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ORIGINAL ARTICLE

Dental calculus as a useful tool for public health evidence in past populations: The case of two individuals from Begho-Ghana (10th—19th C. AD)

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Summary
Background. — Numerous studies have demonstrated that dental calculus is a concrete storehouse of the oral microbiome and micro-remains of dietary and non-dietary origin. Dental calculus analysis allows insight into past populations' dietary contents and public health concerns. This study aimed at questioning whether two individuals from Begho (Ghana) were at risk of industrial pollution from their dental calculus samples.
Materials and method. — Three calculus samples from the two adult individuals were subjected to X-ray fluorescence analysis using the Rigaku NEX CG X-ray fluorescence machine. After calibration with a bead of borosilicate, the 3.5 g samples were run for 15—20 minutes along with the Rigaku NEX CG XRF fundamental parameters (FP) double determination approach and a helium gas test flow rate of 0.660 ml/min. Results are semi-quantitative determinations in percent values.

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Results. — In total, 59 elements and 55 molecular fingerprints were automatically generated. Oxygen and calcium elements were high for all samples, and variations in Fe, Si, and Al elements and corresponding oxides were evidenced in the three samples. The dental calculus analysis revealed an expected composition of calcified aluminium silicate, minimal traces of industrial pollutants such as lead, mercury, and chromium, and no trace of arsenic, antimony, and cadmium.

Conclusion. — By analyzing dental calculus in direct correlation with alimentation, we assert that the two individuals sampled were not exposed to lead, chromium, mercury, arsenic, antimony, and cadmium in Begho (10^{th}—19^{th} C. AD). We infer that industrial pollutants did not jeopardize the health of these Begho individuals.

Introduction

Dental calculus, i.e., precipitates of dental plaque at the surface of the teeth and potentially gingiva, tends to preserve in the long term the oral microbes, dietary and non-dietary residues of varied forms. In ancient and contemporary contexts, calculus has been of interest to archaeologists and anthropologists for explaining individual and population dietetics and health as well as the organization of the natural and built environments [1—5]. Residue analyses of dental calculus have revealed micro-remains of silica, phytoliths, oral microbiome, food debris, organic compounds, crystals, and vegetal or cotton fiber [1,6—8]. Hence, dental calculus analysis provides objective data for insights into the past dietary patterns and health of populations. The research objective was to determine whether the two individuals from Begho were exposed to industrial pollutants via the food-water chain during their life course from their dental calculus.

In this paper, we present the result of the X-ray fluorescence analysis of three calculus samples from two individuals excavated from the Brong quarter of Begho. One individual (BG'21-F 73.116 (70 B1) was associated with potsherds and animal (dog) bones included in the storage box. The storage box of the other individual, BG'21-E 73.115 (Bg. 70, E), did not contain any artifacts. Begho was a 10^{th} to early 19^{th} century [9—14] cosmopolitan trading center in the Bono region (7°51'00''°N 2°29'00''°W) of Ghana. It was a socially-structured town that served as a trading route during the trans-Saharan trade in gold, kola, salt, ceramics, dyed textiles, ivory, and iron implements [11,14 p.108-9]. A descendant community called Hani is located at the prehistoric landmark where Begho was located. The Hani people are predominantly farmers and the custodians of the Begho land & trade history [15].

Materials & method

Calculus was extracted from the mandibular teeth (32, 33, 34, 35, 37, 38 & 42, 43, 44, 47, 48) of an adult individual (male?) BG'21-E 73.115 (Bg. 70, E) and from the maxillary (11, 13, 14, 21, 23 & 24) and mandibular (31—37 & 41—48) teeth of a 40—45-year-old male BG'21-F 73.116 (70 B1). The extracted calculus from the maxillary and mandibular teeth were treated as independent samples; thus, three calculus samples from two individuals were prepared for analysis. Although five composite samples were extracted, only these three samples (weighing 3.5 g) mentioned above could be adjusted for the equipment sample intake requirement of 4 g and above. These human remains were excavated in 1970 and are stored in the Museum of Archaeology, DAHS, University of Ghana.

