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EXPLORING THE DIETARY PROCLIVITIES OF NEANDERTHALS USING
DENTAL MICROWEAR

By

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An Honors Thesis submitted for Partial Fulfillment of the Requirements for the
Research with

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TITLE: Exploring the Dietary Proclivities of Neanderthals Using Dental Microwear

Abstract

DIAZ-VILLAQUIRAN, Laura (Georgia State University). *Exploring the Dietary Proclivities of Neanderthals Using Dental Microwear*. Neanderthal fossil molars are found at several sites in Western Europe, including the caves of Hortus, Spy and La Quina. The remains from Hortus cave (n = 7) are particularly well represented archaeologically and all but one individual is associated with a specific phase of the deposit. In order to position unknown individual Hortus VI within a dietary context, microwear analysis was performed on epoxy resin molar casts from Hortus cave (n=7), La Quina (n=1), Spy cave (n=1), Hastière Caverne M and Hastière Trou Garçon C (n=8). The data obtained from Hastière Caverne M and Hastière Trou Garçon C, *Homo sapiens*, was included for comparative purposes and used to conduct a measurement error study in SPSS; which found no statistically significant error. Furthermore, the results of this study point towards age differentiation in the microwear signatures of Neanderthals, microwear signatures which may be reflective of age-related wear and paramasticatory cultural behavior or tool-like use of the dentition.

Keywords: *H. neanderthalensis*, dental microwear

Introduction

Exploring the dietary proclivities of *H. neanderthalensis* requires that we review and integrate the existing literature pertaining to Neanderthal diet, which indicates that Neanderthals had a much more heterogenous diet than previously thought (Naito et al. 2016, Power et al. 2018, Hardy 2010). In the past, Neanderthals were perceived to have been top carnivores, relying exclusively on heavy meat consumption. Hunting large game would constitute the bulk of their daily dietary requirements (Cartmill and Smith 2009). These dietary reconstructions were partially the result of outdated notions associated with prehistoric peoples. As noted by Sterling, “knowledge production in prehistory is impacted by racism, sexism and other forms of oppression” (Sterling 2015: 102). What has been imagined to be primitive has often been conflated with racist tropes and heterosexist assumptions about the past (Sterling 2015). This is evidenced in the cultural evolutionary model which perceived that racialized subjects reflected

past stages in human evolutionary history (Trigger 2006). Other constraints to our understanding of Neanderthal diet are the result of unknown provenience, poor preservation, and the lack of available technologies to analyze the existing remains of Neanderthals. Technologies such as nitrogen isotopic studies are now available and have provided more insight to the degree of plant foods consumed by Neanderthals (Naito et al. 2016). Counterpoints to the wolfish diet are based on analogies regarding the limitations of protein intake in anatomically modern humans (AMH), as too much protein consumption is toxic metabolically, Hockett's (2012) studies make use of an energetics analogy with pregnant *H. sapiens*, suggesting that peri-natal survival in *H. neanderthalensis* would have necessitated plant food consumption. More recent evidence of Paleolithic ethnobotanical samples points to the variability of available food sources, which are largely affected by climatic fluctuation (Hardy 2010). Additionally, material evidence of plant food preparation has been found archaeologically. Plant food consumption has been identified through the analysis of dental calculus of *H. neanderthalensis* dentition. Dental macrowear and microwear studies have yielded evidence of the mechanical wear patterns associated with chewing a more heterogeneous diet, as well as the use of the mouth as a "third hand" (Fiorenza et al. 2019: 175), identified as a paramasticatory cultural practice associated with Neanderthal subsistence strategies.

Climate

Fossil evidence of Neanderthal skeletal remains is widespread in the Northern Eurasia. Material evidence of Neanderthal occupation and has been found at sites throughout Europe and Siberia (Cartmill and Smith 2009). The dates associated with Neanderthal site occupations range from 200 Kya to 30 Kya (Cartmill and Smith 2009). Neanderthals in Europe lived in various

ecosystems, which experienced fluctuating temperature changes during this long-time span. Neanderthals lived in cold tundra biomes, steppe regions, and in regions warm or warmer than today, as is the case with the temperatures associated with Marine Isotope Stage (MIS) 5e, which occurred during 132-115 kya (Hardy 2010). Neanderthals living in the Mediterranean may have experienced similar environmental and climatic phases to the Columbia Plateau (Hardy 2010).

