

Medicinal Substance Detection from Archaeological Dental Calculus

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ABSTRACT

Dental calculus is mineralized dental plaque adhering to tooth surfaces. During the process of mineralization, materials from saliva and the oral cavity are preserved within its layers. Recently, the ability of preservation, withstand time and harsh environment, made dental calculus an emerging topic in archaeological studies. Through the advancement of technology, dental calculus offers a valuable resource for exploring past human behavior, including health, diet, and medicinal practices. Although the study of archaeological dental calculus has been ongoing for many years, investigations of medicinal compounds are still underexplored. This paper aims to identify and analyze the use of medicinal substance to gain valuable insights of past healthcare systems, treatment methods, and the interaction between medicinal substances and culture. Studies have revealed the presence of medicinal plants, animal products, minerals, and metabolites from ancient dental calculus. The discovery also led to the understanding of habitual and cultural practice such as treatments through special diets and the practice of trades. However, challenges still remain, including distinguishing between intentional and accidental substance use, overcoming gaps in historical records, and addressing the underrepresentation of specific regions and eras. These limitations highlight the need for future research so we can deepen our understanding of historical medicine, contribute to preserving cultural knowledge, and shaping modern pharmacological practices.

Keywords: Dental calculus; drug detection; archaeology; forensic

ABSTRAK

Kalkulus gigi adalah plak gigi termineralisasi yang menempel pada permukaan gigi. Selama proses mineralisasi, bahan dari air liur dan rongga mulut diawetkan di dalam lapisannya. Baru-baru ini, kemampuan pelestarian, tahan terhadap waktu dan lingkungan yang keras, menjadikan kalkulus gigi sebagai topik yang muncul dalam studi arkeologi. Melalui kemajuan teknologi, kalkulus gigi menawarkan sumber daya yang berharga untuk mengeksplorasi perilaku manusia di masa lalu, termasuk kesehatan, diet, dan praktik pengobatan. Meskipun studi kalkulus gigi arkeologi telah berlangsung selama bertahun-tahun, penyelidikan senyawa obat masih kurang dieksplorasi. Makalah ini bertujuan untuk mengidentifikasi dan menganalisis penggunaan zat obat untuk mendapatkan wawasan berharga tentang sistem perawatan kesehatan masa lalu, metode pengobatan, dan interaksi antara zat obat dan budaya. Penelitian telah mengungkapkan keberadaan tanaman obat, produk hewani, mineral, dan metabolit dari kalkulus gigi kuno. Penemuan ini juga mengarah pada pemahaman tentang praktik kebiasaan dan budaya seperti perawatan melalui diet khusus dan praktik perdagangan. Namun, tantangan masih tetap ada, termasuk membedakan antara penggunaan zat yang disengaja dan tidak disengaja, mengatasi kesenjangan dalam catatan sejarah, dan mengatasi kurangnya representasi dari wilayah dan era tertentu. Keterbatasan ini menyoroti perlunya penelitian di masa depan sehingga kita dapat

memperdalam pemahaman kita tentang pengobatan sejarah, berkontribusi untuk melestarikan pengetahuan budaya, dan membentuk praktik farmakologis modern.

Kata kunci: Kalkulus gigi; deteksi obat; arkeologi; forensik

INTRODUCTION

Calculus is present across all historical and modern human populations (Forshaw, 2022). Historically, it was often removed and discarded from archaeological remains to facilitate the study of dental stress indicators, such as linear enamel hypoplasia, or to examine dental wear patterns (Mackie et al, 2016). Over the past decade, dental calculus has been recognized as a valuable resource, offering a wealth of microbial and host biomolecules that provide insights into health and dietary patterns on individual and population levels (Warinner et al., 2015).

Dental calculus is mineralized dental plaque that forms through the interaction of saliva and bacteria adhering to tooth surfaces (Handayani et al., 2023). Its uneven texture facilitates further plaque buildup (Hardy et al., 2012). During the process of mineralization, materials from saliva and the oral cavity become embedded and preserved within its layers (Radini et al., 2017). As a readily accessible material, dental calculus serves as a feasible antemortem sample (Cheng et al., 2023). It is not part of the skeleton or teeth but exists as an external, secondary biomaterial or "add-on." Consequently, sampling dental calculus from tooth surfaces is considered a non-destructive analytical method (Scott & Poulson, 2012). Its mineralized composition ensures excellent preservation in archaeological contexts (Forshaw, 2014).

