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Dietary Pathologies and Isotope Diversity in Imperial Rome (First to Fourth Centuries AD)

KRISTINA KILLGROVE AND ANDREA N. ACOSTA

As one would expect for the seat of a geographically large empire, ancient Rome was a complex place, with diversity in its people's origins, social classes, economics, and diet. The city was probably founded around the eighth century BC, and less than a millennium later was massive, cramped, and bustling (Morley 1996; Scheidel 2001; Storey 1997; Wiseman 1969). The population of Imperial Rome was extremely hierarchical. Those at the very top of the social ladder—roughly the top 2%—held the majority of the wealth and controlled the government, economy, religion, and more (Alföldy 1985; MacMullen 1974). The lower classes included the urban and rural poor, in addition to enslaved people, who were often freed after a certain period of service (Bradley 1994).

Against this background, it is no surprise that the ancient Roman diet was anything but monolithic. From historical sources, we get both specific information about the dining habits of the elite as well as a rough outline of the lower-class diet. The typical Roman diet during the Empire was composed largely of wheat (*Triticum* sp.) and barley (*Hordeum vulgare*) bread and grain-based porridges, along with vegetables, fruits, pulses, and the occasional terrestrial meat and fish. The average citizen, on an average day in Imperial Rome, consumed a large proportion of their daily calories at *prandium,* the midday meal. *Prandium* was "a cold, frugal, vegetarian meal for consumption by a single individual. [. . .] Such a meal, offering just the bare minimum necessary for survival, was the nourishment of active citizens" (Dupont 1999:126). Soldiers, on the other hand, consumed quite a lot of bread, as it was compact when cooked and remained edible even after it hardened. In a Lévi-Straussian sense, classicist Florence Dupont (1999) has argued that meat symbolized community and religious sacrifice, vegetables the common citizen, and bread the citizenship granted to Roman peasants who served as soldiers. Dietary choices therefore clearly varied based on social status, with upper-class people having more access to a greater variety of foods than did the lower classes. The diet might also have varied based on age and sex, with children and women receiving disproportionately smaller shares of prized foods. Finally, the diet likely varied from individual to individual. This sort of "differentiated cuisine," as Roman archaeologist Hilary Cool (2006:34) writes, "develops when a society is stratified culturally as well as politically."

Approaching an understanding of variation in the everyday Roman diet cannot be done solely from historical records and requires synthesis of disparate sources, including archaeological context and analysis of human skeletons for stable isotopes and dental pathologies. In this chapter, we therefore take a more granular approach to investigating the variation in the Imperial lower-class diet by examining correlations between paleodietary isotope data and dental pathology frequencies against a backdrop of historically known diet and oral hygiene practices.

Roman Diet and Dentistry

For centuries, the main evidence cited by scholars for the Imperial diet was historical and poetic, spanning hundreds of years of the Empire. In the satirical fiction called *Satyricon* by Petronius (late first century AD) (trans. Walsh 1999), for example, a freedman named Trimalchio hosts a lavish dinner party to demonstrate his rising social status. While Trimalchio's dinner is an exaggeration, when you take away the fictional novelties, Petronius illustrates foods common in Roman dining: chickpeas (*Cicer arietinum*), figs (*Ficus carica*) and other fruits, seafood, poultry, pork (*Sus scrofa*), olives (*Olea europaea*), eggs, oysters (*Ostrea edulis*) and scallops (*Pectinidae* spp.), and a lot of wine.

In the second century AD, we get additional information about the diet in Imperial Rome from the physician Galen, better known for his writings on medicine. Galen's view of the body, however, inextricably linked cooking to digestion, particularly in his *de Alimentorum Facultatibus* (trans. Powell and Wilkins 2003). Foods that were processed and cooked were viewed as easier to digest. Galen also found it important to match a person's diet with their temperament, which was either sanguine, choleric, melancholic, or phlegmatic. A person of a particular temperament was thought to have an imbalance in humors, which may have been caused by a poor or deficient diet.

Galen therefore suggested that a good doctor should also be a good cook and a dietitian, to understand how the properties of food affected people of different temperaments. Galen's *de Alimentorum Facultatibus,* then, is useful for understanding from a historical perspective the variety in the Imperial diet and the possibility that diets because of their purported medicinal qualities varied by individual. Additionally, Galen suggested balance in his *de Sanitate Tuenda* (trans. Green 1951), advocating preventive medicine through appropriate diet, exercise, and sleep habits for physical and mental health. Although Galen notes in this treatise that it is possible for anyone to guard his or her health, in reality only the elite would have had the time and resources to follow all these prescripts. Nevertheless, since his work reflects the state of European medical knowledge in the second century AD, a large section of the population of the Roman Empire was certainly culturally aware of these ideas, even if they did not strictly adhere to them.

