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POST-MORTEM WEAR AS INDICATOR OF TAPHONOMIC PROCESSES AFFECTING ENAMEL SURFACES OF HOMININ TEETH FROM LAETOLI AND OLDUVAI (TANZANIA): IMPLICATIONS TO DIETARY INTERPRETATIONS

ABSTRACT: The buccal microwear pattern of premolar and molar teeth has been linked to the composition of the ingested diet in human populations, both extant and fossil. However, numerous enamel surfaces observed for microwear analyses show microscopic damage that can be attributed to post-mortem *taphonomic processes, not related to dietary habits. Post-depositional processes may greatly affect enamel surfaces, occasionally hindering dietary reconstructions based on dental microwear patterns. The present study analyses the damage patterns that can be observed on fossil Hominin teeth from the sites of Laetoli and Olduvai (Tanzania) to differentiate between* ante-mortem *and* post-mortem *processes. The results obtained show that* post-mortem *wear can be easily differentiated from ante-mortem abrasion for its distinct effects, mainly consisting of obliteration of enamel features. The frequency of abraded surfaces in the samples studied is considerably high. Despite the great antiquity of the remains studied, patches of well preserved enamel can still be distinguished in a number of teeth. Well preserved enamel surfaces can be discriminated for their polished appearance and the presence of distinct microwear features.*

KEYWORDS: Microwear – Erosion – Enamel – Hominins– Laetoli – Olduvai

INTRODUCTION

The presence of striations in the enamel surface of primate teeth has been related to the abrasive effect of particles capable of scratching enamel surfaces during food chewing. These particles frequently come as part of the ingested aliments, as is the case of phytoliths present in plant foods, or are incorporated to them during the food processing (sand, dust or ashes). The analysis of microwear features on enamel surfaces is an important source of information on dietary habits, and has been used as a tool for reconstructing paleodiets and ecological behaviours in primate species (Ryan 1979; Walker 1979, 1981, Ungar *et al.* 1995, Teaford, Lytle 1996, Grine 1984, 1986, Kay 1987, Puech 1976, 1978, 1979, 1982, Puech, Pant 1980, Lalueza, Pérez-Pérez 1993, Lalueza et al. 1996, Pérez-Pérez *et al.* 1994, 1999). However, numerous postdepositional agents can damage the enamel surfaces of teeth causing tooth wear that is not related to the processing or ingestion of foods. Although all types of silica particles harder than the enamel crystals, either phytoliths or sedimentary sands, are good candidates to cause enamel damage (Piperno 1988, Ciochon *et al.* 1990), a clear distinction between the effects of *ante-mortem* and *post-mortem* processes affecting enamel surfaces is needed.

Taphonomic processes have been shown to cause distinct *post-mortem* damage in some experimental studies (King *et al.* 1999), and Teaford (1988) demonstrated that the *post-mortem* effects of postdepositional agents on tooth enamel could be distinguished from *ante-mortem* dental microwear. Moreover, some experimental studies suggest that *post-mortem* damage causes a pattern of microwear that is clearly distinct from that caused by food chewing (Gordon, Walker 1983, Maas 1991). No association between the type of erosive agent (dust, ash, sand or phytoliths) and the microwear pattern has been observed (Peters 1982, Maas 1991, Ungar 1992), neither for the width of striations or their orientations (Ungar 1994). In general, taphonomic erosive effects, both physical and chemical, tend to erase and obliterate the striations that formed during lifetime (Teaford 1988; King *et al.* 1999), rather than to produce new formation or secondary alteration of microwear features. Dietary studies based on dental microwear depend on several factors. The surface to be analysed (occlusal, buccal, lingual or interproximal) depends on the type of information searched. In the occlusal surfaces the presence of microwear features, such as pits, striations, furrows, grooves or polished areas, depends on the force and mechanics of mastication (Kay, Hiiemae 1974, Gordon, Walker 1983), the intensity of the effort produced during mastication (Puech *et al.* 1980, Gordon 1982), and the physical properties of food (Teaford *et al.* 1992). The buccal enamel surfaces are not affected by tooth-to-tooth contact during food chewing and the formation of scratches seems to depend only on the dietary habits (Puech, Pant 1980, Lalueza, Pérez-Pérez 1993, Pérez-Pérez *et al.* 1994, 1999). The length, orientation and density of buccal microstriations have been directly related to the human diet, both in modern hunters-gatherers (Lalueza *et al.* 1996) and fossil human populations of several periods (Puech 1982, Pérez-Pérez *et al.* 1994, 1999). However, the effect of taphonomic processes needs to be considered for a precise dietary interpretation of microwear. Despite Teaford (1988) and King *et al.* (1999) clearly discriminated intact surfaces from those with *post-mortem* damage, especially in occlusal surfaces, further microwear analyses need to show that non-dietary related alterations can be ascertained, describing to what extent they might have affected apparently well preserved or near-to-well-preserved enamel. The present study analyses the buccal enamel surfaces of fossil hominin teeth from Olduvai and Laetoli in order to describe the intensity and the type of erosion *vs.* abrasion that can be observed on their enamel surfaces. The main purpose of this study is to determine if both types of alterations (*ante-mortem* and *post-mortem*) can be discerned.

