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Dietary inferences through dental microwear and isotope analyses of the Lower Magdalenian individual from El Mirón Cave (Cantabria, Spain)

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A B S T R A C T

Dietary habits are inferred from dental microwear and isotope analyses of the Magdalenian human individual from the site of El Mirón, dated to 15,460 ± 40 BP. The pattern of dental microwear was established on the buccal surface of the lower fourth premolar and on the bottom of facet 9 on the occlusal surface of the lower third molar. The results obtained through analysis of different surfaces are consistent and indicate a mixed diet for this Lower Magdalenian individual, including meat, aquatic resources and vegetables. These results are in agreement with those obtained through isotope analysis. This implies a generalized exploitation of the environment as has been previously established in other Late Upper Palaeolithic specimens.

1. Introduction

Dietary reconstruction is an important class of analysis in paleoanthropology, since diet influences a number of human behaviors, including, such things as mobility patterns or social organization (Clutton-Brock and Harvey, 1977). This kind of study can be addressed through isotope and dental microwear analysis. Isotopic analysis is able to determine diet through the Carbon and Nitrogen isotope ratios (Richards and Hedges, 1999; Richards et al., 2000, 2001; García-García et al., 2009).

Dental microwear analysis has proven to be a useful technique with which to characterize diet-related adaptations in non-human primates (Gordon, 1982; Teaford and Walker, 1984; Teaford and Oyen, 1989; Teaford and Robinson, 1989; Ungar, 1994), dietary habits in fossil hominins (Puech, 1983; Puech et al., 1983a; Puech et al., 1986; Grine, 1986; Ryan and Johanson, 1989; Ungar and Grine, 1991; Lalueza et al., 1993, 1996; Pérez-Pérez et al., 2003; Grine et al., 2006; Estebaranz et al., 2009) and subsistence strategies in both prehistoric and recent humans (Bullington, 1991; Molleson and Jones, 1991; Molleson et al., 1993; Pérez-Pérez et al., 1994; Ungar and Spencer, 1999; Schmidt, 2001; Romero et al., 2004; Teruyuki, 2005; Mahoney, 2006a,b, 2007; Hogue and Melsheimer, 2008; Kruege and Ungar, 2009; Gamza and Irish, 2012; Romero et al., 2013; El-Zaatari and Hublin, 2014). These studies are based on the relationship between dental microwear patterns and the general types of foods upon which an organism relies (Schmidt, 2001). The analysis of these patterns can be carried out through the study of occlusal or buccal surfaces.

Occlusal microwear is affected by both abrasion and perhaps tooth–tooth wear. Thus, it yields a surface with pits and scratches. Scratches are formed by particles such as grit, dust and phytoliths

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adhering to the food, while pits are caused by tooth-to-tooth contact. Thus, hard diets, which are reflected by an increase in compression forces, produce frequent and large pits (Gordon, 1982; Teaford and Walker, 1984; Teaford and Oyen, 1989; Teaford and Runestad, 1992; Mahoney, 2006a,b). However, a diet rich in tough foods requires an increase in shear, producing numerous long and narrow scratches (Gordon, 1982; Teaford and Walker, 1984; Teaford, 1988; Walker and Teaford, 1989; Ungar and Spencer, 1999; Mahoney, 2006a,b). In addition, the pattern of microwear can be altered by other agents, such as chewing biomechanics, age and size of abrasive particles (Bullington, 1991; Mahoney, 2006b,c).

On the other hand, buccal microwear is only affected by abrasion; thus, pits are rarely formed (Puech and Pant, 1980; Pérez-Pérez et al., 1994; Ungar and Spencer, 1999). The variables analyzed in this case are the density and orientation of the striae (Pérez-Pérez et al., 1994; Lalueza et al., 1996). The number of buccal striation depend on the abrasive particles present in the food, such plant phytoliths, sand or ash, while the length of the striation may depends on other additional factors, such the pressure applied by the chewing muscles (Pérez-Pérez et al., 1994). Studies on fossil hominins have suggested that vertical scratches should become longer and more frequent in meat-eating populations, while horizontal ones should be more abundant and longer in a diet with a high consumption of vegetables (Puech, 1978, 1979; Puech and Pant, 1980; Puech, 1983; Puech and Albertini, 1981; Puech et al., 1980, 1983a,b, 1986). Subsequent research has shown that the indices of relative frequency of scratches (categorized by their orientation) are more informative about dietary habits (Pérez-Pérez et al., 1994; Lalueza et al., 1996; Pérez-Pérez et al., 1999).