A final example of historical diet comes from a cookbook attributed to Apicius from the fourth century AD; while no one knows who actually authored the recipes, *de Re Coquinaria* is arranged according to featured ingredients (trans. Vehling 1977). From the chapters devoted to vegetables, pulses, poultry, red and white meat, and seafood, as well as from the lists of ingredients, it is possible to get a general idea of the kinds of foods popular among the upper-class Romans. For example, there are 23 pork recipes and just 4 with beef (*Bos taurus*), showing the popularity of the former. But the lower classes were likely eating very little of the meals whose recipes are in this cookbook; it was mostly the literate but enslaved cooks who were using the recipes to create dishes for their upper-class masters during the Empire.

Archaeological investigation into the Roman diet has arisen comparatively more recently than historical approaches, but it allows us to verify and expand on what the historical record reveals about the Roman diet, particularly regarding the lower classes. The sites of Pompeii and Herculaneum, roughly 250 km south of Rome, provide the best-preserved archaeological evidence of everyday diet in the Empire, owing to their complete, near-instantaneous destruction and to their exemplary preservation following the eruption of Mt. Vesuvius in AD 79.

At Herculaneum, dietary evidence can be found in the sewers of a Roman *insula* or city block. Insula Orientalis II housed several workshops and *tabernae* (restaurants) on the first floor, and private apartments on the second floor (Rowan 2017). Remains of more than 190 edible plants and animals were recovered from the sewer of the *insula.* Among the botanical finds from Insula Orientalis II were olive pits, pine nuts (*Pinus pinea*), and hard-shelled nuts such as hazelnuts (*Corylus avellana*), almonds (*Prunus dulcis*), and walnuts (*Juglans regia*). Evidence of grains included wheat (einkorn, bread wheat, and emmer), barley, and Italian/foxtail millet (*Setaria italica* or *Panicum italicum*). Fruit remains found in the sewer included apples (*Malus* spp.), mulberries (*Morus* spp.), pears (*Pyrus* spp.), and blackberries (*Rubus* spp.) (Rowan 2016, 2017). The large number of eggshells discovered were mostly from chickens (*Gallus gallus*) or ducks (*Anatidae* spp.); together with chicken bones, these make up most of the protein from terrestrial animals. Bones from several species of fowl, fish, and shellfish suggest that additional protein came from a maritime source (Rowan 2017). Interestingly, archaeologists discovered the remains of black pepper (*Piper nigrum*). Not native to the Italic peninsula, it must have been imported from India. This discovery suggests that this exotic spice was accessible even to the middle and lower classes at Herculaneum (Rowan 2017).

A similar study was conducted in Pompeii from the sewage of Insula V (Murphy et al. 2013). Among the grain types found were wheat and barley, but broomcorn millet (*Panicum miliaceum*) grains were the most numerous. Besides the cereals, pulses such as lentils (*Lens culinaris*), vetches (*Vicia* spp.), broad beans (*Vicia faba*), and peas (*Pisum sativum*) were present. Additionally, seeds of fruits such as figs, olives, and grapes (*Vitis vinifera*) made up a large proportion of the food assemblages. Remnants of pomegranates (*Punica granatum*), blackberries, melons (Cucurbitaceae), and peaches (*Prunus persica*) were also found in lower quantities. Walnuts, almonds, and hazelnuts were represented as well.

Although detailed research into alimentary resources is ongoing at these two Vesuvian sites, at neither site have dental or skeletal pathologies or paleodietary isotope data been integrated with the sewer remains, leaving a lacuna in the bioarchaeological record that could be closed with analysis of multiple data sources.

Also under-researched is the practice of ancient Roman dentistry, as only a handful of studies claim to have found concrete evidence of extracted or modified teeth. Archaeologically, the practice of dentistry dates back about 14,000 years (Oxilia et al. 2017), but historically there is evidence from the Egyptians of dentistry roughly 4,000 years ago; the Greeks and Romans were similarly well versed in dental care.

Among the most famous classical physicians are Hippocrates (fl. sixth–fifth centuries BC), the aforementioned Galen (fl. second century AD), and Celsus (fl. first century AD). While works in the Hippocratic corpus focus largely on a whole-body wellness plan, they do mention dental care (Guerini 1909). For example, *de Morbis Mulierum* (trans. Potter 2018) outlines a treatment for a woman's diseased gums: mix carbonate of lime and burned animal remains to rub onto the affected area, then clean with greasy wool, rinse with water, and rub with honey. Another work titled *de Affectionibus* (trans. Potter 1988:13) discusses toothaches and explains that "if the tooth is decayed and loose, remove it; if it is not decayed or loose, but produces pain, dry it out by cautery; medications that are chewed are useful as well." Finally, in *de Articulis* (trans. Adams 1868), Hippocrates mentions that jaw fractures should involve binding teeth together using gold wire or linen thread until the bone heals. Archaeological examples of dental appliances are few, due mostly to the fact that any metal of worth would have been removed from a corpse prior to burial; however, several have been found from Etruscan through Imperial Italy (e.g., Minozzi et al. 2007).

