Chapter 18

DENTAL MICROWEAR TEXTURE ANALYSIS AND THE DIET OF THE SCLADINA I-4A NEANDERTAL CHILD

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1. Introduction

Microwear texture analysis, the objective, repeatable, and three-dimensional approach to dental microwear, has proven to be a valuable method for characterizing microwear surfaces and for distinguishing dietary and non-dietary tooth use behaviors in a wide range of extant taxa, including bovids (e.g., Ungar et al., 2007), kangaroos (Prideaux et al., 2009), carnivores (e.g., Ungar et al., 2010), non-human primates (Krueger et al., 2008; Scott et al., 2012) and Recent Modern Human groups (e.g., El Zaatari, 2014; Krueger & Ungar, 2010; Krueger, 2014). In particular, this approach can provide different information depending on the tooth type examined. When applied to the anterior dentition, it has been effective in differentiating bioarchaeological human groups based on diet, non-dietary anterior tooth use, and dietary and/or abrasive loads (Krueger & Ungar, 2010). On the other hand, when applied to their occlusal molar surfaces, microwear texture analysis has been useful in distinguishing recent human groups based on their diets and food preparation techniques (El Zaatari, 2014). The relationship between dental microwear texture signatures, diet, and behavior established among modern human populations has led to additional important insights into dietary and non-dietary tooth-use behaviors of Neandertals (Krueger, 2011; Krueger & Ungar, 2012; El Zaatari et al., 2013).

The wide-scale occlusal molar microwear texture analysis of adult Neandertal specimens from numerous western Eurasian sites has revealed that not all Neandertals are top-level carnivores (El Zaatari et al., 2011), as they had been perceived based on stable isotope analyses (e.g., Bocherens et al., 1999, 2001, 2005; Richards et al., 2000; Bocherens & Drucker, 2003; Richards & Trinkaus, 2009). Specifically, the microwear signatures of many of the Neandertals analyzed, especially those that lived in more open, cold-steppe habitats, were found to be similar to recent human populations whose diets consisted almost exclusively or primarily of meat. However, some Neandertals, specifically those that lived in wooded habitats, were found to have microwear textures similar to recent hunter-gatherer groups with a mixed diet. This indicates that, at least for some Neandertals, plant foods formed an important part of the diet (El Zaatari et al., 2011).

Moreover, the application of anterior microwear texture analysis to adult Neandertal specimens has helped better understand non-dietary anterior tooth use behaviors among these fossil hominins (Krueger, 2011; Krueger & Ungar, 2012). Previous examinations of the unusual and excessive anterior dental wear found on some noteworthy Neandertal specimens, such as La Ferrassie 1 and Spy 1, has been linked to their use of their dentition for non-dietary purposes (e.g., Stewart, 1959; Wallace, 1975; Smith, 1976; Wolpoff, 1979). These behaviors have been described in a variety of ways, with the most cited scenario proposed from ethnographic reports of Alaskan Eskimo and Canadian and Greenland Inuit, and referred to as the 'stuff and cut' method. This scenario suggested that Neandertals would clamp a piece of meat between their anterior teeth, and slice a portion off close to their lips (Brace, 1967, 1975; Ryan, 1980; Brace et al., 1981). This idea has been expanded to propose other types of non-dietary anterior tooth use behaviors, such as animal hide processing, sinew thread production, weaving tasks, wood softening, and tool production and retouching (Cybulski, 1974; Lukacs & Pastor, 1988; Foote, 1992; Mayes, 2001). The results of the microwear texture analysis of Neandertals' anterior dentition confirmed that the Neandertals did in fact use their dentition for non-dietary purposes (Krueger, 2011). Yet, this analysis also showed that the Neandertals' engagement in such behaviors was linked to climatic conditions, such that those that lived under cold, open steppe conditions were found to use their anterior dentition in non-dietary behaviors much more intensely than those in the warm, woodland climates (Krueger, 2011).

For the current study, anterior and molar microwear textures of the Scladina Neandertal were analyzed. The examination of the microwear texture signatures of the Scladina Neandertal is an interesting addition to the present dataset of adult Neandertal specimens. Not only will it provide additional insight into the dietary and behavioral strategies of Neandertals as a whole, but it will also begin to allow the examination of sub-adult Neandertal individuals.

2. Materials

Microwear data was recovered from one permanent canine (RC$_1$; Scla 4A-12) and one permanent molar (RM$_1$; Scla 4A-1/M$_1$) of the Scladina Juvenile. Since it remains unclear whether permanent and deciduous dentitions have similar levels of resistance to premortem masticatory wear, permanent rather than deciduous dentitions were selected to represent the Scladina individual for this study to allow for securely comparing its microwear data to similar data available for permanent dentitions of: 1) adult individuals belonging to six recent human groups of known or inferred diet, anterior tooth use behaviors, and abrasive loads, and 2) adult Neandertal specimens (El Zaatari, 2014; Krueger, 2014; Krueger & Ungar, 2010, 2012; El Zaatari et al., 2013).

Aleut

Study sample: The specimens were collected from the islands of Agattu, Amaknak, Kagamil, Unmak, and Unalaska, Alaska, USA (Hrdlička, 1945) and date to 3400–400 years BP (Coltrain, 2010). Anterior dental microwear data was recovered from 24 individuals and molar microwear data was recovered from 21 individuals.

Diet: The Aleutian diet consists predominantly of marine animals including sea mammals, fish, shellfish, supplemented by land resources including, foxes, birds, rodents, and tubers (Hrdlička, 1945; Laughlin, 1963; Coltrain, 2010).

Abrasive loads: The Aleut are known for their extensive chewing of frozen and dried animal meat and skin (Hoffman, 1993). Environmental abrasives, such as sand and grit, are hypothesized to have been a daily inclusion in their diet (Moorrees, 1957).

Non-dietary anterior tooth use behaviors: Ethnographically, the Aleut used their anterior dentition in non-dietary anterior tooth use behaviors, including hide production and wood softening (Hrdlička, 1945; Moorrees, 1957).

Arikara

Study sample: This sample consists of individuals from the Mobridge Site (39WWI), South Dakota, USA, and date to 400-300 years BP (Jantz, 1973). Anterior microwear data was recovered from 18 individuals and molar microwear data was recovered from 16 individuals.

Diet: The Arikara's diet had strong emphasis on big game, supplemented by a mix of wild and cultivated plant foods including peppers, pumpkins, grapes, black cherries, beans, squash, corn, and sunflowers (Hurt, 1969; Meyer, 1977; Tuross & Fogel, 1994; Blakeslee, 1994).

Abrasive loads: It has been suggested that the Arikara were subject to dietary abrasives from corn phytoliths and food processing techniques, including the use of stone mortars, as well as the frequent consumption of dried strips of game meat (Leigh, 1925; Meyer, 1977).

Non-dietary anterior tooth use behaviors: None documented.

Ipiutak

Study sample: These specimens were recovered from the site of Point Hope, Alaska, USA, and date to 2050-1450 years BP (Larsen & Rainey, 1948). Anterior microwear data was recovered from 22 individuals and molar microwear data was recovered from 17 individuals.

Diet: While inhabiting the coast during the summer months, the Ipiutak's diet was based on caribou, and sea mammals, including seals and walrus (Lester & Shapiro, 1968).

Abrasive loads: Point Hope is a coastal site, and environmental abrasives, such as sand, would have been included in the Ipiutak's diet.

Non-dietary anterior tooth use behaviors: Evidence suggests the Ipiutak used their anterior dentition in intense caribou hide preparation and processing (Krueger, 2014).

Tigara

Study sample: These specimens were recovered from the site of Point Hope, Alaska, USA, and date to 750-250 years BP (Larsen & Rainey, 1948). Anterior microwear data was recovered

Site	Specimen	Palaeovegetation Cover
Spy	I	Open (Cordy, 1988)
La Quina	5 20	Open (Bouchud, 1966; Henri-Martin, 1966)
Subalyuk	1	Open (Gross, 1956; Kordos in Schwartz & Tattersall, 2002)
Grotte de l'Hyène (Arcy-sur-Cure)	IVb6 B9	Open (Leroi-Gourhan, 1988)
Saint-Césaire	1	Mixed (Lavaud-Girard, 1993; Leroyer & Leroi-Gourhan, 1993; Marquet, 1988, 1993; Miskovsky & Lévêque, 1993; Morin, 2004; Patou-Mathis, 1993)
Vindija	11.45 11.46 12.1	Mixed (Miracle et al., 2010)
Petit-Puymoyen	2 4	Mixed (Bœuf, 1969)
Rochelot	1098	Mixed (Tournepiche & Couture, 1999)
La Chaise Bourgeois-Delaunay	8	Mixed (Fellag, 1996)
Kebara	2	Mixed (Eisenmann, 1992; Speth & Tchernov, 1998, 2001, 2002)
Tabun	II	Mixed (Jelinek et al., 1973)
Zafarraya	4	Wooded (Barroso Ruiz et al., 2006)
Grotta Breuil	2	Wooded (Kotsakis, 1990-1991; Stiner, 1994; Recchi, 1995)
El Sidrón	SDR-005	Wooded (Fortea et al., 2003)
Lakonis	LKH1	Wooded (Panagopoulou et al., 2002-2004)
Amud	I	Wooded (Rabinovich & Hovers, 2004; Kolska Horwitz & Hongo, 2006; Belmaker & Hovers, 2008)

Table 1: Neandertal specimens whose occlusal molar microwear textures were used for the comparison with those of the Sladina Child (see El Zaatari et al., 2011 for details on the specimens and the palaeovegetation cover reconstructions).

from 34 individuals and molar microwear data was recovered from 27 individuals.