The samples were subjected to X-ray fluorescence analysis to ascertain the elemental and oxide/molecular composition at the Department of Earth Science of the Basic and Applied Sciences School, University of Ghana, using the Rigaku NEX CG X-ray fluorescence machine. A multichannel analyzer calibration (MCA) was done using a borosilicate bead to calibrate the relationship between the channels of spectrum data and the energy of fluorescent X-rays. The three calculus samples were ground into powder using a mortar and a pestle and weighed on powder paper. Due to the small quantity of calculus samples, they were not preweighed before grinding. The weight of the sample after grinding was 3.5 g. The powdered samples were transferred into a sample cup, covered, and loaded into the assigned sample chamber position in the Rigaku NEX CG X-ray fluorescence machine. The calculus samples were run in the XRF chamber for approximately 15—20 minutes along with the Rigaku NEX CG XRF fundamental parameters (FP) double determination approach and a helium gas test flow rate of 0.660 ml/min. The FP method involved the use of the QuantEZ® software for controlled spectrometer functions and data analysis of the excitation source, element-element interactions, beam intensity of each element (detected by a high-performance Silicon Drift Detector), band overlaps, incidence angle & wavelengths, and mass absorption coefficients to calculate the elemental and molecular concentrations in the calculus as percent levels. The Rigaku NEX CG's FP produces semi-quantitative determinations of the concentrations with minimal standards. Therefore, 59 elements and 55 molecular fingerprints were automatically generated non-destructively. The presence of Helium gas permitted the measurement of lighter elements such as Si, Al, Na, and Mg.

Results

Details of the results are provided in Table 1. Oxygen and calcium were the outstanding elements for all three samples. Comparatively, Fe2O3 and SiO2 were relatively higher (1.64% & 32.9%, respectively) in the maxillary sample of individual BG'21-F 73.116 (70 B1) than in the mandibular samples for both individuals. There was not much difference in the composition of phosphorus for the three samples. While there was no difference in aluminium composition for the mandibular sample of individual BG'21-E 73.115 (Bg. 70, E) and the maxillary sample of individual BG'21-F 73.116 (70 B1), - 4.24% and 5.18% respectively-, the mandibular sample of individual BG'21-F 73.116 (70 B1) was low in aluminium (1.91%). Lastly, there were minimal traces of classical industrial pollutants such as lead, mercury, and chromium and no trace of arsenic, antimony, and cadmium within the limits of the analysis.

Discussion

This dental calculus analysis allowed an objective glimpse into the health (i.e., intra-vitam exposure via alimentation process) of the two individuals from Begho, displaying a relatively high composition of calcified aluminium silicate, and no or tiny intoxication of industrial pollutants such as arsenic, antimony, lead, mercury, and chromium. Potential exposure also includes the ceramic release of toxins during cooking or alimentary activities. Bourdin et al. [16] found non-worrying concentrations (as for French standard limits [17]) of lead (2.01 μg/L), cadmium (0.69 μg/L), and arsenic (5.56 μg/L) in a ceramic sample from Begho [16], which was in association with the skeletal remains of individual BG'21-F 73.116 (70 B1). But our study recorded no trace of arsenic and cadmium in the calculus samples of the same individual. Comparatively, the arsenic concentration in a potsherd from Sekondi, Ghana, was found to be 10.30 μg/L [16], slightly higher than the standard of 10 μg/L [17]. Even though ceramics and calculus are incomparable, values from the two media can supplement public health and environmental reconstruction. We could not clearly establish the primary or secondary use of all the Begho ceramics, but the sherd size, thickness, and reconstructed shape suggested exclusively funerary artifacts and not cooking vessels. Hence, a somewhat indirect environmental transfer of the pollutant into the ceramics could be proposed. That said, the arsenic concentration in the Begho pottery sample may have also originated from the fabrication paste or a post-mortem leach of the pollutant within the burial environment into the ceramic.

The leach of contaminants into food followed by ingestion is a likely explanation when significant concentrations are detected in calculus samples. Dental calculus represents layers of lifetime plaques, and episodes of contamination through the vessel-food medium [18] or water [19] can be traced in its composition. We believe the crystalline nature of dental calculus preserves all trapped elements without the possibility of reverse leaching. Hence, no dietary toxicity could be associated with these individuals because of the absence of industrial pollutants such as arsenic and antimony and non-disturbing concentrations of lead, mercury, and chromium evidenced in the dental calculus analysis.