MATERIALS AND METHODS

A total of 235 teeth belonging to 53 hominin specimens from two eastern African sites, Laetoli (N=88) and Olduvai (N=147), were studied. The sample spans from 3.7 to 1.4 myr. The 88 Laetoli teeth analysed belong to 23 individuals attributed to three different species: *Australopithecus afarensis* (22 individuals), *Homo erectus* (1 individual) and *Homo sapiens* (1 individual). The 147 teeth from Olduvai belong to 29 individuals also of three species: *Australopithecus boisei* (5 individuals), *Homo habilis* (19 individuals) and *Homo erectus* (5 individuals). In order to study the enamel erosion not attributable to dietary habits, all teeth with well-preserved enamel surfaces for SEM were selected dietary analysis. In this study the anterior dentition (I1, I2, C) was discarded to control for paramasticatory use of teeth that could modify the dietary microwear. The M3 teeth were also excluded because they do not show a standard eruption pattern in modern human populations and because the effect of their position at the end of the tooth row to buccal microwear is not well known yet. The final sample, only including premolars and molars, was then limited to 164 teeth (69.8%) belonging to 44 individuals (*Table 1*). Replicas of the original teeth curated at the National Museums of Kenya (Nairobi) and Tanzania (Dar es Salaam) were obtained with *President MicroSystem* Regular Body (Coltène®) polyvinylsiloxane. The complete standard procedure is fully described in Galbany *et al.* (2004). SEM micrographs were obtained at 100x magnification for enamel surface comparisons, and in some cases a higher magnification was used to observe detailed structures, such as enamel prisms or perikymata. Micrographs of both *ante-mortem* scratched and *post-mortem* damaged enamel surfaces were obtained on the medial third of the buccal side of the tooth crowns, avoiding both the occlusal and cervical thirds of the tooth, as in standard buccal microwear research.

RESULTS

A clear distinction between *ante-mortem* and *post-mortem* buccal enamel surfaces can be made from the observation of SEM images. The buccal surfaces studied can be classified in two groups: 1) nearly flat, clear surfaces with fine dietary striations of various lengths and widths (10–20 µm), and 2) eroded surfaces with irregular aspect, rough and eroded in appearance, and in some cases with a high density of striations which run parallel to each other, as indicator of *post-mortem* alteration processes (King *et al.* 1999). Only 23 (14%), of the 165 analysed teeth, had a well-preserved enamel surface, without evident *post-mortem* alterations (Pérez-Pérez *et al.* 2003). This low percent of well-preserved surfaces suggests that intense post-depositional effects affected the teeth from Olduvai and Laetoli. The damaged teeth showed distinct wear patterns that could be clearly attributed to *post-mortem* damage. The presence of these alterations was not homogeneous in all the studied teeth, and a single tooth could show both types of surfaces (well-preserved and damaged), as well as different types of alterations.