Diet: The Tigara diet consisted predominantly of sea mammals, including whales, walrus, and seals, and was supplemented by fish, birds, berries, and other edible plants (Larsen & Rainey, 1948; Dabbs, 2009; Brubaker et al., 2010).

Abrasive loads: The Tigara's food preparation techniques, which included freezing meat underground as a year-round staple (de Poncins, 1941; Giddings, 1967), would have led to the inclusion of large amounts of environmental abrasives, such as sand, in their diet. Also, dried and frozen uncooked meat and skin -together with its attached subcutaneous fat- were often chewed for prolonged periods of time (Balikci, 1970).

Non-dietary anterior tooth use behaviors: Ethnographically, the Tigara used their anterior dentition in some hide processing and sinew thread production (Foote, 1992).

Fuegian

Study sample: The sample consists of specimens from the Yamana Tribe of the Beagle Channel Islands, Argentine Tierra del Fuego, extreme southern South America and date to AD 1880 (Manzi, 1986). Molar microwear data was recovered from 6 individuals.

Diet: The Fuegians relied on seals, sea lions, guanaco (*Lama guanicoe*), shellfish, fish, penguin, and waterfowl for subsistence (Bridges, 1885; Snow, 1861; Yesner et al., 2003).

Abrasive loads: None documented

Non-dietary anterior tooth use behaviors: None documented

Puye Pueblo

Study sample: This sample consists of specimens from the volcanic plateau in northcentral New Mexico, USA dating to 100–330 BP (Barnes, 1994). Anterior microwear data was recovered from 18 individuals.

Diet: The Puye Pueblo diet consisted predominantly of maize, squash, and bean agriculture, supplemented by prickly pear, yucca fruit, plums, grapes, foxes, deer, rabbits, and beeweed (Hewett, 1938; Trierweiler, 1990; Barnes, 1994).

Abrasive loads: Maize phytoliths and stone-on-stone grinding processes contributed dietary abrasives, and environmental abrasives, including dust and grit common to the open setting (Trierweiler, 1990).

Non-dietary anterior tooth use behaviors: None documented.

Neandertals

The anterior microwear textures of the Scladina Juvenile were compared to a sample of

		Asfc	*epLsar*	*Smc*	*Tfv*	*$HAsfc_9$*	*$HAsfc_{81}$*
SCLADINA NEANDERTAL		**1.22**	**0.0051**	**0.34**	**10778.82**	**0.44**	**0.97**
Aleut (*n* = 24)	**Mean**	0.93	0.0030	0.40	7434.50	0.38	0.61
	SD	0.45	0.0011	0.36	5272.19	0.07	0.12
Arikara (*n* = 18)	**Mean**	0.77	0.0036	0.38	1897.76	0.37	0.56
	SD	0.40	0.0016	0.22	2466.36	0.08	0.12
Ipiutak (*n* = 22)	**Mean**	3.43	0.0020	0.34	12143.02	0.66	1.36
	SD	3.03	0.0008	0.28	4253.49	0.31	0.80
Tigara (*n* = 34)	**Mean**	1.20	0.0032	0.35	7296.02	0.53	0.89
	SD	0.99	0.0015	0.12	5391.20	0.26	0.46
Puye Pueblo (*n* = 18)	**Mean**	1.24	0.0040	0.31	5093.03	0.48	0.75
	SD	1.01	0.0012	0.22	4183.08	0.14	0.32
Neandertals Krapina (*n* = 17)	**Mean**	1.27	0.0031	0.39	5810.11	0.42	0.68
	SD	0.45	0.0013	0.14	3620.88	0.08	0.16

Table 2: Raw data for the Scladina Neandertal anterior teeth microwear texture and summary statistics for the modern human and Neandertal comparative samples. Five texture variables were generated: complexity (*Asfc*), anisotropy (*epLsar*), scale of maximum complexity (*Smc*), textural fill volume (*Tfv*), and heterogeneity (*$HAsfc_9$* and *$HAsfc_{81}$*).

Neandertals from the site of Krapina (Krueger & Ungar, 2012). The Krapina Neandertals date to 130,000 ± 10,000, and are generally attributed to MIS 5e. If accurate, this would suggest these individuals were living in a warm, wooded climate (Rink et al., 1995; Simek & Smith, 1997; Karavanić, 2004). These Neandertals are noted for the presence of labial-lingual rounding (incisor beveling) on some specimens, and the cause of this has been suggested to be non-dietary anterior tooth use behaviors (Wolpoff, 1979). Labial striations on the incisors and anterior dental microwear analyses support this hypothesis (Lalueza-Fox & Frayer, 1997; Krueger & Ungar, 2012). Specifically, microwear textures suggest that the Krapina Neandertals were engaging in moderate non-dietary anterior tooth use behaviors that did not require a heavy anterior loading regime (Krueger & Ungar, 2012).

The molar microwear data of the Scladina Juvenile was compared to those of a total of 20 adult Neandertal individuals from 16 sites (listed in Table 1) located in different parts of Europe (southern, central, northern) as well as the Levant and dating to between MIS 6 to MIS 3 (El Zaatari et al., 2011, 2013). An analysis of the molar microwear textures of these specimens examining the effects of time, geography, and palaeoecology on their diets showed that their diets differed significantly in response to the changes in palaeoecological conditions. Indeed, the microwear textures of these Neandertals indicate that they increased their intake of plant foods with the increase in tree cover, whereas they increased their intake of meat with the spread of cold, open steppic conditions (El Zaatari et al., 2011). Thus, for the comparisons with the Scladina molar microwear texture, the Neandertal specimens were grouped into three groups based on habitat, i.e., open, mixed, and wooded habitats.

3. Methods

The microwear analyses of the Scladina teeth were conducted on high resolution dental casts. Following gentle cleaning of the dentition with cotton swabs soaked with distilled water, negative molds were first made of the Scladina teeth using Coltène President microSystemTM (*Coltène*®; polysiloxane vinyl) impression material and the positive casts were then poured using Epo-Tek 301 epoxy resin and hardener (Epoxy Technologies).

A Sensofar Plμ white-light scanning confocal microscope (Solarius Development Inc., Sunnyvale California) with a 100× objective lens was used to scan the labial surface nearest the occlusal edge of the Scladina canine and the crushing/grinding facet 9 of the molar. Point clouds were generated for a total of four adjoining scans for each surface, with a lateral sampling interval of 0.18 μm, and a total field of view of 276 × 204 μm for each tooth. Any identifiable defects, such as adhesive or dust particles were then removed and photosimulations and 3D images were generated using the Solarmap Universal software (Solarius Development Inc., Sunnyvale, CA).