Table 1 Elemental and oxide composition of the three calculus samples from two individuals.

BG'21-E 73.115 (Bg. 70, E). Mandible				BG'21-F 73.116 (70 B1) Maxilla				Mandible			
Elementals		Oxides		Elementals		Oxides		Elementals		Oxides	
Component	Average (%)	Component	Average (%)	component	Average (%)	Component	Average (%)	Component	Average (%)	Component	Average (%)
O	59.7	CaO	33.2	O	49.9	SiO2	32.9	O	65.2	CaO	43.4
Ca	16.3	SiO2	27.8	Ca	20	CaO	31.7	Ca	17.4	P2O5	31.4
Si	9.88	P2O5	24.5	Si	14.4	P2O5	20	P	9.12	SiO2	15.5
P	8	Al2O3	10	P	7.99	Al2O3	10.45	Si	4.76	Al2O3	5.48
Al	4.24	Fe2O3	1.36	Al	5.18	Fe2O3	1.64	Al	1.91	Fe2O3	1.49
Fe	0.586	Na2O	1.36	Fe	1.004	Na2O	1.18	Na	0.715	Na2O	0.874
Na	0.411	TiO2	0.607	Na	0.61	TiO2	0.6835	Fe	0.461	MgO	0.768
Ti	0.233	MgO	0.329	Ti	0.363	MgO	0.562	Mg	0.336	TiO2	0.49
Mg	0.184	SO3	0.25	Mg	0.304	K2O	0.2735	Ti	0.144	SO3	0.293
K	0.141	K2O	0.243	K	0.204	SO3	0.2015	Zr	0.103	ZrO2	0.287
Zr	0.0991	ZrO2	0.21	Zr	0.13	ZrO2	0.195	K	0.0834	K2O	0.176
S	0.0618	MnO	0.0518	S	0.065	MnO	0.0555	S	0.0576	SrO	0.0822
Mn	0.0241	SrO	0.0406	Mn	0.0374	SrO	0.03975	Sr	0.0294	MnO	0.065
Cl	0.0237	ZnO	0.031	Sr	0.0293	ZnO	0.03115	Cl	0.0285	ZnO	0.0586
Sr	0.0201	V2O5	0.0134	Cl	0.0227	V2O5	0.01205	Mn	0.023	V2O5	0.0132
Zn	0.0149	Co2O3	0.0049	Zn	0.0215	Co2O3	0.0069	Zn	0.0211	Co2O3	0.0071
V	0.0035	CuO	0.0047	V	0.0058	CuO	0.0052	V	0.0028	BaO	0.0066
Cu	0.0023	NiO	0.0035	Cu	0.0041	Cr2O3	0.00495	Cu	0.0022	CuO	0.0063

Table 1 (*Continued*)

