil record, dental materials from the earliest vertebrates are very rare and too precious to be sectioned. Furthermore, thin sectioning does not reveal the three-dimensional organisation of the tissues, and thus gives a misleading impression of the structure. Propagation phase-contrast synchrotron microtomography (PPC-SRμCT) scans performed at ESRF beamline ID19 have revealed a variety of early dentitions from the Late Silurian to the Early Devonian periods, approximately 410 to 425 million years old. The details of the subtle embedded microstructures modelled in 3D revealed the true growth pattern hidden inside.

Radotina and *Kosoraspis* are among the most primitive jawed vertebrates and shed surprising light on the origin of teeth. In *Radotina*, teeth are already added lingually but have not been integrated to a specific jawbone. The most primitive form of tooth-bearing bones is found in *Kosoraspis*, where the jaw bones carry alternate tooth files but consist of multiple short pieces. The teeth of *Radotina* and *Kosoraspis* were not shed. Tooth shedding by basal resorption (where the base of the tooth is dissolved away before it drops out, as happens with our own milk teeth) first evolved in the so-called stem osteichthyans, the common ancestors of all later bony fishes and land vertebrates including ourselves. In the Silurian stem osteichthyans *Andreolepis* and *Lophosteus* [1-3]. Both genera have a primary non-shedding dentition that resemble that of *Kosoraspis*. But it is later overgrown by dermal odontodes and thus invisible in surface view; this non-shedding dentition gives rise to the later shedding dentition, where teeth are repeatedly replaced by basal resorption. These data, which could only be obtained by PPC-SRμCT with sub-micron resolution, give us an extraordinarily vivid insight into the biology of tooth growth and replacement more than 400 million years ago, and promise to illuminate the evolution of the linear tooth rows of modern osteichthyans.

The unique ability of ESRF to perform high-resolution spot PPC-SRμCT on large specimens, which will be further enhanced on the new BM18 beamline, creates great potential for investigating not only small isolated bones but large articulated specimens in this way. This has made possible the study of *Radotina* and *Kosoraspis*, and is further illustrated by an ongoing study of *Megamastax*, another Silurian stem osteichthyan related to *Andreolepis* and *Lophosteus* but much larger and more complete.

References

[1] - H. Botella, H. Blom, M. Dorka, P.E. Ahlberg and P. Janvier, Nature **448**, 583-586 (2007).
[2] - D. Chen, H. Blom, S. Sanchez, P. Tafforeau and P.E. Ahlberg, Nature **539**, 237-241 (2016).
[3] - D. Chen, H. Blom, S. Sanchez, P. Tafforeau, T. Märss and P.E. Ahlberg, Royal Society Open Science **4**, 1-21 (2017).