Both Galen and Celsus continued the Hippocratic medical tradition into the Roman Empire. In *de Medicina* (trans. Spencer 1938), Celsus suggests that toothache sufferers abstain from wine and consume a soft food diet, and also encourages extraction when necessary. Further on, Celsus explains how to remove a tooth: "if a tooth gives pain and it is decided to extract it because medicaments afford no relief, the tooth should be scraped round in order that the gum may become separated from it; then the tooth is to be shaken [. . .] if the tooth is decayed, the cavity should be neatly filled first, whether with lint or with lead" (trans. Spencer 1938: 369). Convincing archaeological evidence of an ancient dental practice comes from the Roman Forum, where a cache of carious teeth dating to the first century BC was discovered in a drain (Becker 2014). Finally, it appears that Greek and Roman dentists knew not just about carious lesions and periodontal disease, but also about dental plaque. Celsus advised that blackish stains on teeth should be scraped away, followed by cleaning with myrrh and disinfection with wine. Despite this clear understanding of issues related to oral hygiene among the Romans, however, there is no evidence that they made a link between foods consumed and caries, chipping, or calculus, given that classical medicine was predicated on the imbalance of bodily humours rather than on germ theory.

In order to look more closely at ancient diets and the variation in them both by population and by individual, we can employ stable light isotope analysis of bones and diet-linked pathologies in teeth. The goal of this case study is to investigate correlations between conditions such as carious lesions, dental calculus, and dental chipping and the variations in isotopically understood diets, with the aim of discovering whether patterns in the data can speak to individual level variations in consumption of foods and use of organic materials in oral healthcare.

MATERIALS AND METHODS

Materials for this study come from three Imperial-era cemeteries outside the city walls of Rome (Figure 12.1). Earliest in time is Castellaccio Europarco, a burial area situated along the ancient via Laurentina about 12 km south of Rome, dating to the first to second centuries AD (Buccellato 2007; Buccellato et al. 2008; Grandi and Pantano 2007). This is a suburban cemetery, likely associated with a nearby villa and its agricultural fields. The second cemetery is Casal Bertone, located about 2 km east of the city walls in the modern Roman neighborhood of the same name. It consists of a mausoleum dating to the second to third centuries AD and a slightly older necropolis with simple burials (Musco et al. 2008; Nanni and Maffei 2004). The third cemetery is associated with the city of Gabii, about 12 km east of Rome along the via Praenestina.

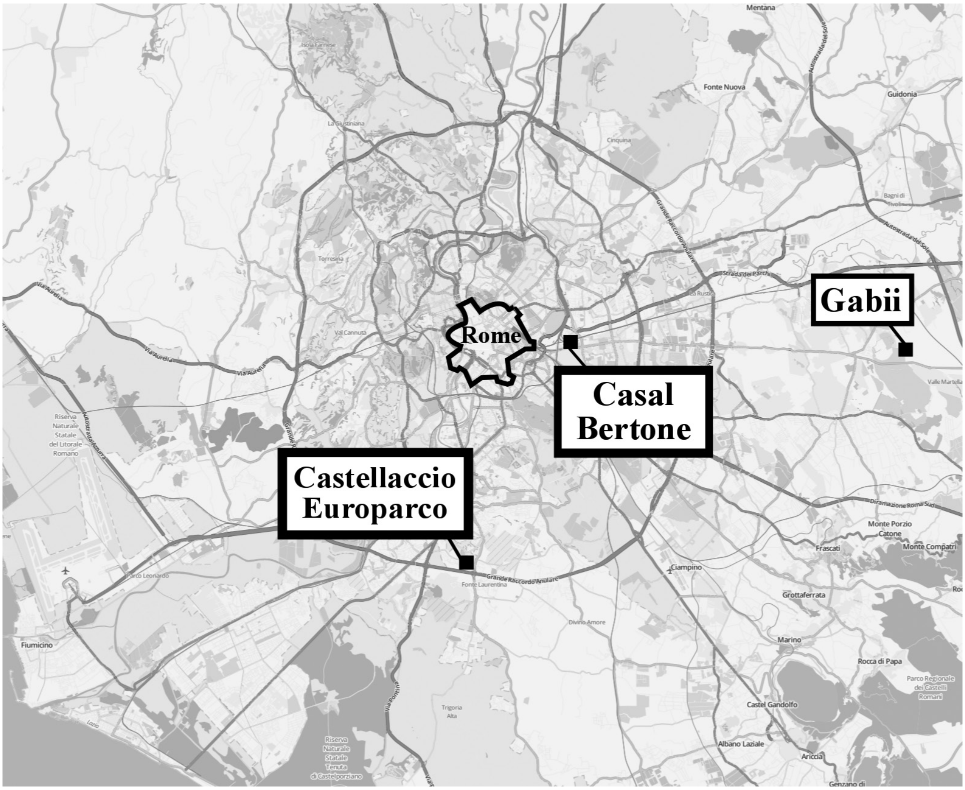

Figure 12.1. Rome-area sites used in this case study (created by Kristina Killgrove using base map tiles © OpenStreetMap.org contributors, available for use under the open database license CC BY-SA 2.0 https://www.openstreetmap.org/copyright).