BG'21-E 73.115 (Bg. 70, E). Mandible				BG'21-F 73.116 (70 B1) Maxilla				Mandible			
Elementals		Oxides		Elementals		Oxides		Elementals		Oxides	
Component	Average (%)	Component	Average (%)	component	Average (%)	Component	Average (%)	Component	Average (%)	Component	Average (%)
Cr	0.0017	Cr2O3	0.0034	Cr	0.0028	NiO	0.00355	Co	0.0017	NiO	0.0036
Ni	0.0017	Y2O3	0.0016	Ni	0.0027	Ta2O5	0.00175	Ni	0.0017	Cr2O3	0.0024
Ta	0.0016	Ta2O5	0.0015	Co	0.002	Y2O3	0.0016	Y	0.0008	Ta2O5	0.0022
Y	0.0009	HgO	0.0013	Pb	0.0013	HgO	0.0014	Cr	0.0007	Y2O3	0.002
Pb	0.0009	Rb2O	0.0012	Y	0.0012	Rb2O	0.00135	Rb	0.0007	HgO	0.0018
Rb	0.0008	Ir2O3	0.0012	Rb	0.0011	PbO	0.00125	Ir	0.0007	PbO	0.0017
Br	0.0007	PbO	0.0012	Pt	0.0009	Ir2O3	0.00115	Pb	0.0007	Rb2O	0.0016
Au	0.0006	Au2O	0.001	Au	0.0009	Au2O	0.00105	Br	0.0006	Au2O	0.0014
Ga	0.0005	Ga2O3	0.0008	Br	0.0008	Ga2O3	0.0007	Au	0.0006	Ga2O3	0.0011
Hg	0.0005	As2O3	0.0002	Ir	0.0008	PdO	0.0002	Ta	0.0005	As2O3	0.0004
Co	0	GeO2	0	Ga	0.0007	As2O3	0.0002	Pt	0.0005	GeO2	0
Ge	0	SeO2	0	Hg	0.0007	GeO2	0	Tl	0.0005	SeO2	0
As	0	Nb2O5	0	Sn	0.0003	SeO2	0	Hg	0.0004	Nb2O5	0
Se	0	MoO3	0	Ge	0	Nb2O5	0	Ga	0.0002	MoO3	0
Nb	0	RuO2	0	As	0	MoO3	0	Ge	0	RuO2	0
Mo	0	Rh2O3	0	Se	0	RuO2	0	As	0	Rh2O3	0
Ru	0	PdO	0	Nb	0	Rh2O3	0	Se	0	PdO	0
Rh	0	Ag2O	0	Mo	0	Ag2O	0	Nb	0	Ag2O	0
Pd	0	CdO	0	Ru	0	CdO	0	Mo	0	CdO	0
Ag	0	In2O3	0	Rh	0	In2O3	0	Ru	0	In2O3	0
Cd	0	SnO2	0	Pd	0	SnO2	0	Rh	0	SnO2	0
In	0	Sb2O3	0	Ag	0	Sb2O3	0	Pd	0	Sb2O3	0
Sn	0	TeO2	0	Cd	0	TeO2	0	Ag	0	TeO2	0
Sb	0	Cs2O	0	In	0	Cs2O	0	Cd	0	Cs2O	0
Te	0	BaO	0	Sb	0	BaO	0	In	0	La2O3	0
I	0	La2O3	0	Te	0	La2O3	0	Sn	0	CeO2	0
Cs	0	CeO2	0	I	0	CeO2	0	Sb	0	Pr6O11	0
Ba	0	Pr6O11	0	Cs	0	Pr6O11	0	Te	0	Nd2O3	0
La	0	Nd2O3	0	Ba	0	Nd2O3	0	I	0	HfO2	0
Ce	0	HfO2	0	La	0	HfO2	0	Cs	0	WO3	0
Pr	0	WO3	0	Ce	0	WO3	0	Ba	0	Ir2O3	0
Nd	0	PtO2	0	Pr	0	PtO2	0	La	0	PtO2	0
Hf	0	Tl2O3	0	Nd	0	Tl2O3	0	Ce	0	Tl2O3	0
W	0	Bi2O3	0	Hf	0	Bi2O3	0	Pr	0	Bi2O3	0
Ir	0	ThO2	0	Ta	0	ThO2	0	Nd	0	ThO2	0
Pt	0	U3O8	0	W	0	U3O8	0	Hf	0	U3O8	0
Tl	0	Sc2O3	0	Tl	0	Sc2O3	0	W	0	Sc2O3	0
Bi	0			Bi	0			Bi	0		
Th	0			Th	0			Th	0		
U	0			U	0			U	0		
Sc	0			Sc	0			Sc	0		

Conclusion

The calculus's calcified and particularly dense nature makes it unlikely to be contaminated or modified by taphonomic processes or other post-mortem activities. Thus, the probability of the leaching (both in and out) of organic and inorganic substances is considered improbable for altering the content. From the XRF results, we preliminarily concluded that the two individuals from Begho were not exposed to any industrial pollutants, which could have negatively impacted on their health and lifespan. The sample size of three calculus samples from two individuals limits the research. Regardless, the results should be considered references for pre-industrial dental calculus elemental and molecular results for future alimentation and health analysis or comparison. We recommend extensive sampling and analyses to support our results and conclusions and comparative studies to holistically comprehend toxicity in human remains and ceramics regarding industrial pollutants. This study demonstrates the ability of dental calculus not only to reconstruct precise alimentation but also extensive public health concerns for past populations.

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Disclosure of interest

The authors declare that they have no competing interest.

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