Climate has an important effect on diet, as it directly affects the amount of food available, meat or otherwise. Seasonal changes produce variation in terms of the foods that become abundant or restricted. Available foods are restricted by latitudinal and ecogeographical regions. Additionally, food shortages can directly influence the subsistence strategies of human populations (Hockett 2012). Some researchers have linked the disappearance of Neanderthals to a restricted dietary range, “giving them a disadvantage against Upper Paleolithic peoples” (Power 2018: 27).

Paleoecology

Faunal remains from Neanderthal sites have been associated with large and small fauna. In southwestern France and northern Spain, faunal remains of bison, rhino, horse and elephant have been found, as well as medium-sized chamois, red deer, and ibex (Hardy 2010).

Nitrogen isotope studies from the bone collagen of three individuals from Spy Cave, Belgium (Spy I, Spy II) have yielded values indicating that these individuals relied heavily on the consumption of large herbivore meat (Naito et al. 2016). Spy Cave Neanderthals consumed, reindeer, elk, horses, rhinoceros, and mammoths (Naito et al. 2016).

Zooarchaeological evidence of small fauna is present in Southern Iberia and Western Italy (Power 2018). Zooarchaeological remains of tortoise and shellfish have been found at the sites of Kamalakia (Greece), Grotta dei Morcerini (Italy), Nahal Meged (Israel), Bolomor and Bajondillo Cave (Spain) (Power 2018). There is widespread evidence of the animal food sources available to Neanderthals, this discussion section will focus more specifically on the Hortus collection (See, Table 2).

Paleoethnobotany

Many edible root plant species are cold-tolerant and have wide geographic ranges. Climate modeling by Hardy examined the potential biome distribution of edible plant roots during the last interglacial (OIS5e), “OIS3(c 36-39 kya), and the last glacial maximum (c21 kya)” (Hardy 2010: 672). Hardy (2010) proposed that some of the following wild plants may have been available food sources in Pleistocene Europe: *Daucus carota* (wild carrot), *Pastinica sativa* (wild parsnip), *Artium lappa* (greater burdock), *Typha latifolia* (cattail), *Erythronium dens-canis* (dog tooth’s violet), *Polygonum bistorta* (mountain bistort), *Sagittaria sagittifolia* (arrow head), and *Polygonum viviparum* (alpine bistort).

The microfossil extraction from dental calculus of an adult Neanderthal from the site of El Sidrón, Spain, has yielded microscopic remains of plants with known medicinal compounds. Hardy et al. (2012) identified comalin and azulene derivatives associated with chamomile and yarrow. The dental calculus samples from several individuals at El Sidrón contained the combustion markers fluoranthene, Pyrene, fluorene, and phenanthrene (Hardy 2010), indicating that Neanderthals at this site were inhaling smoke from fire and potentially roasting their food.

Plant residues and food processing

Plant residue analysis has found non-diagnostic residues on stone tools from Crimea, Buran Kaya III, Starosele, and La Quina (Hardy 2010). Stone tools from these sites yielded evidence of starchy storage organs. At the site of Königsau, Germany; there is evidence of Neanderthal production of pitch, a waterproofing material obtained from plant resin (Hardy 2010). This plant pitch has also been identified on stone tools from Central Italy's Miel Pleistocene deposits. Additional evidence of Neanderthal food processing tools is present at the sites of Moldova I and V, where grinding stones have been identified (Hardy 2010), as well as in Salzgitter-Lebenstadt where modified mammoth ribs were presumably used as bark peelers (Hardy 2010).

Protein ceiling analogy

In "*Climatic variability and plant food distribution in Pleistocene Europe: Implications for Neanderthal diet and subsistence*," Hardy describes the potentially harmful effects that a diet exclusively reliant on meat consumption can have on AMH; some of these effects are the following: hyperammonemia, fat starvation, hepatic urea synthesis, calculuria, and scurvy (Hardy 2010). Interestingly, the toxic properties of protein over-consumption can be counteracted through the consumption of fruits, lean meat proteins, and underground storage organs (USOs). Lean meat protein, often associated with wild game, is a good source of micronutrients such as Vitamin B12, docosahexanoic acid (DHA) and eicosapentanoic acid (EPA) (Hardy 2010); However, lean meat is not a good source of fat and fiber.