Technically, Gabii was a separate city from Rome, although they urbanized in parallel in the early first millennium BC (Becker et al. 2009; Mogetta and Becker 2014). As Rome rose to become the capital of an empire, Gabii collapsed and was abandoned. The first Imperial burial at Gabii at the end of the first century AD marks the city's transition from one of the living to one of the dead, but burials were made well into the fourth century AD. Research at this site is ongoing, and precise phasing of the burials is still being worked out.

Approximately 200 skeletons were found from these three sites combined; however, not all of them could be tested for paleodietary isotopes, so a representative cross section of the adult population was selected (Killgrove 2010, 2021; Killgrove and Tykot 2013, 2018). In total, 7 adults from Castellaccio Europarco, 23 from Casal Bertone, and 18 from Gabii had their carbon and nitrogen isotopes measured from bone samples (Killgrove and Tykot 2013, 2018) and their dental pathologies recorded (Killgrove 2010, 2015).

As covered in more depth elsewhere in this volume (see Dent and Hutchinson), bioarchaeological analyses of paleodiet use carbon and nitrogen isotopes obtained from the collagen and/or apatite portion of bones and teeth. In these analyses, nitrogen isotopes provide information about proteins consumed in the diet, with nitrogen values increasing with higher trophic levels or position on the food chain. Carbon isotopes from collagen also speak to dietary protein, while those from bone or tooth apatite reveal more about carbohydrates and lipids. Essentially, higher carbon isotope values measured from bone collagen are related to diets higher in tropical C_4 grasses such as millet, a grain commonly grown and consumed in Italy, while low carbon isotope values are more aligned with temperate C_3 grasses such as wheat and barley. Together, carbon and nitrogen isotope analyses allow researchers to understand the protein and energy sources in the ancient Roman diet (Hedges and Reynard 2007; Katzenberg 2008; Kellner and Schoeninger 2007; Krueger and Sullivan 1984; Larsen et al. 1992; Schoeninger and DeNiro 1984; Schoeninger et al. 1983).

Given what we know from historical and archaeological records about the Roman diet, we would expect to see low carbon isotope values from consumption of a vegetarian and wheat-based diet, as well as low- to mid-range nitrogen isotope values from consumption of terrestrial meat and pulses. Figure 12.2 plots the available paleodietary data from the three cemeteries. The carbon axis reveals little variation—save a couple extreme outliers, people were eating mostly C_3 plants. Barley was considered more of a Greek food by this point in the Empire (Wilkins et al. 1995), so wheat is the most likely explanation for this signature, as it was being imported to Rome from various locales (Garnsey and Rathbone 1985). The nitrogen axis, however,

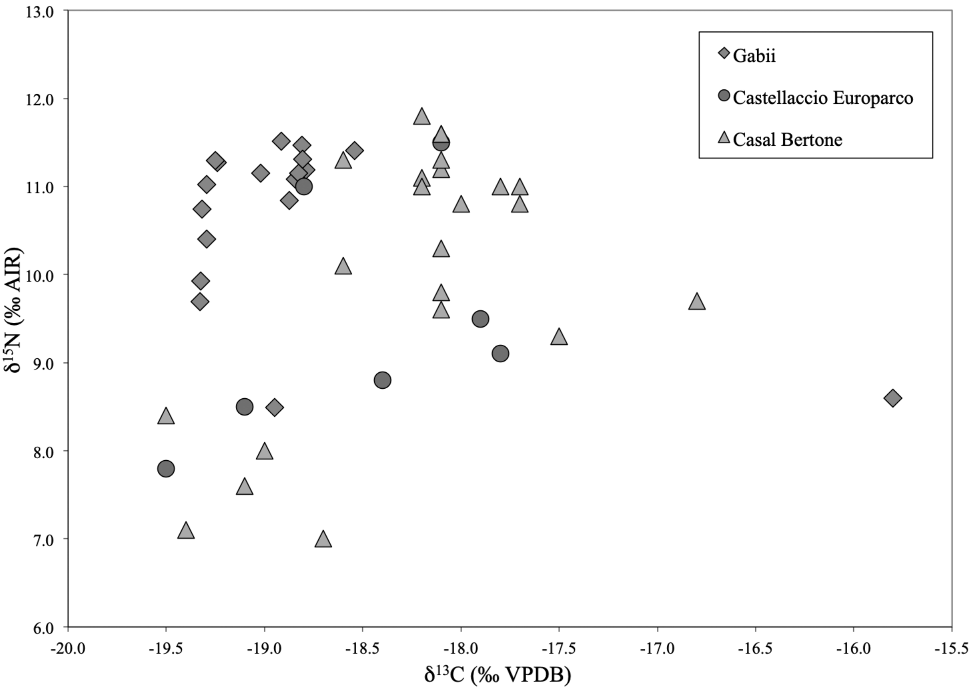

Figure 12.2. Imperial isotope values from three Rome-area sites (created by Kristina Killgrove with data from Killgrove and Tykot 2013, 2018).