Well-preserved surfaces had a clear buccal striation pattern, with scratches running in different orientations and lengths (*Figure 1*). No dietary pits were observed on well-preserved enamel surfaces. In some cases, well-preserved teeth also showed patches of slightly damaged enamel,

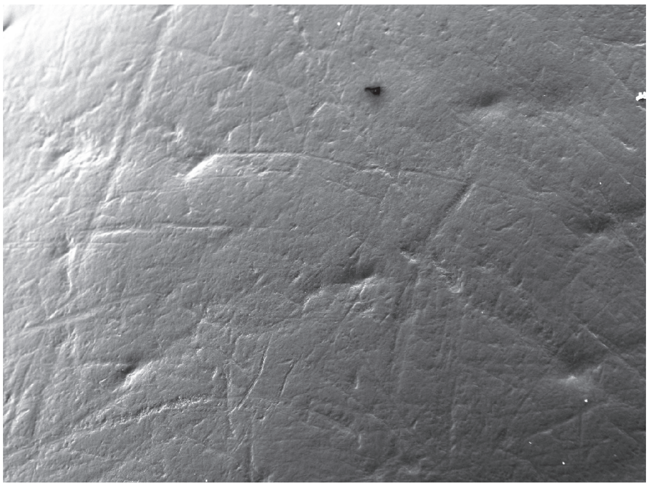

FIGURE 1. S300623 OH-57, lower left Pm.

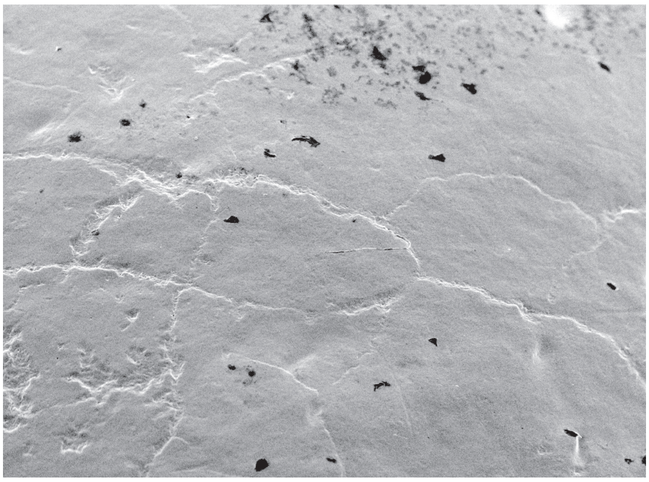

FIGURE 2. S330612a. *H. habilis* (OH 44), upper right M1.

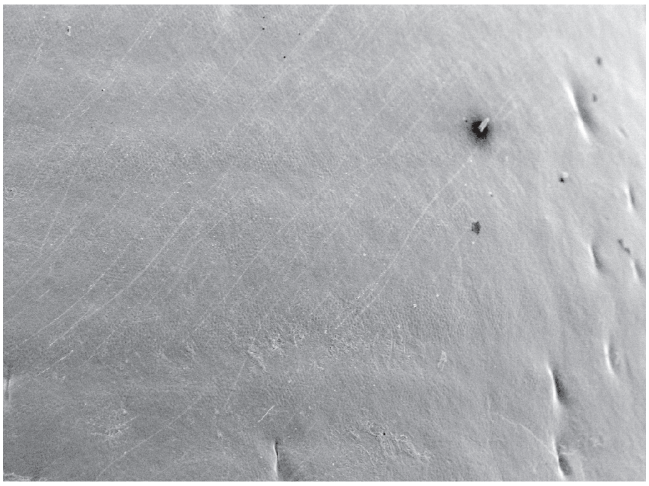

FIGURE 3. S320593b. *H. habilis* (OH 6), upper right M1.