Although studying dietary residues in human archaeological dental calculus has been ongoing for many years, investigations into the deposition of medicinal compounds in calculus are still limited (Sørensen et al., 2021). The underexplored potential of dental calculus as a reservoir for medicinal evidence offers opportunities to expand our understanding of historical medicine and pharmacological practices. By identifying and analyzing the use of this substance, researchers can gain valuable insights into past healthcare systems, treatment methods, and the interaction between medicinal substances and culture. This paper aims to review existing research on detecting medicinal substances within dental calculus.

MATERIAL AND METHOD

This literature review focuses on studies and findings on medicinal substances detected in dental calculus. The search was conducted using *PubMed* and *Scopus* databases, using keywords such as "dental calculus," "drug detection," "archaeology," and "forensic." Only English-language papers published within the last 20 years were considered, while duplicates and pre-reviewed articles were excluded. The screening process began with an analysis of titles and abstracts. Relevant papers were then retrieved for a full-text review, and those considered to be relevant to the study's objectives underwent further analysis.

RESULT AND DISCUSSION

Dental Calculus as a Reservoir of Information

Dental calculus holds great potential to reveal new insights about human behavior spanning both modern and historical contexts. Its rough surface creates an optimal environment for microbial activity, promoting plaque development and resulting in the layered accumulation of calculus (Hardy et al., 2012). Saliva has been found to preserve a unique metabolic signature throughout daily activities (Wallner-Liebmann et al., 2016), and particulate matter, such as food residues and airborne pollutants, can become trapped within the mineralized matrix. This process, often described as "fossilization," captures these materials over time (Radini et al., 2017).

Extracting dental calculus from archaeological specimens involves carefully removing it from the surface of teeth using a sterilized dental pick. Analysis is typically performed using light microscopy, morphological examination, and gas chromatography-mass spectrometry (GC-MS). Additional methods include ultra-high-performance liquid chromatography coupled with quadrupole high-resolution mass spectrometry (Riboni et al., 2023), scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS) (Radini et al., 2019), thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS), pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) (Buckley et al., 2014; Hardy et al., 2012, 2018), and DNA sequencing (Baldoni et al., 2019; Gismondi, Baldoni, et al., 2020; Sawafuji et al., 2020).

Morphological examination and species identification through microscopic analysis often rely on existing databases. The use of specific species is typically guided by historical texts and records, such as those by Pliny the Elder and Dioscoride (Fiorin et al., 2019). At the same time, a more advanced approach by using GC-MS and DNA sequencing offers a more comprehensive approach to past dietary and medicinal practice. The presence of metabolites may suggest that specific substances can be used for medicinal purposes alongside dietary consumption (Gismondi et al., 2018; Gismondi, Baldoni, et al., 2020).

Medicinal Substance Found on Dental Calculus

Medicinal plants in archaeological specimens are the most widely discovered and studied (D'Agostino et al., 2020; Hardy et al., 2012). However, other substance derived from non-plant origin are also discovered. D'Agostino et al. (2019), identified traces of bee products, such as honey, which, while a common dietary component, are also renowned for their antimicrobial properties. An intriguing discovery was the presence of muscimol, a toxic fungal compound, in an individual with a fractured right fibula. This metabolite may have been used at low doses for its analgesic properties (Gismondi et al., 2018). Additionally, minerals like Lapis Lazuli were detected in archaeological specimens from the Dalheim burial site near Lichtenau, Germany. While the uses of these particles vary, one hypothesis suggests their application in lapidary medicine (Radini et al., 2019).

Medicinal-Dietary Overlaps

Evidence of intake alone cannot confirm that a substance was consumed for medicinal purposes. Without prior knowledge of the individual's previous health condition and cause of death, the intake of a substance may be for various reasons. In the past, medical practices often relied on traditional substances that also served as common dietary components (Fiorin et al., 2024). Many substances, such as honey, grapes, and mint, serve both dietary and therapeutic purposes, showing an overlap between food and medicine (Gismondi, Baldoni, et al., 2020). These findings suggest a holistic approach to health and well-being in the past.