shows more clear variation. Romans on the low end of the nitrogen scale appear to have been eating a more vegetarian diet, while others were consuming more terrestrial meat protein, and still others likely had input from marine resources. What becomes clear in Figure 12.2 is that, in spite of the same general time frame, these Roman adults were not eating the same thing. Unfortunately, teasing out the root of the variability is complicated.

In order to take a higher-resolution view of Roman diet, we employ dental pathology data, gathered using standard data collection protocols (Buikstra and Ubelaker 1994) as a potential method of providing more information about dietary variation among individuals. Dental pathology frequencies have been used by bioarchaeologists as a proxy for ancient diet, and we propose to test three hypotheses about the correlation between paleodietary data and pathology frequencies.

Hypothesis 1—Higher frequencies of carious lesions are typically seen in agricultural populations compared with horticulturalists or foragers (Larsen 2015; Turner 1979). In the ancient Americas, high frequencies of carious lesions are traditionally linked to a rise in the consumption of cariogenic maize (*Zea mays*), while in Europe, sticky fruits, honey, and porridge can be to blame (Larsen 2015). However, it is unclear whether a wheat- or rice-based (*Oryza* spp.) diet results in dental caries (Tayles et al. 2000). Nonetheless, because of an assumed trend toward increasing frequencies of carious lesions with intensive agricultural development, we hypothesize that individuals with more positive carbon isotope signatures from greater consumption of millet will have higher frequencies of dental caries.

Hypothesis 2—There is also a posited relationship between high frequencies of dental calculus and high protein consumption (Hillson 1979; Lillie 1996; Powell 1985), as the latter increases the alkalinity of the oral environment and encourages precipitation of minerals. Although the exact mechanisms behind formation of dental calculus are not fully known, it appears to be affected largely by diet in addition to cultural factors (Lieverse 1999). Given the assumption that dental plaque is positively correlated with consumption of a high-protein diet, individuals with higher nitrogen isotope signatures are hypothesized to have higher frequencies of dental calculus.

Hypothesis 3—Finally, dental chipping has also been assumed to be a predictor of diet, albeit a weak one (e.g., Turner and Cadien 1969), as individuals who are consuming hard, shell-covered species or foods with bone or grit in them are more likely to chip their teeth. Even more so than with caries and calculus, chipping could have a number of cultural and extramasticatory causes, and it can also predispose an individual to other oral pathologies. However, it is worth looking into any correlation between high frequencies of dental chipping and high nitrogen signatures indicative of marine resource consumption.

In order to investigate correlations between dietary isotopes and dental pathology data, we calculated the true prevalence rate (TPR) of the latter by counting the number of teeth exhibiting a particular pathological condition and dividing that number by the total teeth examined. Using Mann-Whitney U and Pearson's r, we explored statistical patterns and graphed the data to tease out any potential correlations at the individual level.

This method has been previously used by one of the authors (Acosta 2017) to see correlations between diet and pathology in skeletons dating to the Archaic period (sixth to fifth centuries BC) of Gabii. Acosta found a surprisingly low frequency of dental caries in this small population (TPR 0.5%), a normal frequency of calculus for a Roman population (56.9%), and a relatively low frequency of dental chipping (15.4%). Combining these pathology frequencies with isotope values established some potential dietary correlations. Low nitrogen values statistically correlated with low chipping frequencies, and high nitrogen values statistically correlated with higher calculus frequencies in the Archaic Gabine population. Lower carbon isotope values, however, were found to be weakly correlated with higher caries frequencies. Acosta's (2017) study involved a population that was found to be relatively homogeneous in diet in comparison with studies based on Imperial-era populations in Rome (e.g., Killgrove and Tykot 2013, 2018; Prowse et al. 2004, 2005; Rutgers et al. 2009). As Acosta's (2017) study appears to have elucidated dietary trends in a small population, revealing an interesting dietary shift, it is worth applying the same methodology to the later, more complex dietary environment of the Imperial period in order to further interrogate hypotheses about diet-pathology correlations.

RESULTS

Interpopulation Comparisons

The carbon and nitrogen isotope means for each of the three populations sampled are presented in Table 12.1. Although the carbon average is similar across sites, there is a statistically significant pairwise difference between Gabii and the other two sites, suggesting a diet more reliant on wheat at Gabii (Gabii to Casal Bertone, Mann-Whitney U = 79.0, $p < 0.001$; Gabii to Castellaccio Europarco U = 37.5, $p = 0.05$). Nitrogen isotope means appear to increase over time; however, they were not statistically different using a Mann-Whitney U comparison.