Underground storage organs are rich sources of complex carbohydrates, fiber, calcium, and vitamin C. Many USOs contain toxic cyanogenic compounds which can be lethal in high doses (Hardy 2010). However, these cyanogenic compounds can be endogenically eliminated

through food processing such as peeling and cooking. The detoxification of cyanogenic compounds from the body can also be achieved with heavy meat consumption. Consuming USOs can be advantageous during times of food shortage, such as in the winter when consuming wild game depleted of fat storages could lead to fat starvation. USOs are excellent sources of energy and are largely available year-round (Hardy 2010).

Hardy (2010) emphasizes that the survival of *H. neanderthalensis* would have depended on a diet which would include USOs, fruits, and animal proteins. Although, it is important to highlight that consumption of USOs is not novel in human evolution and has been associated with our early human ancestors such as *Australopithecus* (Cartmill and Smith 2009).

Energetics

Hockett's (2012) energetic requirements model can be used to investigate the role that protein poisoning may have played in the morbidity of pregnant and lactating Neanderthals. Hockett suggests that the survival of pregnant *H. neanderthalensis* would have necessitated dietary variation and plant food consumption. An energetics model estimates that the daily calories needed by a pregnant *H. neanderthalensis* would have been 5,500 calories. According to Hockett's calculations, a diet exclusively or primarily dependent on meat consumption would have resulted in peri-natal death (Hockett 2012).

Hockett (2012) notes that the over-consumption or underconsumption of micronutrients could have played a significant role on the reproductive success of Neanderthals. Micronutrients such as folate, which are essential to the reproductive success of modern humans, would have had to be obtained by *H. neanderthalensis* through the consumption of a diverse diet. Plant foods such as fruits, nuts and leafy greens contain a wider array of nutrients than those present in terrestrial

animal proteins (Hockett 2012). Hockett (2012) also argues that paleoanthropologists may be underestimating Neanderthal consumption of insects, eggs, birds, fish and shellfish as dietary sources of essential nutrients. Overall, pre-natal, peri-natal and post-natal nutrition can significantly influence fertility rates, the ability to carry a pregnancy to term, the cognitive and physical development of the fetus, as well as the degree of post-partum recovery experienced by the mother.

Nitrogen isotope studies

Naito et al. (2016) found that the diet of individual Neanderthals from Spy I and II was rather heterogeneous. Their analysis of nitrogen isotopes in the bone collagen of three Neanderthal individuals indicates that ~20% of their overall diet was composed of plant sources (Naito et al. 2016). Furthermore, the trophic position estimates of Spy Neanderthals show that they fall into a range between 2.7-2.8. When this value is compared to that of other animals, such as herbivores which fall into a TP of 2, or wolves, which have been estimated to have a TP of 2.9, and hyenas, who have a TP ranging between 3.4-3.8 (Naito et al. 2016), then it is clear that Neanderthals have a diet that clusters much more positively toward top carnivores than true herbivores. An interesting finding of Naito et al. (2016) indicates that there are higher values associated with the $\delta^{15}N$ of carnivore deciduous teeth, likely resulting from a dietary signature associated with breastfeeding. Naito et al. (2016) conclude that the Spy Neanderthal diet must have included both animal protein as well as plant sources and was variable between individuals. A diet solely based on protein would have been toxic and would have driven Neanderthals to a physiological limit (Naito et al. 2016).

Dental calculus

Dental calculus studies provide evidence of the foods that were being consumed by Neanderthal individuals and groups. Evidence of known macro botanical plant remains associated with Neanderthals have been found at the archaeological sites of Douara Cave, Vanguard Cave, Gorham, Kebara Cave and other sites in Israel (Power et al. 2018).