The four adjoining scans of each specimen were characterized using Toothfrax and SFrax (Surfract, www.surfract.com) scale-sensitive fractal analysis (SSFA) software packages. Five texture variables

		Asfc	*epLsar*	*Smc*	*Tfv*	*$HAsfc_1$*
SCLADINA NEANDERTAL		**0.76**	**0.0014**	**1.67**	**9422.17**	**0.13**
Aleut (*n* = 21)	**Mean**	2.59	0.0028	0.45	10383.20	0.22
	SD	1.60	0.0011	0.73	5419.60	0.14
Arikara (*n* = 16)	**Mean**	1.15	0.0027	0.82	5672.80	0.20
	SD	1.09	0.0015	0.97	5997.80	0.15
Ipiutak (*n* = 17)	**Mean**	10.03	0.0019	0.18	13984.20	0.20
	SD	7.61	0.0006	0.05	3133.60	0.13
Tigara (*n* = 27)	**Mean**	6.41	0.0031	0.22	12434.10	0.29
	SD	5.62	0.0016	0.07	4946.70	0.20
Fuegians (*n* = 6)	**Mean**	0.95	0.0044	0.40	5224.80	0.11
	SD	0.29	0.0014	0.14	3522.50	0.03
Neandertals Open (*n* = 5)	**Mean**	1.08	0.0023	0.30	10770.26	0.11
	SD	0.24	0.0008	0.10	1645.88	0.09
Neandertals Mixed (*n* = 10)	**Mean**	1.54	0.0030	0.44	10935.31	0.26
	SD	0.47	0.0010	0.57	5519.59	0.14
Neandertals Wooded (*n* = 5)	**Mean**	2.87	0.0023	3.72	14560.62	0.53
	SD	0.52	0.0016	4.98	2085.99	0.44

Table 3: Raw data for the Scladina Neandertal molar microwear texture and summary statistics for the modern human and Neandertal comparative samples. Five texture variables were generated: complexity (*Asfc*), anisotropy (*epLsar*), scale of maximum complexity (*Smc*), textural fill volume (*Tfv*), and heterogeneity (*$HAsfc_1$*).

were generated: complexity (*Asfc*), anisotropy (*epLsar*), scale of maximum complexity (*Smc*), textural fill volume (*Tfv*), and heterogeneity (*HAsfc*). These variables have been discussed in detail elsewhere (see Scott et al., 2005, 2006; Ungar et al., 2007). Briefly, complexity (*Asfc*) is a measure of the change of surface roughness across different scales of observation. Anisotropy (*epLsar*) is a reflection of the concentration of wear feature orientations. Scale of maximum complexity (*Smc*) is an indicator of the size of the microwear features. Textural fill volume (*Tfv*) is a reflection of the geometrical shape and depth of wear features. Heterogeneity (*HAsfc*) reveals the variability in complexity across the surface. It should be noted that the individual heterogeneity value for the Scladina molar used in this study was calculated using the four scans for this tooth without splitting single scans into smaller sub-regions, whereas two values of heterogeneity for the Scladina canine were calculated by dividing each field of view into 3×3 ($HAsfc_9$) and 9×9 ($HAsfc_{81}$) grids. Finally, for the four scans, median values for each of the five texture variables were calculated for each tooth.

The values for the five variables for the Scladina canine were then compared to data available from maxillary central incisors of the modern comparative samples and from maxillary and mandibular incisors and canines of the Krapina Neandertals (Krueger & Ungar, 2010, 2012; Krueger, 2014). Microwear textures have been shown to not differ significantly between these tooth types and jaws (Krueger, 2011). The values for the texture variables for the Scladina molar were compared to similar data collected from molars of the modern human and Neandertal samples (El Zaatari, 2014; El Zaatari et al., 2011, 2013). The lack of significant differences in microwear patterns by molar type or position in recent hunter-gatherer groups makes it possible to include data from molars with different positions for the specimens analyzed (El Zaatari, 2010).

4. Results

Representative 2D photosimulations of the surfaces of the Scladina and the comparative groups' dentition are presented in Figures 1 & 2. Raw data for the Scladina Neandertal microwear textures, along with the summary statistics for the modern human and Neandertal comparative samples are presented in Tables 2 & 3. Results are illustrated in Figures 3 & 4.

4.1. Complexity

The Scladina canine complexity value is 1.22. It is nearly identical to, and intermediate between, the mean values for the Puye Pueblo and the Tigara modern human samples. This value also falls within the one standard deviation ranges of the means of the Ipiutak and Aleut. The complexity value of the Scladina canine is very close to the mean value of the Krapina Neandertal sample.

Figure 1: Representative 2D photosimulations of an area of 276 x 204 µm² of the anterior dentitions of: a) Scladina, b) Aleut, c) Arikara, d) Ipuitak, e) Tigara, f) Puye Pueblo, g) Neandertal (Krapina 73).

The complexity value of the Scladina molar falls within the one standard deviation ranges of the means of the Arikara, Fuegians, and Neandertals from open habitats, and outside the ranges of variation of the rest of the modern and Neandertal groups.

4.2. Anisotropy

The Scladina canine anisotropy value, which is 0.0051, is higher than the mean values for all the modern human samples as well as the sample of Krapina Neandertals. It also falls outside the ranges of all the comparative groups with the exception of the Puye Pueblo and Arikara.

The molar anisotropy value for the Scladina Juvenile falls within the one standard deviation ranges of the means of the Arikara, Ipiutak, and Tigara and outside the ranges of the Aleut and Fuegians. From the Neandertal groups, the anisotropy value of the Scladina molar falls within the ranges of the Neandertals from open as well as those from wooded habitats.

4.3. Scale of maximum complexity

The Scladina canine *Smc* value is 0.34, and is identical to that of the Ipiutak. It is also very close to the value for the Tigara. The Scladina individual is within the range of every modern human sample and the Krapina Neandertals.

The Scladina molar has a relatively high value for the scale of maximum complexity. This value falls within the one standard deviation range of the mean of the Arikara from the recent human groups and the Neandertals from wooded habitats from the Neandertal groups analyzed.

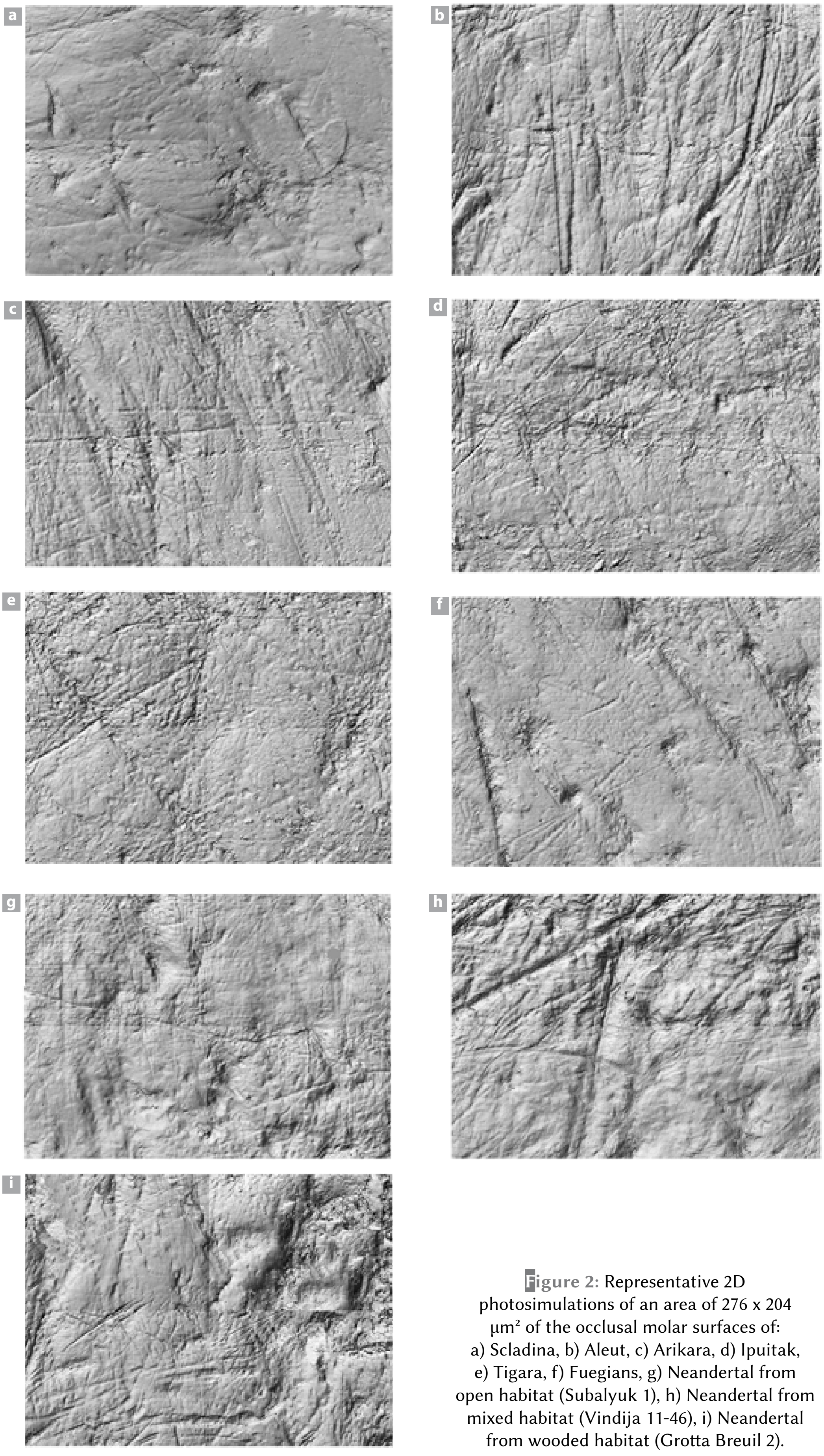

Figure 2: Representative 2D photosimulations of an area of 276 x 204 µm² of the occlusal molar surfaces of: a) Scladina, b) Aleut, c) Arikara, d) Ipuitak, e) Tigara, f) Fuegians, g) Neandertal from open habitat (Subalyuk 1), h) Neandertal from mixed habitat (Vindija 11-46), i) Neandertal from wooded habitat (Grotta Breuil 2).