The selection of the tooth surface to study depends on the type of information desired, although a recent study demonstrated that, at least in *Australopithecus afarensis*, buccal and occlusal microwear analysis offers consistent results (Estebaranz et al., 2009). There are two main factors to bear in mind for making this choice. First, it is important to note that meat consumption is hard to infer through the occlusal microwear pattern (Mahoney, 2007). And secondly, both the formation dynamic and overall turnover rate shown in these two surfaces are clearly different (Teaford and Oyen, 1989; Pérez-Pérez et al., 1994; Romero et al., 2007). The turnover rate is faster on the occlusal surfaces than on the buccal ones, so the dental microwear pattern in the former is more susceptible to the "last supper effect" (Pérez-Pérez et al., 1994; Romero and De Juan, 2007; Romero et al., 2007, 2012). Therefore, analysis of microwear features on buccal surfaces provides information about dietary habits over a relatively longer period of time, while the interpretation of these features on occlusal surfaces should reflect seasonality of food resource exploitation (Rivals and Deniaux, 2005, Rivals et al., 2009a,b; Merceron et al., 2010).

Thus, to obtain more complete dietary inferences through dental microwear patterns, both buccal and occlusal analyses should be integrated. In this sense, the main goal of the present study is to make dietary inferences through dental microwear patterns on buccal and occlusal surfaces of the partial human skeleton recovered from a Lower Magdalenian context in El Mirón Cave. These results are compared with those obtained through stable isotopic analysis.

The skeleton from El Mirón Cave is referred to as the "Red Lady" because the bones were stained with ochre (for a complete anthropological study, see Carretero et al., 2015). It has been directly dated to 15,460 ± 40 BP, which, together with the stratigraphic position and the associated archaeological material, place it in the Lower Cantabrian Magdalenian (Straus et al., 2011, 2015).

2. Material

This study is based on the analysis of teeth from the human mandiblerecovered from El Mirón Cave. Dental microwear analysis was performed in the lower right fourth premolar (P_4) and lower left third molar (M_3) from the human mandible. Lower first (M_1) and second (M_2) molars were excluded from the study because they showed a high degree of dental wear (see Carretero et al., 2015). Stable isotope analysis was carried out on collagen extracted from the bone as part of the radiocarbon dating process for the El Mirón individual.

Microwear data for comparative purposes were obtained from different bibliographic sources. For the P_4, these data were extracted from Lalueza et al. (1996), who analyzed the buccal surface of the P_4, M_1 and M_2, either mandibular or maxillary, in ten different samples. Although our data come from a lower P_4, comparisons with data provided by Lalueza et al. (1996) are possible since the intra-individual variation is smaller than the inter-individual variation (Pérez-Pérez et al., 1994). The different comparative samples are sorted into four dietary groups: 1) agriculturalist group, which is characterized by an exclusively vegetarian diet; 2) hunter–gatherers from tropical environments, showing a diet with a higher intake of vegetable foods than that of meat; 3) carnivorous hunter–gatherer and pastoralists, whose diet is mainly based on meat and 4) hunter–gatherers from arid environments, with a mixed diet.

In the case of the $M_{3,}$ comparative data have been limited to the bottom of facet 9 (located toward central fossa of the distobuccal cusp) on second and third lower molars, because there is a high intra-individual variation between teeth and in the location of the wear facet (Mahoney, 2006a,b,c). Occlusal microwear data of comparative collections were obtained from Mahoney (2007), who provides both summary statistics and raw data for each group. The samples used by Mahoney (2007) included those from four prehistoric human groups belonging to different archaeological periods in the southern Levant, plus two molars from the late Upper Paleolithic Ohalo II site. The prehistoric groups are: Natufian hunter–gatherers, early Pre-Pottery Neolithic people from Sultain sites (PPNA), Pre-Pottery Neolithic hunters and farmers (PPNB) and Chalcolithic farmers. From this four, two dietary sets can be established: one with a hard diet (Natufian and PPNB samples) and the other with a softer diet (PPNA and Chalcolithic samples).

3. Methods

3.1. Imaging procedure

The two teeth from El Mirón were imaged directly using an environmental scanning electron microscope (ESEM) JEOL JSM-6460LV in lower vacuum mode. The use of ESEM in physical anthropology is growing, as it eliminates the necessity of casting procedures. Although this is a great advantage, it is important to point out that this technique presents some limitations. The most important is the "skirt effect" which adversely affects the spot size (Timofeeff et al., 2000). The spot size is a dimensionless magnitude which measures the probe current (i.e., the current that impinges upon the specimen and generates the imaging signals). In the ESEM used in this study, the spot size varies between 0 and 99 (0 implies a minimum probe current and 99 a maximum one).

Several procedures can be used to minimize this effect, including maximizing the relationship among working distance, accelerating voltage, pressure and brightness and contrast levels (Timofeeff et al., 2000; Kirk et al., 2009).

Although these cautions were all taken into account, spot size for images used in this study were clearly larger (between 66 and