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65 years of using X-rays to study tooth replacement in Therapsida

Content

The widespread adoption and implementation of three-dimensional (3-D) imaging techniques has had an enormous impact in palaeontology. Researchers now have access to delicate internal cranial structures (e.g., maxillary canals, inner ear labyrinths, and unerupted dentition) that were not available to their predecessors in such immaculate detail. In the past, these structures would only have been accessible through destructive techniques, and indeed, the earliest studies of therapsid tooth replacement relied upon such practices. These earliest studies employed either the process of serial grinding of specimens, or physical breaks in the specimen to expose the unerupted teeth within the bone. Due to the destructive nature, these studies could only be undertaken once—and usually on well preserved individuals to minimise the loss of additional specimens—and each specimen could only be sampled in a single direction (i.e, sagittal, coronal, transverse). In addition to the entire specimen being destroyed, a small amount of information, dependent on the thickness of the cutting blade, was lost during the sectioning process.

Medical X-rays were first used to image the dentition of therapsids from the South African Karoo in a detailed study of the tooth replacement patterns in Gorgonopsia and Therocephalia published 65 years ago by Kermack. Although these early images only allowed for the unerupted teeth to be viewed in a single plane, they had the distinct advantage of being non-destructive. By making radiographs of various specimens in lateral view, Kermack was able to describe the root morphologies of the canines, and demonstrate that basal theriodonts retained the ancestral condition of two maxillary canines.

Recent advances in imaging techniques, including the development of computed microtomography (μCT), as well as the establishment of three dedicated μCT facilities at South African research institutes (NECSA, Stellenbosch University, and Wits University) has allowed for Karoo fossils to be imaged, reconstructed, visualised, and prepared virtually. The non-destructive nature of μCT, makes it possible for studies to include multiple individuals of the same taxon. Often these individuals are of different sizes so as to sample an inferred ontogenetic sequence (e.g., *Thrinaxodon liorhinus* and *Galesaurus planiceps*). Inclusion of multiple individuals has allowed for a wider range of tooth developmental stages to be observed, further enabling the inference of replacement patterns, and facilitating the estimation of the number of times a tooth at a particular position in the jaw was replaced during an animal's lifespan. The non-destructive nature of X-ray imaging has also allowed for the inclusion of holotypes (e.g., *Euchambersia mirabilis* and *Lycosuchus vanderrieti*), which is important as several therapsids from the Karoo are only known from a handful of specimens(e.g., *Euchambersia mirabilis*).

As synchrotron radiation becomes increasingly more accessible to South African scientists, we are poised to gain an even greater understanding of the mechanisms of tooth replacement of our distant ancestors. Synchrotron radiation allows for sub-micron resolution of developing teeth, permitting the determination of individual lines of enamel deposition in tooth crowns. Such information may grant insight into the timing of initiation of development of a replacement tooth relative to the functional predecessor.

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