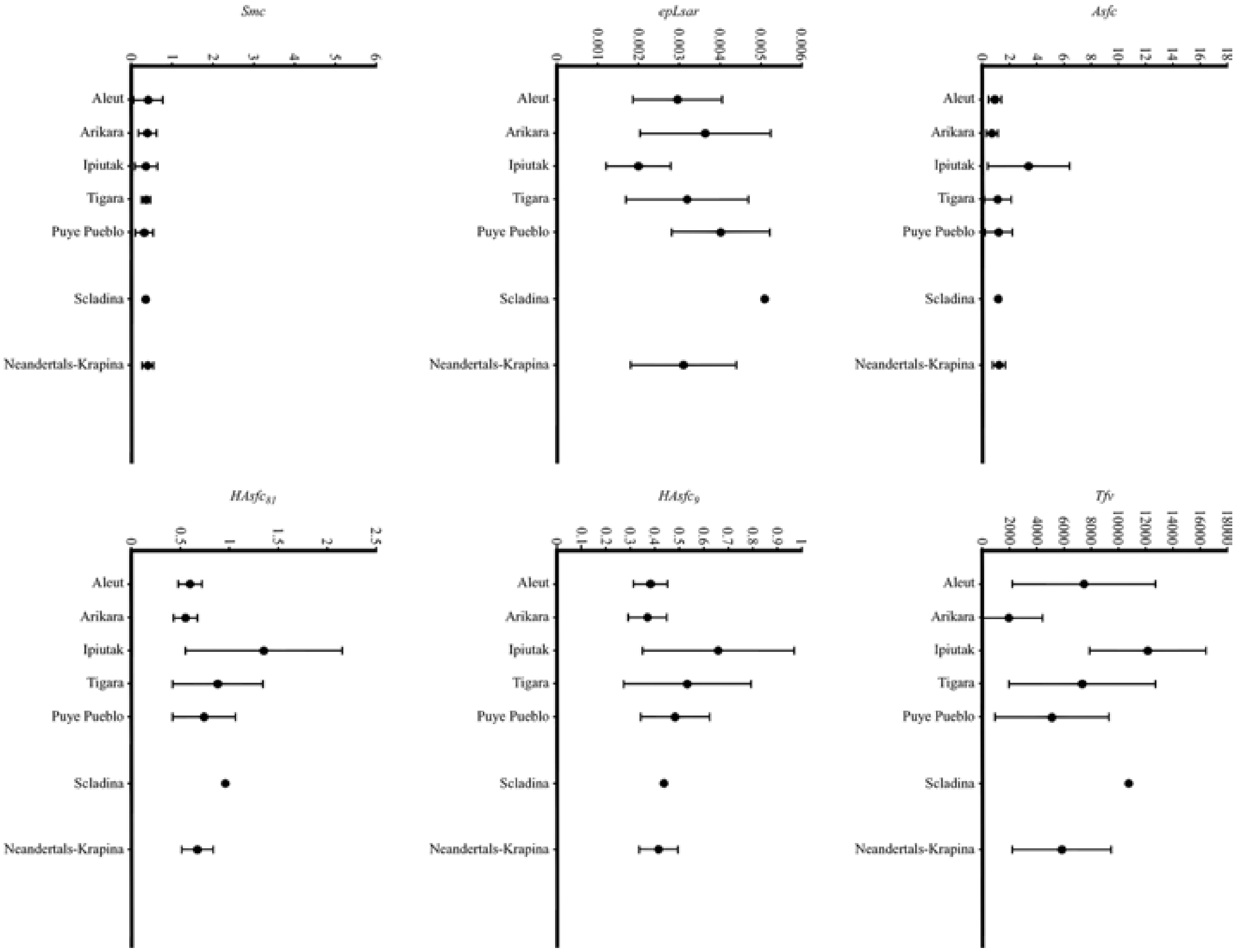

Figure 3: Plots of the means (dots) and one standard deviation ranges (bars) for the anterior dental microwear texture variables for Scladina and the modern human and Neandertal comparative groups.

4.4. Textural fill volume

The Scladina canine textural fill volume is 10,778.82. This Tfv value falls within the range of the Ipiutak, Tigara, and Aleut, i.e., all the arctic comparative samples used in this study, and outside the ranges of the Arikara and the Puye Pueblo. It is higher than the mean Krapina Neandertal value, and also falls outside the range of this sample.

The textural fill volume value for the Scladina molar falls within the ranges of one standard deviation of the means of the Aleut, Arikara, and Tigara from the recent human groups, as well as the Neandertals from open and mixed habitats, and outside the ranges of the remaining recent human groups and the Neandertals from wooded habitats.

4.5. Heterogeneity

The Scladina canine heterogeneity 3×3 and 9×9 values are 0.44 and 0.97. The 3×3 value is closest to the mean of the Puye Pueblo from the modern comparative samples. Yet, this value also falls within the ranges of the Tigara and Ipiutak from Point Hope. The Scladina canine 3×3 value is also very close to the mean of the Krapina Neandertal sample. On the other hand, the 9×9 value is closest to the mean of the Tigara sample, but it also falls within the one standard deviation ranges of the means of the Ipiutak and Puye Pueblo. The Scladina canine 9×9 value is not only considerably higher than the mean of the Krapina Neandertals, but is also above the range for this sample.

The heterogeneity value ($HAsfc^{1}$) of the Scladina molar falls within the one standard

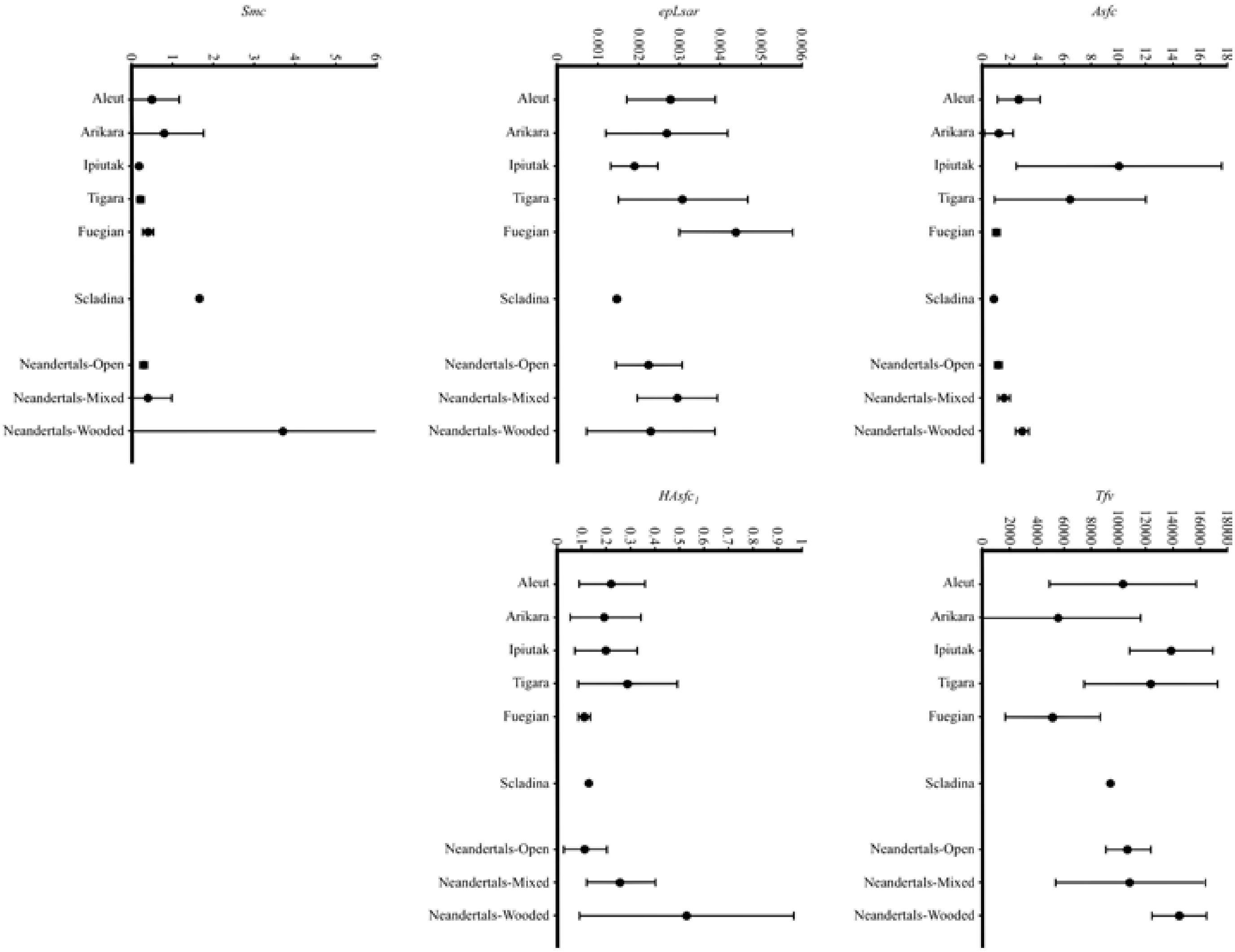

Figure 4: Plots of the means (dots) and one standard deviation ranges (bars) for the molar microwear texture variables for Scladina and the modern human and Neandertal comparative groups.