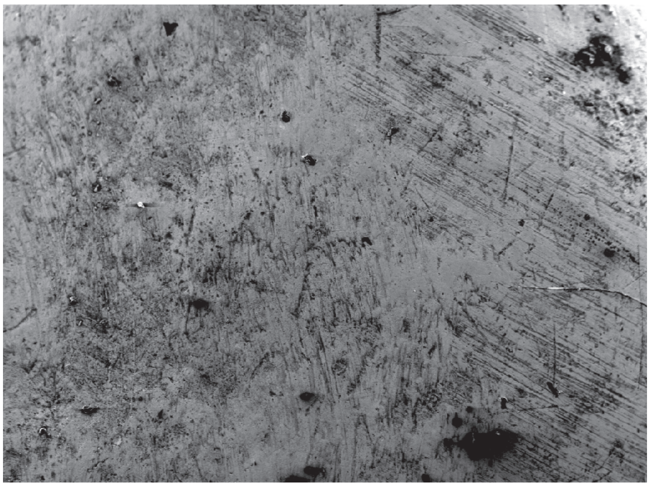

FIGURE 4. S270567. *H. habilis* (OH 7), lower left M1.

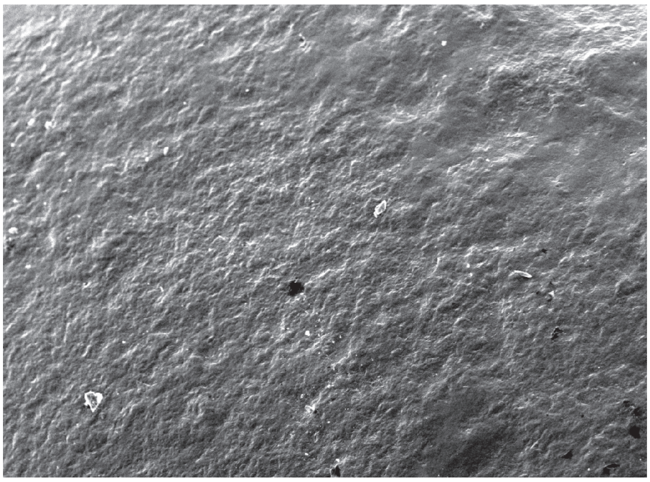

FIGURE 5. S300636. *Homo ergaster* (OH 22), lower right M1.

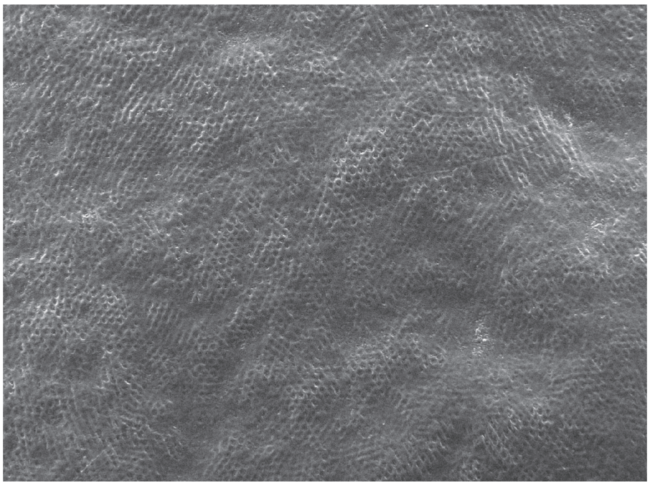

FIGURE 6. S360669.2. *A. afarensis* (LH 6), unerupted upper left premolar.

irregular surfaces, or enamel cracks (*Figure 2*) that tended to erase the normal striation pattern. The combination of well-preserved and altered surfaces in the same teeth seems to be indicative of low to moderate erosion not affecting the whole tooth. More eroded surfaces showed a high density of parallel striations, sometimes combined with enamel prisms exposure and pitting (*Figure 3*). These surfaces probably rolled along the sediment in a *post-mortem* process resulting in an intense pattern of parallel scratching and (*Figure 4*). If the erosion is very heavy and