Power et al. (2018) found a large amount of microremains in the dental calculus of Neanderthal individuals from Vindja, an archaeological site in what is now Croatia. The dentition of Vindja Neanderthals contained starches of Triticeae grass seeds, as well as two starches associated with legumes, and three starches morphologically associated with hard seeds and nuts. Some non-diagnostic microremains found in the Vindja samples represent different fungi spores. The analysis of Neanderthal dentition from Grotta Guatari and Grotta Fossellone (Italy) yielded a multicellular phytolith indicating the presence of “dicot leafy [...] fruit matter” (Power et al. 2018: 35). Fourteen plant tissue fragments were present in the dental calculus samples. These fragments included plant “vascular bundles, reflecting plants that entered the mouth” (Power et al. 2018: 37). Additionally, samples from both sites yielded evidence of fungi associated with edible species: the diagnostic spores found are associated with fusiform boletoid fungi (Power et al. 2018).

Macrowear

Neanderthal macrowear patterns typically indicate a greater degree of anterior tooth wear localized on the incisal surface of incisors and canines ($C_1 - C_1$) (see fig.1). This anterior wear pattern has been linked to cultural paramasticatory uses of the dentition (Fiorenza et al. 2019), also known as “tooth-tool-use” (Fiorenza et al. 2019: 74), meaning that Neanderthals used their

teeth for non-masticatory habitual practices linked to subsistence strategies. Neanderthals used their teeth as cutting tools, as well as aides in the shaping and holding of objects.

Macrowear analysis of the mandible of a Neanderthal individual known as Regourdou 1 is an optimal example of the “tooth-tool” wear pattern associated with Neanderthals (see Fig.1) (Fiorenza et al. 2019: 74). The mandible of Regourdou 1 exhibits a right sided asymmetrical labial wear pattern indicating that the right of the mandible bore the most stress in the process of chewing. This asymmetry has also been observed in human populations, however the contrasted anterior wear pattern seen in Regourdou 1 is “ubiquitous among adult Neanderthals and other Middle Pleistocene hominins” (Fiorenza et al. 2019: 181).



Figure 1. 2-D virtual image of the mandible of Regourdou 1, exhibiting the asymmetrical labial wear pattern associated with Neanderthal paramasticatory cultural wear. Illustration by L. Fiorenza et al. (2019) in “Dental macrowear and cortical bone distribution of the Neanderthal mandible from Regourdou (Dordogne, Southwestern France)” courtesy of the *Journal of Human Evolution* (Original scale bar 10 mm).

The mandible of Regourdou 1 displayed significant observable wear on the posterior dentition and a greater degree of observable wear on the right lower P₃ (see Fig.1), however, the left lower P₃ evidenced advanced wear mesiodistally as well (see Fig.1). The right lower molars M₁-M₃ evidenced “flatter lingual facets” and a lower metaconid is observable on the right lower M₁, which exhibited the greatest observable wear out of all the posterior dentition. Microwear analysis of Regourdou 1 indicated a large proportion of “right oblique scratches” on the labial surface of the incisal dentition, further evidencing this asymmetric wear pattern (Fiorenza et al. 2019: 175)

Microwear

Dental microwear is an indirect tool for assessing dietary proclivities, and valuable for providing evidence of the mechanical properties associated with chewing. Williams et al. in press (2019) indicates that less wear is often linked to the mastication of meat, while a greater degree of textured wear occurs when grit from other foods, such as leafy greens and nuts are introduced to the occlusal dental surface. Microwear can be a helpful tool for investigating ancestral hominin lifeways as there are constraints in the available archaeological evidence of USOs, fruit remains, fungal, and aquatic food sources due to poor archaeological preservation of organic materials. Other constraints presented by the study of the archaeological record are unknown archaeological provenience, as is the case with the study of the individual Hortus VI. Thus, it is hoped that microwear analysis can assist in the investigation of the relationship between Hortus VI and the rest of the Hortus assemblage, which has known archaeological provenience.

Hypothesis

It is expected that the Hortus remains will cluster as a group but that Hortus VI will be more similar to either Hortus IV and Hortus XI (warm/wet interval) or to Hortus II, Hortus V, Hortus VIII and Hortus 42 (cold/arid interval).

Materials

Hortus

Hortus cave is dated to approximately 40,000 years ago. Some of the Neandertal remains such as Hortus IV and Hortus XI are older and come from a relatively warm and wet period during the past ice age of MIS 3 “Sub-Phase IVb and Sub-Phase Va, respectively” (Williams et al. 2018b:10), perhaps with greater plant foods available. Other Neandertals from Hortus derive from an extreme cold and arid period with fewer plant resources available (Sub-Phase Vb), including Hortus III, Hortus V, Hortus VIII and Hortus 42 (Williams et al. 2018b). Hortus VI is the only individual from this cave site without known archaeological context. Thus, it is hoped that microwear analysis will assist in the investigation of how Hortus VI compares to the rest of the Hortus assemblage, elucidating Hortus VI potential diet and life history patterns.