deviation of the mean ranges of all the recent human and the Neandertal groups analyzed.

5. Discussion

5.1. Anterior dental microwear textures

Microwear texture analysis of anterior dentition in bioarchaeological modern human groups with known dietary and non-dietary anterior tooth use behaviors have shown that the different microwear texture variables reflect these behaviors (Krueger & Ungar, 2010; Krueger, 2011). The anisotropy variable has been demonstrated to be good at distinguishing non-dietary from dietary anterior tooth use behaviors (Krueger & Ungar, 2010; Krueger, 2011). Specifically, the samples with low anisotropy values (0.0032 and lower) are those that are documented as using their anterior dentition in non-dietary behaviors. On the other hand, those with higher values are the samples that only use their anterior dentition for dietary purposes, such as incising a food item (Krueger & Ungar, 2010; Krueger, 2011). Textural fill volume has been associated with anterior loading regimes (Krueger, 2011). Those samples with high textural fill volume values indicate high anterior loading, while those with low values suggest the opposite (Krueger, 2011). Both Point Hope samples as well as the Aleut have high texture fill volume values. These samples are documented to have participated in high loading regimes which were related to various uses of the anterior dentition in non-dietary behaviors. Heterogeneity 3×3 and 9×9 has been linked to coarse- and fine-scale abrasive particle density and size, respectively (Krueger & Ungar, 2010; Krueger, 2011). If the heterogeneity values are high, exposure to abrasives were also high, and vice versa. Complexity values of anterior dentition have been linked to two factors:

1) the level of abrasive exposure and 2) the level of non-dietary anterior tooth use behaviors (Krueger, 2011). Thus, if both factors are high or low, complexity will be high or low, respectively. If one factor is high, then complexity will be moderate. Lastly, the *Smc* variable has not been shown to be particularly useful for distinguishing samples in anterior dental microwear studies, and will not be discussed further here.

Overall, in comparison to the modern human samples, the Scladina Neandertal anterior microwear texture values for anisotropy, texture fill volume, and heterogeneity 9×9 are relatively high, while those for heterogeneity 3×3 and complexity are relatively moderate. The relatively very high Scladina Neandertal anisotropy value and its congruence only with the Puye Pueblo and Arikara, the two samples that used their anterior dentition solely for dietary purposes, strongly indicates only dietary use of the anterior dentition. Similarly, the high textural fill volume value of the Scladina Neandertal suggests that this individual participated in high anterior loading regimes, yet its relatively high anisotropy value indicates that these anterior loads were most likely associated with incising tough food items rather than non-dietary anterior tooth use behaviors. Both heterogeneity values for the Scladina individual fall within the ranges of the modern human comparative groups that were exposed to relatively high amounts of dietary and environmental abrasive loads (i.e., Puye Pueblo, and the two Point Hope samples). This suggests that the Scladina Juvenile was also exposed to a relatively high amount of environmental and/or dietary abrasive loads. The Scladina canine complexity value is relatively moderate. Yet, since other texture values do not suggest non-dietary anterior tooth use behaviors for the Scladina Neandertal, this is not a factor here. Thus, the moderate value of the Scladina Neandertal is congruent with high levels of abrasive exposure only.

In comparison to the Krapina Neandertals, the Scladina anterior dental microwear values for heterogeneity 3×3 and complexity fall within the Krapina sample's ranges for these two variables. This suggests that the Scladina Neandertal was exposed to similar amounts of dietary and/or environmental coarse abrasive loads as the Krapina Neandertals. The Scladina values for the remaining variables, i.e., anisotropy, heterogeneity 9×9, and textural fill volume, are all higher than those of the Krapina Neandertals. This suggests that the Scladina Juvenile engaged in fewer non-dietary tooth use behaviors and was exposed to relatively higher amounts of fine-scale abrasive loads compared to the Krapina Neandertals. It should be mentioned that the Krapina Neandertal values for these variables reflect a moderate anterior loading regime associated with moderate non-dietary anterior tooth use behaviors and an exposure to relatively low amounts of fine-scale abrasive loads (Krueger & Ungar, 2012).

The results of the anterior microwear texture analysis of the Scladina Neandertal show that, while Neandertals are often associated with non-dietary anterior tooth use behaviors, most often associated with intense clamping and grasping activities, this is not always the case, at least for the Scladina individual. Several explanations can be put forth for the lack of a non-dietary anterior tooth use signal for the Scladina Neandertal. One possible explanation is that perhaps the Scladina Neandertal lived during a relatively warm period of MIS 5 which would have allowed for the release of the anterior dentition from intense non-dietary behaviors that are often affiliated with the processing of hide for protective purposes. Unfortunately, this cannot be confirmed as environmental reconstructions for the layer from which the Scladina Neandertal was recovered are unavailable (see Chapter 5). Another explanation is that the Scladina Neandertal was too young to participate in non-dietary anterior tooth behaviors. Indeed, this individual is approximately eight years old (Smith et al., 2007), and it remains unknown when sub-adult Neandertals would have fully participated in adult activities. Thus, the anterior dental microwear analysis of the Scladina individual offers a unique look into the dietary and behavioral strategies of Neandertals, and perhaps offers a glimpse into the responsibilities of sub-adults.

5.2. Molar microwear textures

Differences in occlusal molar microwear textures of Recent Modern Human groups were found to be highly correlated with the ethnographically documented or archeologically inferred differences in the diets and food preparation techniques of these groups (El Zaatari, 2014). Specifically, the complexity values have been found to be positively correlated with the levels of abrasives (hard brittle items) ingested. These abrasives can either be of dietary nature or can also be extraneous particles (i.e., environmental abrasives such as sand, grit, etc) that get attached to the food items as a result of food preparation techniques (El Zaatari, 2014). To this end, the two Point Hope populations, known to ingest very high amounts of environmental abrasives, have very high complexity values compared to the remaining groups. On the other hand, the anisotropy variable has been found to be linked to the level of consumption of softer, but tougher items, such that a high anisotropy value would indicate the consumption of large amounts of tough foods compared to hard foods (El Zaatari, 2014). The high anisotropy value of the Fuegians compared to the rest of the modern human samples analyzed illustrates the relation between the anisotropy variable and the consumption of tough foods relative to abrasive foods. Unlike the other groups, the Fuegians' based their subsistence almost exclusively on meat (a relatively tough dietary item) that was generally free of dietary and environmental abrasives. The scale of maximum complexity was found to be mostly correlated with the size of the wear causing particles (El Zaatari, 2014). The two Point Hope populations who ingested substantial amounts of small sand particles along with their food were found to have the lowest, as well as the least dispersed, values for scale of maximum complexity among the groups analyzed. On the other hand, the Arikara whose diet consisted of different kinds of plant food abrasives were found to have the highest scale of maximum complexity mean value and the most dispersion in individual values for this variable among the groups analyzed (El Zaatari, 2014). Textural fill volume values are most likely affected by two factors, the amount and size of the abrasive particles. A high textural fill volume value would indicate a large consumption of abrasive particles or a consumption of very hard abrasive particles that would cause deep features on the occlusal molar surface (El Zaatari, 2014). The heterogeneity variable has not been found to be a differentiating factor among the recent human populations analyzed to date (El Zaatari, 2014). But, studies of non-human primates have suggested this variable to be associated with the level of individual dietary variability. Ingesting different kinds of particles would increase the variability in microwear texture across the tooth surface, and thus would lead to a higher heterogeneity value (Scott et al., 2012).