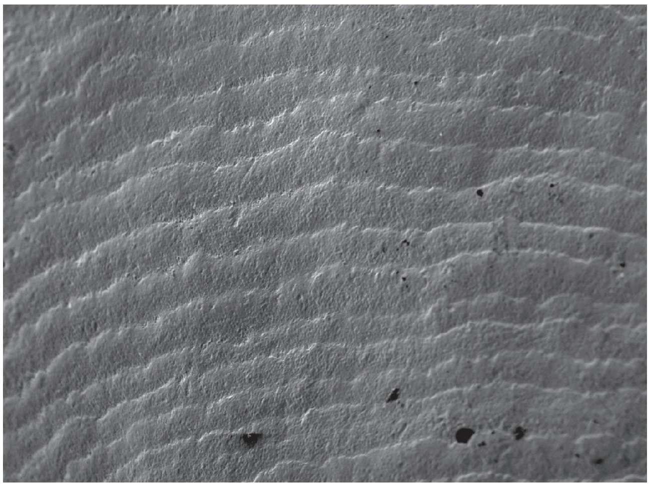

FIGURE 7. S260542.1. *H. habilis* (OH 13), lower right Pm4.

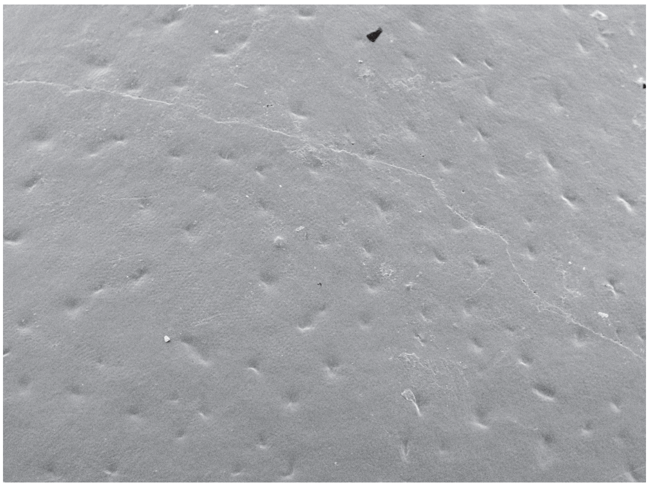

FIGURE 8. S320591a. *Homo ergaster* (OH 15), upper right molar.

generalised, it may result in enamel loss, without striations (*Figure 5*). In some cases, enamel prisms exposure affects large surfaces of enamel, if not the whole crown (*Figure 6*), something especially frequent in deciduous teeth. Such generalised pattern of prisms exposure could be due to chemical weathering (King *et al.* 1999). When prisms exposition is due to physical abrasion, the prisms are mainly observed only in reduced, prominent areas. However, physical wear can also affect large areas of enamel, which is especially frequent on unerupted teeth (*Figure 5*), perhaps because the enamel is more susceptible to *post-mortem* physical erosion. The kind of the sediment, such as carbonates or silicates, can also chemically affect the enamel (King *et al.* 1999). When the chemical erosion is intense, it is usual to observe a generalised exposition of growth lines (*Figure 6*) or perykimata, attributable to some type of chemical alteration due to the uniformity and large extension of the affected area. Physical erosion tends to produce less extended and slight enamel prisms and perykimata exposure (*Figure 3*). In some surfaces enamel alteration was observed as large and flat enamel surfaces, with almost evenly dispersed *pits* (*Figure 8*). The linear and uniform distribution of these *pits* suggests that erosion was in initially affecting the enamel layers and that if erosion had continued, perykimata lines would have been exposed.

All the enamel alterations observed on the analysed teeth should be attributed to *post-mortem* damage. In all instances their appearance clearly differed from the buccal surfaces where the *a.m.* microwear pattern is clearly observed (Pérez-Pérez 1990). Although the sample comes from two different sites with different dating (Laetoli 3.7–3.5 myr, and Olduvai 1.9–1.4 myr) we have observed no relevant differences in the distribution of these taphonomic features. Whenever an individual showed a well-preserved tooth surface, other teeth of the same individual also tended to show non-eroded enamel. In the same way, whenever a given tooth showed a heavy pattern of erosion, all the teeth of the same individual were also affected in the same way. Finally, the among-species distribution of the *p.m.* erosion patterns has not showed yet differences in tooth preservation among species.

