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Problems and limitations of X-ray microtomography for the endostructural characterization of fossil tooth tissues

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Dental remains usually represent the most common available evidence attesting of the life history of extinct taxa. Advances in comparative developmental morphology and microanatomy of extant and extinct primates show that a significant amount of valuable information for assessing their taxonomy, adaptive strategies, evolutionary pathways and phylogenetic relationships are preserved in the structure of tooth crowns and roots. In response to the potentially conflicting requirements of safeguard vs. fruition/exploitation of this record, the available technologies based on X-ray microfocus tubes (μCT) and synchrotron (SR-μCT) microtomography allow the quantification of the meso-microstructural signature stored in the mineralized tissues through high-resolution "virtual histology". Nonetheless, depending on their taphonomic history and degree of diagenetic alterations, fossil tooth tissues do not systematically provide a distinct inner signal, preventing the extraction of crucial paleobiological information.

In our record, the extent of such problems and investigative limitations is well illustrated by two spatially and chronologically distant fossil dental assemblages whose taxonomic and phylogenetic status is a matter of contention since over a century: the Late Miocene ape Oreopithecus bambolii and the Lower-Middle Pleistocene hominids from Java, Indonesia.

O. bambolii is peculiar in many aspects, with a typical hominoid postcranial skeleton, a very specialized dentition, and an unusual cranial morphology, developed under insular conditions. Craniodental anatomy has always played an important role in discussions of the phylogenetic relationships of this fossil primate. Albeit reported as the "enigmatic anthropoid", Oreopithecus is currently broadly accepted as a hominoid belonging to the great ape and human clade (Hominidae s.l.). In order to assess its intraspecific variation, we used SR-μCT to image two dental samples from Sardinia and Tuscany, Italy. However, while the record of the Sardinian specimens revealed sufficient contrast among the mineralized components, thus allowing a reliable quantification in terms of tissue proportions and enamel-dentine junction surface morphology, it was not possible to confidently retrieve any information from the assemblage from Tuscany despite the application of advanced post-processing imaging techniques.

Most of the fossil hominid dental remains collected at Java have been attributed to Homo erectus. However, due to the strong convergence in external size and morphology between the human and the pongine (orangutan-like) molar crowns, a larger taxonomic diversity has been suspected since the early discoveries. In our sample from the Sangiran Dome, only less than 50% among the fifteen fossil molar crowns imaged by μCT provided a signal suitable for endostructural assessment, the remaining cases revealing a contrast threshold enamel-dentine-sediment inhibiting any reliable quantitative analysis.

Diagenetic alterations capable to variably hide the inner structural morphology are quite common in the tooth fossil record. Besides phase-contrast SR-μCT, neutron microtomography (n-μCT), whose absorption profile differs from X-rays by being more strongly attenuated by organic than mineral material, could represent an effective investigative tool for imaging the fossil material with a better contrast resolution despite the variably hazy appearance of the inner structural signal.

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