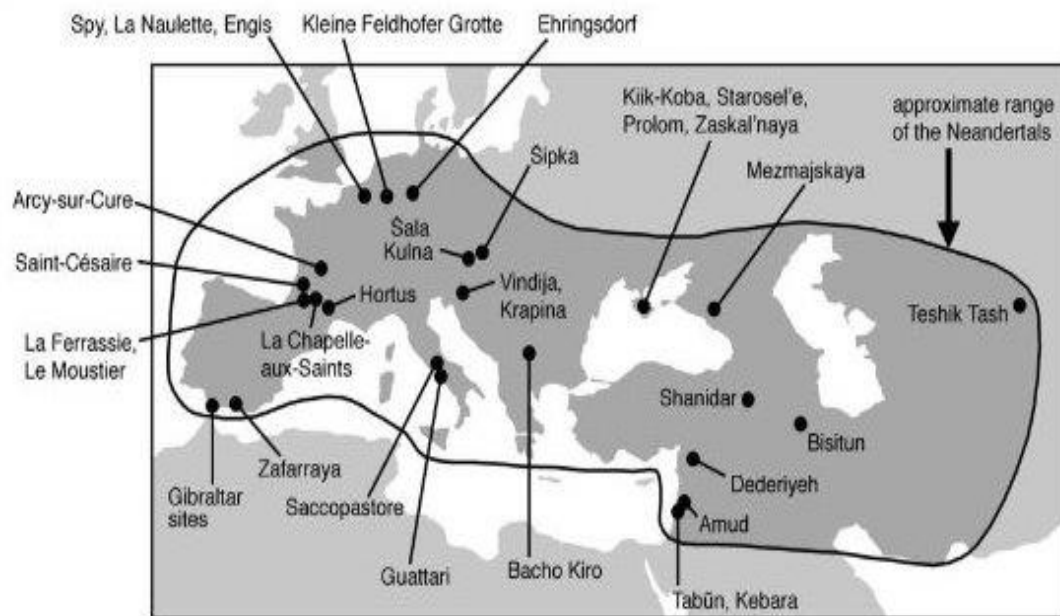


Figure 3. Locates the sites of Hortus and Spy. Illustration by Smith, H Fred. (2013) “The Fate of Neanderthals.” *Journal of Anthropological Research* 69: 167-200. Courtesy of Journal of Anthropological Research.

Spy

Spy Cave, located in Namur, Belgium (Naito et al. 2016) is one of the first documented sites where Mousterian tools and ice age fauna have been found *in situ* along with Neanderthal osteological remains (Williams in press. 2019). The Spy I individual is a late adult who lived during the Glacial Maximum MIS 3, which is recognized as one of the harshest environments in which prehistoric humans have lived (Williams in press. 2019). Spy I has been radiocarbon dated to “35, 810 + 260, -224 years BP” (Williams in press. 2019: 2).

La Quina

La Quina V is a Neanderthal individual from La Quina Cave in southwestern France, which has been dated to the MIS 3 between 47-43 kya (Williams in press 2019: 4).

Comparative material*Hastière Caverne M*

The Hastière individuals included in this study come from Hastière Caverne M, located in the Meuse River Basin, Belgium. Hastière Caverne M individuals lived during the Neolithic and are radiocarbon dated to ~4,350 years B.P. (Williams et al. 2018a). Some of the funerary caves of the Meuse River Basin dating to the Neolithic period contain evidence of funerary practices which are indicative of various behaviors such as the comingling of bones, the purposeful arrangement of bones into “elements, such as circles of crania” (Williams et al. 2018a:18), long bone bundles, the maceration of osteological remains with flint tools and the cremation of individuals. There is evidence of both collective and single burials.

Hastière Trou Garçon C

Some Neolithic individuals included in this study belong to the cave site of Hastière Trou Garçon C also located within the Meuse River Basin and radiocarbon dated to ~4,250 years B.P. (Williams, Lane, and Anderson 2017a).