Fisher's exact test was used to compare the pairwise frequencies of dental pathologies (Table 12.2). No significant differences were found in caries among the three sites (Castellaccio to Casal Bertone, $p = 0.43$; Casal Bertone to Gabii, $p = 0.38$; Gabii to Castellaccio, $p = 1.00$), pointing to a similar level of oral hygiene and/or diet across these Imperial populations. Calculus frequencies, however, were significantly different in all comparisons, with p values < 0.001 in all cases. Gabii has the highest nitrogen values and calculus frequencies, suggesting a potential correlation between the two. Finally, chipping frequencies were significantly different between Castellaccio and Casal Bertone ($p = 0.017$) and between Casal Bertone and Gabii ($p < 0.001$), but not between Gabii and Castellaccio ($p = 0.228$). Casal Bertone has the highest frequency of this dental issue, but a nitrogen average in between the other two sites. Given these broad differences in diet and significant differences in pairwise comparisons in both isotopes and dental pathologies, the potential correlation between stable isotope values and dental pathology frequencies was explored further.

Table 12.1. Stable isotope means from sampled populations

Site	$\delta^{13}C$ mean	$\delta^{15}N$ mean
Castellaccio Europarco	–18.5‰	9.5‰
Casal Bertone	–18.3‰	10.1‰
Gabii	–18.8‰	10.7‰

Table 12.2. Frequencies and TPR for dental pathologies at Rome-era sites

Site	Caries	Calculus	Chipping
Castellaccio Europarco	18/211 (8.5%)	106/211 (50.2%)	35/211 (16.6%)
Casal Bertone	38/559 (6.8%)	207/559 (37%)	163/559 (29.2%)
Gabii	33/391 (8.4%)	266/391 (68%)	60/391 (15.3%)

Hypothesis 1—Carbon and Caries

While bioarchaeological investigation in the Americas has demonstrated a clear positive relationship between carbon isotope values and frequency of dental caries with intensification of maize agriculture, the same relationship is not necessarily expected in Eurasia, where domestication of rice did not lead to an increase in dental caries (Tayles et al. 2000). Wheat is difficult to generalize, but a diet high in cooked wheat products, particularly with the addition of sugar, has been seen as correlated with high caries frequencies (Firestone et al. 1982; Lingström et al. 2000; Temple and Larsen 2007). Therefore, a diet based largely on wheat bread and porridge such as the Roman one could be expected to correlate with a high frequency of dental caries.

To examine this hypothesis, we produced a scatter plot of the carbon isotope data versus caries frequency (Figure 12.3), and removed from the chart any individual with zero caries. Little patterning can be seen in this graph, and the strength of the correlation (R^2) is only very slightly positive (0.00933). That is, individuals with higher carbon isotope values had very slightly more carious lesions, but not in any statistically meaningful way.

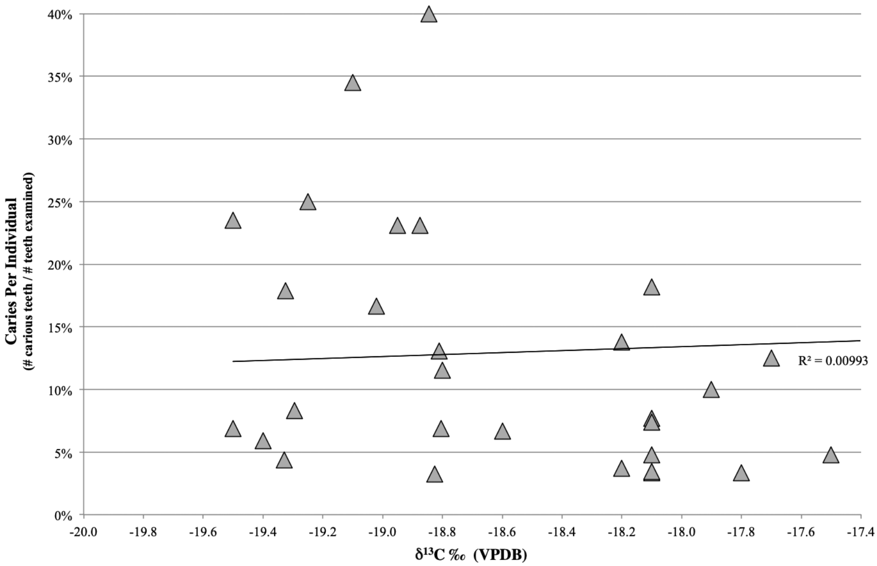

Figure 12.3. Dental caries frequencies versus $\delta^{13}C$ values (created by Kristina Killgrove with data from Killgrove 2015; Killgrove and Tykot 2013, 2018).

