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Deciphering DNA survival in bone mineral: physicochemical mechanisms controlling long-term persistence

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The recovery and sequencing of ancient DNA (aDNA) has revolutionized the way we investigate our past. The aDNA extracted from skeletal remains or from sediments/mineral surfaces has provided unparalleled insights into human evolutionary history and ancient ecosystems[1]. However, the geochemical basis and mechanistic understanding of aDNA preservation in skeletal material and sediments remains elusive.

DNA is prone to rapid degradation in the environment by a variety of physicochemical processes, most notably by nuclease enzymes. Despite this, DNA is known to persist in skeletal material and sediments over timescales of tens of thousands to even millions of years. Skeletal remains are primarily composed of the biomineral hydroxyapatite, which offers a variety of adsorption sites. Adsorption to mineral surfaces is known to protect DNA against enzymatic degradation[2]. However, the mechanisms leading to protection and long-term DNA preservation on hydroxyapatite surfaces are poorly understood. Mineral properties, such as particle size, crystallinity, surface charge and topography, as well as DNA properties, including polymer length, conformation, and nucleobase composition, can influence adsorption and could, therefore, impact DNA protection. However, a systematic approach to elucidate these mineralogical and biochemical controls is lacking.

This study investigates various mineralogical and biogeochemical controls over DNA adsorption and preservation at the hydroxyapatite surface. We performed a series of controlled batch experiments to study the role of mineral particle size, solution chemistry and DNA polymer length on adsorption. We further studied the hydrolysis of surface-bound DNA by a model nuclease DNase I, using qPCR. The findings of this work suggest a strong correlation between DNA polymer length and mineral particle size in DNA adsorption and protection against enzymatic hydrolysis. Our work not only provides a mechanistic understanding of processes governing the long-term preservation of aDNA in bones but also lays the foundation for understanding aDNA preservation in sediments via adsorption on non-biogenic minerals, which were recently used to extract two-million-year-old DNA[3].

References

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