Methods

Dental microwear features were observed on the enamel surface of seventeen (n=17) epoxy resin molar casts, housed at Georgia State’s Dental Microwear Lab, belonging to

Neanderthal individuals from Hortus (n=7), Spy (n=1), and La Quina (n=1). A group of individuals from Hastière Caverne M and Hastière Trou Garçon C (n=8), were included in this study for comparative purposes. The observed microwear features included small pits, large pits, puncture pits, fine scratches, coarse scratches and hyper coarse scratches (see figures 2-3). These features were identified through a 0.4 by 0.4 mm ocular reticle using an external light source at 40x. Photographs were taken on all the locations from which data was collected, using the microscopic imaging software ToupView. Microwear features were counted in two trials; counting occurred twice on the protoconid and metaconid of mandibular molars and twice on the paracone and protocone of maxillary molars, paying special attention to collect data in a separate location on the same cusp during the second trial. The two observations for each individual were averaged and subject to principal components analysis to examine how individuals were distributed across multivariate axes. A scoring error study was conducted using the data gathered from Hastière Caverne M and Trou Garçon C (n=8). Counts of microwear features occurred twice in the same location and the two trials were subject to a t-test.



Figure 4. The mandibular metaconid on the second molar (M_2) of Hortus V exhibits a well-defined coarse scratch. For reference purposes a small pit, a large pit, a puncture pit, a coarse scratch and a hyper coarse scratch are indicated. Photo by author.

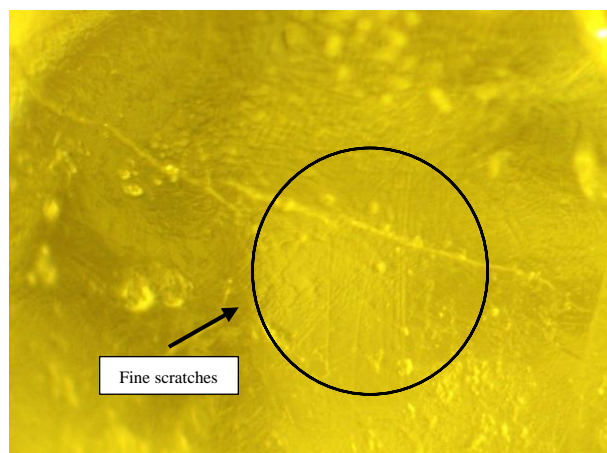


Figure 5. A cluster of well-defined fine scratches are exhibited on the right maxillary protocone of the first maxillary molar (M^1) of Hastière Caverne M 25. Photo by author.

Results

Table 1. T-test error study

Group Statistics					
	Trial	N	Mean	Std. Deviation	Std. Error Mean
SP	1.00	7	50.2857	33.73778	12.75168
	2.00	7	51.5714	30.38562	11.48468
LP	1.00	7	9.2857	3.45033	1.30410
	2.00	7	9.5714	6.13344	2.31822
PP	1.00	7	6.0000	5.13160	1.93956
	2.00	7	6.2857	3.63842	1.37519
FS	1.00	7	6.1429	4.94734	1.86992
	2.00	7	5.7143	4.38613	1.65780
CS	1.00	7	6.5714	3.45722	1.30671
	2.00	7	6.1429	2.91139	1.10040
Hyp	1.00	7	4.4286	3.20713	1.21218
	2.00	7	5.8571	3.18479	1.20374

The significant error study (see. Table 1) indicates that there is no significant difference. Meaning that none of the means are below 0.05, showing a high degree of consistency and reliability in the data.