DISCUSSION

Paleodietary research requires the analysis of tooth surfaces not affected by *post-mortem* erosion. Therefore, to demonstrate a clear relationship between abrasiveness of diet and the buccal microwear pattern, it is necessary to discern between both taphonomic altered surfaces and well-preserved ones. The erosion shown in the observed surfaces can be attributed, in the majority of the cases, to physical *post-mortem* effects, such as transport along the sediment, rolling or impact of siliceous particles. This kind of erosion usually produces striations which run parallel to each other, with a clear directionality pattern, obliterating any dietary microwear feature. Generalised and uniform alterations affecting enamel surfaces tend to be characterised by exposition of growth lines and enamel prism, and most likely due to chemical weathering of the enamel caused by acidic sediment or waters. Slight levels of enamel erosion tend to produce a combination of well-preserved and slightly eroded surfaces. In general, both physically and chemically eroded enamel surfaces seem to be result in the obliteration of the *a.m.* microwear pattern, at least on the buccal surfaces of teeth. Experimental studies have demonstrated that chemical and physical erosions are readily identifiable, and both are responsible of the obliteration of the microwear pattern (King *et al.* 1999). These experimental analyses have shown that an intense chemical erosion was produced with exposition to 2.5% clorhidric acid for 2 hours, resulting in a generalised exposition of enamel prisms with almost all microwear features removed (as in *Figure 6*). This chemical effect was not so extensive when the citric acid was used instead, but prism exposure was also observed. However, alkali treatment (pH 10.54) did not modify the enamel microwear.

Other experimental analyses have focused on the effects of different particle size sediments, showing that the most noticeable alteration was due to medium grain sand. In this case the alteration started with gradual formation of *pits*, progressively extending to greater areas of enamel and eventually causing obliteration of microwear features that was not uniform in the entire tooth crown. If we take into account these experimental studies (Gordon 1984; King *et al.* 1999), we can conclude that in the sites of Olduvai and Laetoli both chemical and physical *post-mortem* alteration processes took place, and that, as noted by other authors (Teaford 1988, King *et al*. 1999), such alterations are clearly distinguishable from well-preserved surfaces.

REFERENCES

CIOCHON R., PIPERNO D., THOMPSON R. G., 1990: Opal phytoliths found on the teeth of the extinct ape *Gigantopithecus blacki:* Implications for paleodietary studies. *Proc. Nat. Acad. Sci. U.S.A.* 87: 8120–8124.

GALBANY J., MARTÍNEZ L. M., PÉREZ-PÉREZ A., 2004: Tooth replication techniques, SEM imaging and microwear analysis in primates: methodological obstacles. *Anthropologie* XLII, 1. This issue.

GORDON K. D., 1982: A study of microwear on chimpanzee molars: Implications for dental microwear analysis. *Amer. J. of Phys. Anthrop.* 63: 164–164

GORDON K. D., 1984: Taphonomy of dental microwear, II. *Amer. J. of Phys. Anthrop.* 64: 164–165.

GORDON K. D., WALKER A., 1983: Playing' possum: A microwear experiment. *Amer. J. of Phys. Anthrop.* 60: 109–112.

GRINE F. E., 1984: Deciduos molar microwear of South African australopithecines. In: D. J. Chivers, B. A. Wood, A. Bilsborough (Eds.): *Food Acquisition and Processing in Primates.* Plenum Press, New York.

GRINE F. E., 1986: Dental evidence for dietary differences in *Australopithecus* and *Paranthropus*: A quantitative analysis of permanent molar microwear. *J. of Hum. Evol.* 15: 783–822.