One method to differentiate between dietary and medicinal use of substances is through evidence of pathological conditions. For instance, Gismondi et al. (2023) discovered markers such as nettle, *Artemisia* and methylephedrine from *Ephedra L.* species, on the dental calculus of an individual with severe bilateral temporomandibular joint (TMJ) ankylosis. These substances are known for their medicinal properties, and their use is suggested for alleviating symptoms due to the individual's impairment.

Cultural Practice Insight

The discovery of substances within dental calculus provides a deeper understanding of substance use and valuable insights into past cultural practices. Baldoni et al. (2018) identified pain-relieving and anti-inflammatory alkaloids in the dental calculus of Allumiere miners. This discovery shows the link between harsh working conditions may lead to reliance on medicinal substances. Another perspective focuses on tracing the origins of these substances. When a substance is non-native and associated with trade or import history, it suggests the possibility of its commercialization as medicine. The use of exotic ingredients as "essential medicines" is widely adapted across different cultures. For instance, Fiorin et al. (2024) identified ginger as a potential treatment for leprosy, while Gismondi et al. (2020) detected turmeric and ginseng used for managing coeliac disease. Despite differences in location and periods, the similar use of substances underscores the universal therapeutic properties of medicinal plants and the interaction of human societies through trade and the exchange of knowledge.

Medicinal Practice Across Time

The consistent use of plants like *Ephedra spp.*, *Artemisia spp.*, and *Salix spp.* (willow) across various societies and periods suggests the possibility of either shared knowledge or independent discoveries of their medicinal properties (D'Agostino et al., 2019; Gismondi et al., 2018; Hardy et al., 2012). The consistent use of these substances for a specific disease indicates an understanding of their therapeutic properties. Variations of substance in another region also offer valuable insights that can inform and refine modern medicinal practices and applications.

Findings of medicinal substances in an individual with known pathology leads to the development of disease-specific treatment (Gismondi, D'Agostino, et al., 2020;

Gismondi et al., 2023). *Artemisia spp.* was detected in regions where malaria may have been endemic, suggesting its role in managing febrile conditions and parasitic infections (Gismondi, Baldoni, et al., 2020). These findings reflect humanity's persistent effort to combat diseases and improve health using available resources. Past pharmacological systems also provide a foundation for modern drug development.

Limitations and Further Research

The study of dental calculus offers valuable insights into ancient medicinal practices but faces challenges due to methodological, interpretative, and geographical limitations. A key difficulty is distinguishing between intentional uses—whether dietary, medicinal, cultural, or accidental exposure (Radini et al., 2019). Species naming and use of substances in the past also may differ from modern times. Thus, historical correlations are essential. However, not all findings can be confirmed as medicinal use due to the lack of comprehensive historical records.

Furthermore, the focus of many studies is limited to specific regions and periods. This has resulted in the underrepresentation of medicinal practices from other areas and times. Broadening research to more diverse regions and timeframes offers a more comprehensive understanding of historical practices and their relevance to modern medicine. Advancements in analytical techniques, such as untargeted substance identification and the integration of multiple methods, can enhance the accuracy and depth of findings while minimizing sample destruction.

CONCLUSION

Dental calculus is a remarkable resource for understanding historical behaviors across different societies and periods. Through advanced analytical techniques and multidisciplinary approaches, studies have revealed the presence of medicinal plants, animal products, minerals, and metabolites from ancient dental calculus. This sheds light on ancient pharmacological systems and their contribution to modern medicine. Not only revealing historical medicine and pharmacological practices, the discovery also led to the understanding of habitual and cultural practice such as treatments through special diets and the practice of trades.

However, challenges still remain, including distinguishing between intentional and accidental substance use, overcoming gaps in historical records, and addressing the underrepresentation of specific regions and eras. These limitations highlight the need for broader investigations and the development of more sophisticated methods to extract and analyze dental calculus. By addressing these gaps, future research can deepen our understanding of historical medicine, contribute to preserving cultural knowledge, and shaping modern pharmacological practices.

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