Table 2. Independent samples t-test
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
SP	Equal variances assumed	.015	.903	-.075	12	.942	-1.28571	17.16110	-38.67654	36.10511
	Equal variances not assumed			-.075	11.871	.942	-1.28571	17.16110	-38.72168	36.15025
LP	Equal variances assumed	.368	.556	-.107	12	.916	-.28571	2.65986	-6.08104	5.50961
	Equal variances not assumed			-.107	9.452	.917	-.28571	2.65986	-6.25917	5.68774
PP	Equal variances assumed	1.615	.228	-.120	12	.906	-.28571	2.37762	-5.46610	4.89467
	Equal variances not assumed			-.120	10.816	.907	-.28571	2.37762	-5.52972	4.95829
FS	Equal variances assumed	.235	.637	.171	12	.867	.42857	2.49898	-5.01624	5.87338
	Equal variances not assumed			.171	11.830	.867	.42857	2.49898	-5.02492	5.88206
CS	Equal variances assumed	.477	.503	.251	12	.806	.42857	1.70832	-3.29354	4.15069
	Equal variances not assumed			.251	11.662	.806	.42857	1.70832	-3.30553	4.16268
Hyp	Equal variances assumed	.003	.956	-.836	12	.419	-1.42857	1.70832	-5.15069	2.29354
	Equal variances not assumed			-.836	11.999	.419	-1.42857	1.70832	-5.15071	2.29356

In the independent sample t-test (see. Table 2), the P-values range between 0.942 and 0.491. The highest P-values correspond to small pits while the lowest P-values correspond to hyper coarse scratches, suggesting that the greatest statistical reliability lies on all of the

observed features except for hyper coarse scratches. However, even here, there is no significant difference. The principal component analysis data (see. Table 3) indicates that 83% of the variance is accounted for by 3 factors. Components 1, 2, and 3 all have eigenvalues greater than one. Component 1 represents the x-axis (see. graphs 1 & 2), component 2 (REGR. factor score 2) represents the y-axis, while component 3 represents the secondary y-axis (REGR. factor score 3).

Table 3. Total Variance Explained
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.197	36.614	36.614	2.197	36.614	36.614
2	1.417	23.617	60.231	1.417	23.617	60.231
3	1.383	23.042	83.273	1.383	23.042	83.273
4	.544	9.073	92.345			
5	.335	5.577	97.923			
6	.125	2.077	100.000			

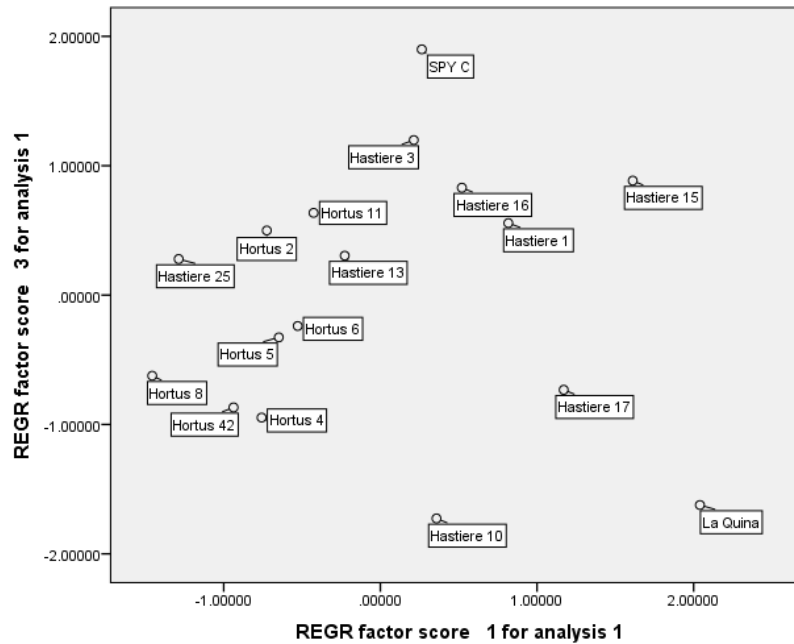
Extraction Method: Principal Component Analysis.

Table 4. Component Matrix
Component Matrix^a

	Component		
	1	2	3
SP	.751	-.333	-.489
LP	.831	-.444	.096
PP	.166	-.251	.869
FS	.149	.851	-.030
CS	.755	.415	-.233
Hyp	.569	.388	.569

Extraction Method: Principal
Component Analysis.

a. 3 components extracted.