Hypothesis 2—Nitrogen and Dental Plaque

As the presence of dental plaque is often positively correlated with the consumption of high-protein foods, it is worth investigating whether that relationship holds between the isotope and calculus data from Imperial Rome. Figure 12.4 presents a scatterplot of individual nitrogen values plotted by frequency of calculus on the teeth that could be examined. Once again, we removed from the chart any individual with zero evidence of calculus.

Those Romans with high numbers of calculus-covered teeth do appear to be in the upper end of the nitrogen range, while those at the bottom of the nitrogen range have less severe calculus. The coefficient of determination here is indeed positive ($R^2 = 0.03906$), but a Pearson correlation was positive but not significant ($r = 0.181$, $p = 0.219$).

Hypothesis 3—Nitrogen and Dental Chipping

Finally, as chipping can be seen as a proxy for a diet that contains high amounts of shellfish such as oysters (which the Romans were fond of) or bits of animal bone, we investigated whether a positive relationship existed between high nitrogen values and high frequencies of dental chipping. Figure 12.5 shows these data.

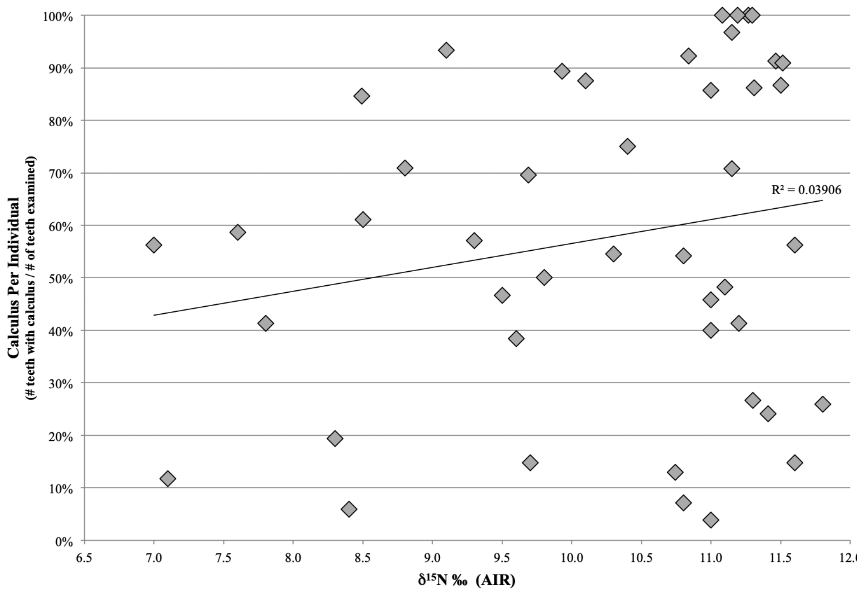

Figure 12.4. Calculus frequencies versus $\delta^{15}N$ values (created by Kristina Killgrove with data from Killgrove 2015; Killgrove and Tykot 2013, 2018).

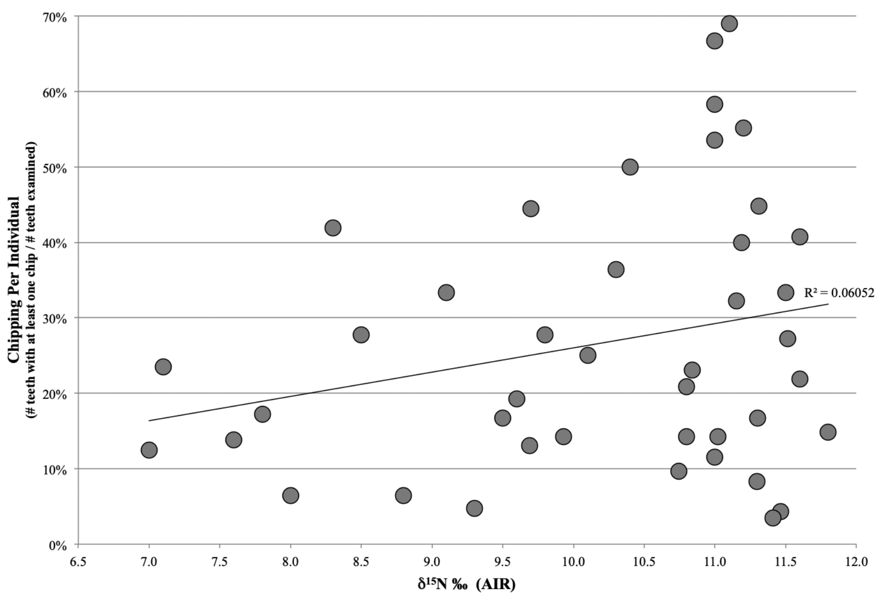

Figure 12.5. Chipping frequencies versus $\delta^{15}N$ values (created by Kristina Killgrove with data from Killgrove 2015; Killgrove and Tykot 2013, 2018).