Compared to the recent human samples, the relatively low surface complexity of the Scladina molar and its similarity to those of individuals belonging to two of the recent human samples, the Fuegians and the Arikara, whose diets consisted of the smallest amount of abrasives among the groups analyzed, reflects a diet focused on softer foods with a low level of abrasives for the Scladina Neandertal. The low anisotropy value of the Scladina molar suggests that this juvenile's diet did not consist exclusively of tough foods. Indeed, The Scladina molar has anisotropy value that is substantially lower than the Fuegians' values, but falls within the lower range of values of the Arikara, a group that is known to have consumed substantial amounts of dried bison meat (a tough food item) along with dietary abrasives for its subsistence. The Scladina molar textural fill volume value is relatively intermediate. This most likely reflects large abrasive particles since, as illustrated by the complexity value, the diet of the Scladina Child did not consist of large amounts of abrasives. The ingestion of large size abrasive particles by the Scladina Child is also supported by its relatively large scale of maximum complexity value. This value is substantially higher than individuals from Point Hope whose diets consisted of large amounts of small extraneous grit and sand particles and similar to specimens from the Arikara group, whose diet consisted of abrasives of dietary nature. Overall, the molar microwear texture indicates that the diet of the Scladina Child consisted of a mix of soft and tough food items along with some abrasive items that were most likely dietary rather than environmental in nature. Stable isotope analyses have indicated a meat based diet for this Neandertal (Bocherens et al., 1999, 2001). The results of this study are in accord with this reconstruction since meat is generally a soft, but tough food item. Yet, the microwear data also reveals that the diet of the Scladina Child most likely included small amounts of abrasive plant foods as well.

The Neandertal groups from different palaeoecological conditions were best distinguished based on the complexity and heterogeneity variables. For the complexity variable, the low value of the Scladina Juvenile is most similar to adult Neandertals from open habitats. The Scladina heterogeneity value falls within the range of the Neandertals from open as well as wooded habitats. Yet, it is much closer to the mean of the former rather than that of the latter. Neandertals from wooded habitats were found to have a relatively wide dispersion of values most likely reflecting a high level of variation in individual dietary variability. The relatively low heterogeneity value for the Scladina Juvenile reflects a diet consisting of low variability in food items ingested by this child. Unfortunately, palaeoenvironmental reconstructions are unavailable for the layers of the Scladina site that yielded the Neandertal juvenile (see Chapter 5). Thus, it remains unclear whether the similarity in molar microwear textures between the Scladina Juvenile and the adult Neandertals from open habitats is simply a reflection of dietary similarity in similar environmental conditions or whether it was linked to other factors such as the young age of this individual.

6. Conclusions

In this study the microwear textures of the anterior and molar dentition of the Scladina Neandertal were analyzed and compared to those of bioarchaeological human populations as well as adult Neandertals. The aim of this study was to gain insights into the diet and behavior of the Scladina Juvenile. The results of this study show that the Scladina Neandertal used his/her anterior dentition solely for dietary purposes and that this child did not practice non-dietary anterior tooth use behaviors. Concerning diet, the microwear textures of the Scladina Child show that the diet of this Neandertal can be best described as having consisted of a mix of soft and tough foods in addition to some amounts of dietary abrasives. Also, the anterior dental microwear texture results suggest that some of the foods ingested by this child required a high anterior loading regime. Synthesizing these data, perhaps the Scladina Neandertal was subsisting on dried meat. Incising such a foodstuff would require a high anterior loading regime. Once in the oral cavity, it would be tough, but as the saliva and molars break it down chemically and mechanically, respectively, it would become soft. This is just one explanation of many possible ideas, and perhaps further research can shed more light. Overall, the dental microwear analysis of the Scladina individual offered a unique look into the dietary and behavioral strategies of Neandertals, and perhaps also offered a glimpse into the diets and responsibilities of sub-adults.

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References

BALIKCI A., 1970. *The Netsilik Eskimo. Prospect Heights*. Natural History Press, 264 p.

BARNES E., 1994. Puye and the Pajarito: historical background. In E. BARNES (ed.), *Developmental Defects of the Axial Skeleton in Paleopathology*. Boulder, University of Colorado Press, 298–317.

BARROSO RUIZ C., MARCHI F., ABDESSADOK S., BAILÓN S., DESCLAUX E., GRÉGOIRE S., HERNANDEZ CARRASQUILLAS F., LACOMBAT F., LEBRETON V. & LECERVOISIER B., 2006. Contexte paléoécologique, paléoclimatique et paléogéographique des Néandertaliens de la grotte du Boquete de Zafarraya. In C. BARROSO RUIZ & H. DE LUMLEY (eds.), *La grotte du Boquete de Zafarraya (Málaga, Andalousie): Junta de Andalucía*, Consejería de Cultura: 1127–1166.

BELMAKER M. & HOVERS E., 2008. A diachronic study of the micromammal remains of Amud Cave, Israel: implications for the paleoecology of a Neanderthal site during MIS 4-3 in the Levant. *Abstracts of the 73rd Society for American Archaeology Meeting*: 75.

BLAKESLEE D. J., 1994. The archaeological context of human skeletons in the northern and central Plains. In D. W. OWSLEY & R. L. JANTZ (eds.), *Skeletal Biology in the Great Plain: Migration, Warfare, Health and Subsistence*. Washington, DC, Smithsonian Institution Press: 9–32.

BOCHERENS H., BILLIOU D., MARIOTTI A., PATOU-MATHIS M., OTTE M., BONJEAN D. & TOUSSAINT M., 1999. Palaeoenvironmental and palaeodietary implications of isotopic biogeochemistry of late interglacial Neandertal and mammal bones in Scladina Cave (Belgium). *Journal of Archaeological Science*, 26: 599-607.

BOCHERENS H., BILLIOU D., MARIOTTI A., TOUSSAINT M., PATOU-MATHIS M., BONJEAN D. & OTTE M., 2001. New isotopic evidence for dietary habits of Neandertals from Belgium. *Journal of Human Evolution*, 40: 497–505.

BOCHERENS H. & DRUCKER D. G., 2003. Reconstructing Neandertal diet from 120,000 to 30,000 BP using carbon and nitrogen isotopic abundances. In M. PATOU-MATHIS &

H. Bocherens (eds.), *Le rôle de l'environnement dans les comportements des chasseurs-cueilleurs préhistoriques.* Actes du XIVème Congrès de l'Union Internationale des Sciences Préhistoriques et Protohistoriques, Section 3 : Paléoécologie. Colloque C3.1., Université de Liège, Belgique, 2–8 septembre 2001, Oxford, British Archaeological Reports, International Series, 1105: 1–7.

Bocherens H., Drucker D. G., Billiou D., Patou-Mathis M. & Vandermeersch B., 2005. Isotopic evidence for diet and subsistence pattern of the Saint-Césaire I Neanderthal: review and use of a multi-source mixing model. *Journal of Human Evolution*, 49: 71–87.

Bœuf O., 1969. Faune et nouveaux restes humains du gisement moustérien du Petit-Puyrousseau (Charente). *Mémoires de la Société Archéologique et historique de la Charente*: 53–128.

Bouchud J., 1966. *Essai sur le Renne et la climatologie du Paléolithique moyen et supérieur*. Périgueux, Imprimerie Magne, 300 p.

Brace C. L., 1967. Environment, tooth form and size in the Pleistocene. *Journal of Dental Research*, 46: 809–816.

Brace C. L., 1975. Comment on: Did La Ferrassie I use his teeth as a tool? *Current Anthropology*, 16: 396–397.

Brace C. L., Ryan A. S. & Smith B. H., 1981. Comment: tooth wear in La Ferrassie man. *Current Anthropology*, 22: 426–430.

Bridges T., 1885. The Yahgans of Tierra del Fuego. *Journal of the Royal Anthropological Institute*, 14: 288–289.

Brubaker M., Berner J., Bell J., Warren J. & Rolin A., 2010. *Climate change in Point Hope, Alaska: strategies for community health*. Alaska Native Tribal Health Consortium, Center for climate and Health, 44 p.

Coltrain J. B., 2010. Temporal and dietary reconstruction of past Aleut populations: stable- and radio-isotope evidence revisited. *Arctic*, 63: 391–398.

Cordy J.-M., 1988. Apport de la paléozoologie à la paléoécologie et à la chronostratigraphie en Europe du nord-occidental. In H. Laville (ed.), *L'Homme de Néandertal, vol. 2 : L'Environnement*. Études et Recherches Archéologiques de l'Université de Liège, 29: 55–64.