On the secondary axis (REGR factor score 3), most of the Hortus individuals place negatively with the exception of Hortus II and XI, who respectively represent a juvenile and an elderly individual, indicating that this positive placement is separating the young and old versus the young adult individuals. This may be indicative of a life history effect on the dentition of young adult Neanderthal individuals. Younger individuals are placed more negatively (REGR factor score 3), as is the case with Hortus II, while older individuals are placed more positively, as is the case with Hortus XI and Spy I. Spy I placed on the most positive side of the y-axis. These results are consistent with the high degree of anisotropy as seen by Williams in press (2019). Table 5 represents a discriminant function analysis classification, with Neanderthals classified as 1 and Neolithics labeled as 2. Overall, the Hortus group indicates strong group membership, as most individuals were classified into group 1, with the exception of Hortus XI. Hortus XI was misclassified from its lack of fine and coarse scratches.

Table 5. Discriminant Function Analysis Classification

Individual	Original	Classified
Hortus 2	1.00	1.00
Hortus 4	1.00	1.00
Hortus 5	1.00	1.00
Hortus 6	1.00	1.00
Hortus 8	1.00	1.00
Hortus 11	1.00	2.00
Hortus 42	1.00	1.00
Spy I	1.00	2.00
La Quina V	1.00	2.00
Hastière 1	2.00	2.00
Hastière 3	2.00	2.00
Hastière 10	2.00	2.00
Hastière 13	2.00	2.00
Hastière 15	2.00	2.00
Hastière 16	2.00	2.00
Hastière 17	2.00	2.00
Hastière 25	2.00	2.00

Discussion

Heavy microwear features are separating young adults versus old and juvenile Neanderthal individuals (see. graphs 1 & 2). Coarse and fine scratches are driving young adults from Hortus onto the negative y-axis (REGR factor score 3), this directionality may be indicative of paramasticatory cultural use, as well as potential differences in dietary proclivities. Spy I anisotropy (epLsar) comparisons with Hortus by Williams in press (2019) indicated that “anisotropy [...] is low in juveniles Hortus III and older Hortus XI and highly elevated in the four young adults from different paleoecological phases of Hortus cave” (2019: 6). With respect to diet, Spy I may have had access to a greater variety of plant foods than were available to those of the Hortus assemblage (Williams et al. in press). As noted by Hardy (2010) “the dietary habits of [...] Neanderthals were highly variable and [...] they were capable of adapting and shifting dietary strategies according to [their] environmental constrains” (Hardy 2010: 664).

Table 6. Comparison of Sub-Phase IVb & Sub-Phase Vb

Phase	Climate	Paleoecology	Mousterian Tool
Sub-Phase IVb	Less cold/ very cold/ cold dry/ & cold-wet	Plants: shrubs, grasses, flowering plants, wormwood/sagebush, <i>Cichorideae</i> . Animals: <i>Canis</i> , <i>Bos</i> , <i>Capra</i> , <i>Cervus</i> , <i>Pytimys</i> , <i>Glis</i> , <i>Eliomys</i> , <i>Apodemus</i> , & <i>Olyctodagus</i> .	Mousterian (n=226) associated with Hortus IV
Sub-Phase Vb	Extremely-cold dry	Plants: <i>Anthemidae</i> , Thistle. Animals: <i>Bos</i> , <i>Ursus</i> , <i>Capra</i> , <i>Cervus</i> , <i>Rhinoceros</i> , <i>Equus</i> , <i>Microtus</i> , <i>Glis</i> , <i>Crocidura</i> , <i>Eliomys</i> , <i>Apodemus</i> , <i>Olyctodagus</i> & <i>Felis</i> .	Mousterian tool assemblage with denticulates (n=200)

Source: (Williams et al. 2018b: Table 1)

Conclusion

With respect to our hypothesis it is apparent that Hortus VI is indeed part of the Hortus group relatively distinct from La Quina V, Spy I, Hastière Caverne M and Trou Garçon C. Hastière Caverne M and Trou Garçon C are distinct from Hortus to a lesser extent. Contrary to our hypothesis, the Hortus fossils only loosely group. Additional findings indicate that Hortus II was placed on the high end of the PCA axis (see. Table 3) while young adults are clustered on the lower end. Similar, to the Fiorenza et al. (2019) findings, older individuals present a dietary signature which is indicative of an advanced degree of wear. A greater degree of textured wear may indicate differences in paramasticatory behavior related to age and cultural use of the dentition in Neanderthals. Cultural striations have been previously found in the labial surface of anterior *H. neanderthalensis* incisors (Estalrriich and Rosas 2015).

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