Those Romans with high frequencies of chipping are indeed in the upper range of nitrogen isotopes, with a regression line demonstrating the positive relationship. The Pearson correlation for this relationship, while positive ($r = 0.253$), was also not quite significant ($p = 0.083$).

DISCUSSION

In looking at dietary pathology data and dietary isotope data, there are correlations between the two data sets, but no strong statistical significance at the level of individuals that could confirm our hypotheses. There are three major complicating factors, however. First, the sample size of this study is quite small and is limited by the number of individuals for whom both bones to sample for isotopes and dental pathology data were available. Second, dental pathology and stable isotopes, while both estimating diet at the individual level, record different information. Stable isotopes from bone collagen reflect an individual's diet over the last roughly decade of life (Larsen 2015), while dental pathologies can be cumulative over the individual's entire life. Third, although dental pathologies are used as general proxies for diet, there is no clear association between the two data sets, both of which can be affected by variations in cultural practice such as hygiene, and in class-based access to food and medical resources.

Although correlations between oral health and individual diets could not be identified by the presented method, circling back to the populations can be instructive, to tease out information about overall diet in these larger samples. Imperial Gabii has higher frequencies of dental calculus than the other two sites. This falls in line with what is expected from the nitrogen isotopes, which are higher on average at Gabii and support an interpretation of widespread consumption of seafood, freshwater fish, or other marine resources. As Gabii was located between several freshwater lakes, this population may have had the easiest access to those resources.

Casal Bertone, on the other hand, has the highest average carbon isotope values, as well as the lowest frequency of carious lesions. This result could be a counterexample of a pattern in which individuals consuming low-carbon or C_3 resources—such as boiled wheat porridge—have higher frequencies of carious lesions compared with those consuming more C_4 foods such as millet or a more varied vegetarian diet. The highest frequency of dental chipping, however, was at Casal Bertone, not at Gabii, the site with the highest average nitrogen values. This finding suggests that chipping was not produced solely from consumption of shellfish resources, and could have come from inclusions of grit in grain or extramasticatory uses of the teeth, to name just two alternative explanations.

CONCLUSIONS

The nature of the Imperial Roman diet is, at this point, well supported by historical records, archaeological evidence, and biochemistry of skeletons. All these lines of evidence provide a glimpse into a population-level diet that was likely mostly vegetarian, reliant on bread produced from wheat and with protein coming from poultry, eggs, and pork. The challenge in Roman dietary studies, then, is to work out the patterns in the evidence to arrive at a better understanding of dietary variation and its link to the dynamics of life course and social status. While patterns in diet related to age, sex, migration status, and religion have been found in a variety of studies (e.g., Craig et al. 2009; Killgrove and Montgomery 2016; Killgrove and Tykot 2013, 2018; Prowse et al. 2004, 2005; Rutgers et al. 2009), it is also clear that individual-level differences, such as occupation, subscription to Galenic medicine, or inherited disease (Scorrano et al. 2014), have to be factored into dietary variation in Imperial Rome. More importantly, thanks to copious information about this culture and period in history, we are at a point where we can potentially deal with intersectionality in diets: what would a middle-aged Roman soldier be eating, or a Vestal Virgin, or an immigrant child? Stable isotope results alone are clearly insufficient to capture the range of variation in this most important of social symbols: food.

Although it is easy to say that more disparate lines of data need to be synthesized to tackle this problem, the fact remains that few Roman bioarchaeological studies report frequency data, and essentially none make available the raw data (Killgrove 2015, 2017, 2018). The focus on population-level percentages does a disservice to our understanding of variation not only in diet, but also in all aspects of ancient Roman life. A second complicating factor is lack of tight chronological control over samples. In this study, all three cemeteries date to the Imperial period, but diet almost certainly changed over those four centuries as Rome became more politically complex and then wavered toward collapse.

Future research in this realm, particularly on temporally controlled samples, would be useful. For example, the authors recently collected dental pathology data from a population that perished at Oplontis outside of Pompeii in AD 79. Given the known date-of-death of all individuals, a stable carbon and nitrogen isotope analysis combined with dental and skeletal pathologies (in addition to planned analyses of DNA and Sr/O isotopes) should provide deeper insight into both the Roman diet and its variation. Finally, it is important to work backward in time, into other periods of Roman history, to learn more about the evolution of the Roman diet. As the Empire represents the apex of sociopolitical—and, presumably, dietary—complexity in ancient

Europe, stepping back to investigate earlier dietary traditions, as Acosta (2017) and Acosta and colleagues (2019) have done at proto-urban Gabii, is increasingly important.

We remain optimistic that, even though this analysis did not reveal statistically significant results in the correlation of dental pathologies and isotope values, new technological advances and theoretically informed mathematical models will someday allow us to fully understand the Roman diet *ab ovo usque ad mala* or, as Horace was fond of saying (*Satire 1.3*), from egg to apples.

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