Cybulski J. S., 1974. Tooth wear and material culture: precontact patterns in the Tsimshian area, British Columbia. *Syesis*, 7: 31–35.

Dabbs G. R., 2009. *Health and nutrition at prehistoric Point Hope, Alaska: application and critique of the Western Hemisphere Health Index*. University of Arkansas, 215 p.

de Poncins G., 1941. *Kabloona Reynal*. New York, Reynal & Hitchcock Incorporated, 339 p.

Eisenmann V., 1992. Systematic and biostratigraphical interpretation of the equids from Qafzeh, Tabun, Skhul and Kebara (Acheuloyabrudian to Upper Paleolithic of Israel). *Archaeozoologica*, 1: 43–62.

El Zaatari S., 2010. Occlusal microwear texture analysis and the diets of historical/prehistoric hunter-gatherers. *International Journal of Osteoarchaeology*, 20: 67–87.

El Zaatari S., 2014. The diets of the Ipiutak and Tigara (Point Hope, Alaska): evidence from occlusal molar microwear texture analysis. In C. Hilton, B. Auerbach & L. Cowgill (eds.), *The Foragers of Point Hope: the biology and archaeology of humans on the edge of the Alaskan arctic*. Cambridge University Press: 120-137.

El Zaatari S., Grine F. E., Ungar P. S. & Hublin J.-J., 2011. Ecogeographic variation in Neandertal dietary habits: evidence from occlusal microwear texture analysis. *Journal of Human Evolution*, 61: 411–424.

El Zaatari S., Harvati K. & Panagopoulou E., 2013. Occlusal molar microwear texture analysis: the method and its application for the dietary reconstruction of the Lakonis Neandertal. In S. Voutsaki & S.-M. Valamoti (eds.), *Subsistence, Economy and Society in the Greek World*. Louvain. Peeters Publishers: 55–63.

Fellag H., 1996. Étude palynologique de l'abri paléolithique Bourgeois-Delaunay (Chaise, Charente). *Quaternaire*, 7: 187–196.

Foote B. A., 1992. *The Tigara Eskimos and their Environment*. North Slope Borough, Commission on Iñupiat History, Language and Culture, Point Hope, AK, 190 p.

Fortea J., de la Rasilla M., Martínez E., Sánchez-Moral S., Cañaveras J. C., Cuezve S., Rosas A., Soler V., Julia R., de Torres T., 2003. La cueva de El Sidrón (Borines, Piloña, Asturias): primeros resultados. *Estudios Geológicos*, 59: 159–179.

GIDDINGS J. L., 1967. *Ancient Men of the Arctic*. London, Secher and Warburg, 391 p.

GROSS H., 1956. Die Umwelt des Neandertaler. In K. TACKENBERG (ed.), *Der Neandertaler und seine Umwelt. Gedenkschrift zur Erinnerung an die Auffindung im Jahre 1856*. Bonn, Rheinisches Landesmuseum Bonn und Verein von Altertumsfreunden im Rheinlande: 68–105.

HENRI-MARTIN G., 1966. Découverte d'un temporal humain néandertalien dans le gisement de La Quina, Charente. *Comptes rendus de l'Académie des sciences*, 262: 1937–1939.

HEWETT E. L., 1938. *Pajarito Plateau and Its Ancient People*. Albuquerque, University of New Mexico Press, 191 p.

HOFFMAN K. L., 1993. *Unalaska Aleut subsistence adaptations at the time of early Russian contact as represented in the Reese Bay artifact assemblage*. Fayetteville, University of Arkansas, 1122 p.

HRDLIČKA A., 1945. *The Aleutian and Commander Islands and their Inhabitants*. Philadelphia, Wistar Institute of Anatomy and Biology, 630 p.

HURT W. R., 1969. Seasonal economic and settlement patterns of the Arikara. *Plains Anthropology*, 14: 32–37.

JANTZ R. L., 1973. Microevolutionary change in Arikara crania: multivariate analysis. *American Journal of Physical Anthropology*, 38: 15–26.

JELINEK A. J., FARRAND W. R., HAAS G., HOROWITZ A. & GOLDBERG P., 1973. New excavations at the Tabun Cave, Mount Carmel, Israel 1967–1972. *Paléorient*, 1: 151–183.

KARAVANIĆ I., 2004. The Middle Paleolithic settlement of Croatia. In N. J. CONARD (ed.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*, 2, Tübingen, Kerns Verlag: 185–200.

KOLSKA HORWITZ L. & HONGO H., 2006. Putting the meat back on old bones. A reassessment of Middle Palaeolithic fauna from Amud Cave (Israel). In E. VILLA, L. GOURICHON, A. M. CHOYKE& & H. BUITENHUIS (eds.), *Archaeozoology of the Near East, VIII,* Proceedings of the eighth international Symposium on the Archaeozoology of southwestern Asia and adjacent areas. Travaux de la Maison de l'Orient et de la Méditerranée, 49: 45–64.

KOTSAKIS T., 1990–1991. Late Pleistocene fossil microvertebrates of Grotta Breuil (Monte Circeo, central Italy). *Quaternaria Nova*, I: 325–332.

KRUEGER K. L., 2011. *Dietary and behavioral strategies of Neandertals and anatomically modern humans: evidence from anterior dental microwear texture analysis*. PhD thesis, University of Arkansas, 346 p.

KRUEGER K. L., 2014. Contrasting dietary and behavioral strategies of the Ipiutak and Tigara: evidence from incisor microwear texture analysis. In C. HILTON, B. AUERBACH & L. COWGILL (eds.), *The Foragers of Point Hope: the biology and archaeology of humans on the edge of the Alaskan arctic*. Cambridge University Press: 99-119.

KRUEGER K. L., SCOTT J. R., KAY R. F. & UNGAR P. S., 2008. Technical note: Dental microwear textures of "Phase I" and "Phase II" facets. *American Journal of Physical Anthropology*, 137: 485–490.

KRUEGER K. L. & UNGAR P. S., 2010. Incisor microwear textures of five bioarcheological groups. *International Journal of Osteoarchaeology*, 20: 549–560.

KRUEGER K. L. & UNGAR P. S., 2012. Anterior dental microwear texture analysis of the Krapina Neandertals. *Central European Journal of Geosciences*, 4: 651–662.

LALUEZA-FOX C. & FRAYER D. W., 1997. Non-dietary marks in the anterior dentition of the Krapina Neanderthals. *International Journal of Osteoarchaeology*, 7: 133–149.

LARSEN H. & RAINEY F. G., 1948. *Ipiutak and the Arctic Whale Hunting Culture*. New York, Anthropological Papers of the American Museum of Natural History, 42, 486 p.

LAUGHLIN W. S., 1963. Eskimos and Aleuts: their origins and evolution. *Science*, 142: 633–645.

LAVAUD-GIRARD F., 1993. Macrofauna from the Castelperronian Levels at Saint-Césaire, Charente-Maritime. In F. LÉVÊQUE, A. M. BACKER & M. GUILBAUD (eds.), *Context of a Late Neandertal: Implications of Multidisciplinary Research for the Transition to Upper Paleolithic Adaptations at Saint-Césaire, Charente-Maritime, France*. Madison, Prehistory Press: 71–77.

LEIGH R. W., 1925. Dental pathology of Indian tribes of varied environmental and food conditions. *American Journal of Physical Anthropology*, 8: 179–199.

LEROI-GOURHAN A., 1988. Le passage Moustérien-Châtelperronien à Arcy-sur-Cure. *Bulletin de la Société préhistorique française*, 85: 102–104.

Leroyer C. & Leroi-Gourhan A., 1993. Pollen analysis at Saint-Césaire. In F. Lévêque, A. M. Backer & M. Guilbaud (eds.), *Context of a Late Neandertal*. Madison, Prehistory Press: 61–70.

Lester C. W. & Shapiro H. L., 1968. Vertebral arch defects in the lumbar vertebrae of pre-historic American Eskimos. *American Journal of Physical Anthropology*, 28: 43–48.

Lukacs J. R. & Pastor R. F., 1988. Activity-induced patterns of dental abrasion in prehistoric Pakistan: evidence from Mehrgarh and Harappa. *American Journal of Physical Anthropology*, 76: 377–398.

Manzi G., 1986. I Fuegini del Museo di Antropologia dell'Università di Roma "La Sapienza": Significato di una collezione osteologica. *Museologia Scientifica* V, supplemento: 43–54.

Marquet J.-C., 1988. L'Homme de Néandertal et son environnement dans la moitié ouest de la France d'après les rongeurs. In H. Laville (ed.), *L'Homme de Néandertal, vol. 2 : L'Environnement*. Études et Recherches Archéologiques de l'Université de Liège, 29: 105–110.

Marquet J.-C., 1993. *Paléoenvironnement et Chronologie des Sites du Domaine Atlantique Français d'Âge Pléistocène Moyen et Supérieur d'Après l'Étude des Rongeurs*. Tours, Les Cahiers de la Claise, 2, 344 p.

Mayes A. T., 2001. *Patterns through time: interactions between changes in subsistence and human dentition at Illinois Bluff, Jersey County, Illinois, and Spiro Mounds, Oklahoma*. University of Colorado, 428 p.

Meyer R. W., 1977. *The Village Indians of the Upper Missouri*. Lincoln, NE, University of Nebraska Press, 354 p.

Miracle P. T., Lenardić J. M. & Brajković D., 2010. Last glacial climates, ''Refugia'', and faunal change in Southeastern Europe: Mammalian assemblages from Veternica, Velika pećina, and Vindija caves (Croatia). *Quaternary International*, 212: 137–148.

Miskovsky J.-C. & Lévêque F., 1993. The sediments and stratigraphy of Saint-Césaire: contributions to the paleoclimatology of the site. In F. Lévêque, A. M. Backer & M. Guilbaud (eds.), *Context of a Late Neandertal: Implications of Multidisciplinary Research for the Transition to Upper Paleolithic Adaptations at Saint-Césaire, Charente-Maritime, France*. Madison, Prehistory Press: 7–14.

Moorrees C. F. A., 1957. *The Aleut Dentition: A Correlative Study of Dental Characteristics in an Eskimoid People*. Cambridge, Harvard University Press, 196 p.

Morin E., 2004. *Late Pleistocene population interaction in western Europe and modern human origins: new insights based on the faunal remains from Saint-Césaire, southwestern France*. Unpublished PhD thesis, University of Michigan, 450 p.

Panagopoulou E., Karkanas P., Tsartsidou G., Kotjabopoulou E., Harvati K. & Ntinou M., 2002-2004. Late Pleistocene Archaeological and Fossil Human Evidence from Lakonis Cave, Southern Greece. *Journal of Field Archaeology*, 29: 323–349.

Patou-Mathis M., 1993. Taphonomic and palaeoethnographic study of the fauna associated with the Neandertal of Saint-Césaire. In F. Lévêque, A. M. Backer & M. Guilbaud (eds.), *Context of a Late Neandertal: Implications of Multidisciplinary Research for the Transition to Upper Paleolithic Adaptations at Saint-Césaire, Charente-Maritime, France*. Madison, Prehistory Press: 79–102.

Prideaux G. J., Ayliffe L. K., DeSantis L. R. G., Schubert B. W., Murray P. F., Gagan M. K. & Cerling T. E., 2009. Extinction implications of a chenopod browse diet for a giant Pleistocene kangaroo. *Proceedings of the National Academy of Sciences of the United States of America*, 106, 28: 11646–11650.

Rabinovich R. & Hovers E., 2004. Faunal analysis from Amud Cave: preliminary results and interpretations. *International Journal of Osteoarchaeology*, 14: 287–306.

Recchi A., 1995. Bird remains from the Upper Pleistocene sites of Grotta Breuil (M. Circeo, Latina, Italy) and Riparo Salvini (Terracina, Latina, Italy). *Quaternaria Nova*, V: 81–98.

Richards M. P., Pettitt P. B., Trinkaus E., Smith F. H., Paunović M. & Karavanić I., 2000. Neanderthal diet at Vindija and Neanderthal predation: the evidence from stable isotopes. *Proceedings of the National Academy of Sciences of the United States of America*, 97, 13: 7663–7666.

Richards M. P. & Trinkaus E., 2009. Isotopic evidence for the diets of European Neanderthals and early modern humans. *Proceedings of the National Academy of Sciences of the United States of America*, 106, 38: 16034–16039.

Rink W. J., Schwarcz H. P., Lee H. K., Rees-Jones J., Rabinovich R. & Hovers E., 2001. Electron Spin Resonance (ESR) and Thermal Ionization Mass Spectrometric (TIMS) 230Th/234U dating of teeth in Middle Paleolithic layers at Amud Cave, Israel. *Geoarchaeology*, 16: 701–717.

Rink W. J., Schwarcz H. P., Smith F. H. & Radovčić J., 1995. ESR ages for Krapina hominids. *Nature*, 378: 24.

Ryan A. S., 1980. Anterior dental microwear in Neanderthals. *American Journal of Physical Anthropology*, 52: 274.

Schwartz J. H. & Tattersall I., 2002. *The Human Fossil Record: Terminology and Craniodental Morphology of Genus Homo (Europe)*. New York, Wiley-Liss.

Scott R. S., Teaford M. F. & Ungar P. S., 2012. Dental Microwear Texture and Anthropoid Diets. *American Journal of Physical Anthropology*, 147: 551–579.

Scott R. S., Ungar P. S., Bergstrom T. S., Brown C. A., Childs B. E., Teaford M. F. & Walker A., 2006. Dental microwear texture analysis: technical considerations. *Journal of Human Evolution*, 51: 339–349.

Scott R. S., Ungar P. S., Bergstrom T. S., Brown C. A., Grine F. E., Teaford M. F. & Walker A., 2005. Dental microwear texture analysis shows within-species diet variability in fossil hominins. *Nature*, 436: 693–695.

Simek J. F. & Smith F. H., 1997. Chronological changes in stone tool assemblages from Krapina (Croatia). *Journal of Human Evolution*, 32: 561–575.

Smith P., 1976. Dental pathology in fossil hominids: what did Neanderthals do with their teeth? *Current Anthropology*, 17: 149–151.

Smith T. M., Toussaint M., Reid D. J., Olejniczak A. J. & Hublin J.-J., 2007. Rapid dental development in a Middle Paleolithic Belgian Neanderthal. *Proceedings of the National Academy of Sciences of the United States of America*, 104, 51: 20220–20225.

Snow W. P., 1861. A few remarks on the wild tribes of Tierra del Fuego from personal observation. *Transactions of the Ethnological Society*, 1: 261–267.

Speth J. D. & Tchernov E., 1998. The role of hunting and scavenging in Neandertal procurement strategies: new evidence from Kebara Cave (Israel). In T. Akazawa, K. Aoki & O. Bar-Yosef (eds.), *Neandertals and Modern Humans in Western Asia*. New York, Plenum Press: 223–239.

Speth J. D. & Tchernov E., 2001. Neandertal hunting and meat-processing in the Near East: Evidence from Kebara Cave (Israel). In C. B. Stanford & H. T. Bunn (eds.), *Meat-Eating and Human Evolution*. Oxford University Press: 52–72.

Speth J. D. & Tchernov E., 2002. Middle Paleolithic tortoise use at Kebara Cave (Israel). *Journal of Archaeological Science*, 29: 471–483.

Stewart T. D., 1959. The restored Shanidar I skull. *The Annual Report of the Smithsonian Institution for 1958*: 473–480.

Stiner M. C., 1994. *Honor Among Thieves*. Princeton University Press, 447 p.

Tournepiche J.-F. & Couture C., 1999. The Hyena den of Rochelot Cave (Charente, France). *Monographien des Römisch-Germanischen Zentralmuseums*, 42: 89–101.

Trierweiler W. N., 1990. *Prehistoric Tewa Economy: Modeling Subsistence Production on the Pajarito Plateau*. New York, Garland Publishing.

Tuross N. & Fogel M. L., 1994. Stable isotope analysis and subsistence patterns at the Sully Site. In D. W. Owsley & R. L. Jantz (eds.), *Skeletal Biology of the Great Plain: Migration, Warfare, Health and Subsistence*. Washington, DC, Smithsonian Insitution Press: 283–289.

Ungar P. S., Merceron G. & Scott R. S., 2007. Dental microwear texture analysis of Varswater bovids and early Pliocene paleoenvironments of Langebaanweg, Western Cape Province, South Africa. *Journal of Mammalian Evolution*, 14: 163–181.

Ungar P. S., Scott J. R., Schubert B. W. & Stynder D. D., 2010. Carnivoran dental microwear textures: comparability of carnassial facets and funcitonal differentiation of postcanine teeth. *Mammalia*, 74: 219–224.

Wallace J. A., 1975. Did La Ferrassie I use his teeth as a tool? *Current Anthropology*, 16: 393–401.

Wolpoff M. H., 1979. The Krapina dental remains. *American Journal of Physical Anthropology*, 50: 67–114.

Yesner D. R., Figuerero Torres M. J., Guichon R. A., & Borrero L. A., 2003. Stable isotope analysis of human bone and ethnohistoric subsistence patterns in Tierra del Fuego. *Journal of Anthropological Archaeology*, 22: 279–291.