KAY R. F., HIIEMAE K. M., 1974: Jaw movement and tooth use in recent and fossil primates. *Amer. J. of Phys. Anthrop.* 40: 227–256.

KAY R. F., 1987: Analysis of primate dental microwear using image processing techniques. *Scanning Microscopy* 1: 657–662.

KING T., ANDREWS P., BOZ B., 1999: Effect of taphonomic processes on dental microwear. *Amer. J. of Phys. Anthrop.* 108: 359–373.

LALUEZA C., PÉREZ-PÉREZ A., 1993: The diet of the Neanderthal Child Gibraltar 2 (Devil's Tower) through the study of the vestibular striation pattern. *J. of Hum. Evol.* 24: 29–41.

LALUEZA C., PÉREZ-PÉREZ A., TURBÓN D., 1996: Dietary inferences through buccal microwear analisis of Middle and Upper Pleistocene human fossils *Amer. J. of Phys. Anthrop.* 100: 367–387.

LALUEZA C., PÉREZ-PÉREZ A., TURBÓN D., 1993: Microscopic study of the Banyoles mandible (Girona, Spain): Diet, cultural activity and toothpick use. *J. of Hum. Evol.* 24: 281–300.

LALUEZA C., PÉREZ-PÉREZ A., TURBÓN D., 1996: Dietary inferences through buccal microwear analisis of Middle and Upper Pleistocene human fossils *Amer. J. of Phys. Anthrop.* 100: 367–387.

MASS M. C., 1991: Enamel structure and microwear: An experimental study of the response of enamel to shearing force. *Amer. J. of Phys. Anthrop.* 85: 31–49.

PÉREZ-PÉREZ A., ESPURZ V., BERMÚDEZ DE CASTRO J. M., DE LUMLEY M. A., TURBÓN D., 2003: Non-occlusal dental microwear variability in a sample of Middle and Late Pleistocene human populations from Europe and the Near East. *J. of Hum. Evol.* 44: 417–513.

PÉREZ-PÉREZ A., 1990: *Evolución de la dieta en Cataluña y Baleares desde el Paleolítico hasta la Edad Media a partir de restos esqueléticos.* PhD Dissertation Series, University of Barcelona, Barcelona (Spain).

PÉREZ-PÉREZ A., LALUEZA C., TURBÓN D., 1994: Intraindividual and intragroup variability of buccal tooth striation pattern. *Amer. J. of Phys. Anthrop.* 94: 175–187.

PÉREZ-PÉREZ A., BERMÚDEZ DE CASTRO J. M., ARSUAGA J. L., 1999: Non-occlusal dental microwear analysis of 300,000-year-old *Homo heidelbergensis* teeth from Sima de los Huesos (Sierra de Atapuerca, Spain). *Amer. J. of Phys. Anthrop.* 108: 433–457.

PETERS C. R., 1982: Electron-optical microscopic study of incipient dental microdamage from experimental seed and bone crushing. *Amer. J. of Phys. Anthrop.* 57: 590–592.

PIPERNO D., 1988: Phytolith analysis. *An Archaeological and Geological Perspective.* Academic Press, London. 280 pp.

PUECH P. F., 1976: Recherche sur le mode d'alimentation des hommes du Paléolithique par l'étude microscopique des couronnes dentaires. In: H. De Lumley (Ed.): *La Préhistoire française.* Vol. 1. Pp. 709–710. C.N.R.S., Paris.

PUECH P. F., 1978: L'alimentation de l'homme préhistorique. *La Recherche* 94: 1029–1031.

PUECH P. F., 1979: The diet of early man: Evidence from abrasion of teeth and tools. *Curr. Anthrop.* 20: 590–592.

PUECH P. F., 1982: L'usure dentaire de l'Homme de Tautavel. In: ———————— (Ed.): L'Homo erectus et la place de l'Homme de Tautavel parmi les hominidés fossiles. *1er Congrès International de Paléontologie Humaine, Tome 1.* Pp. 249–275. Nice: Colloque International du C.N.R.S., Nice.

PUECH P. F., ALBERTINI H., MILLS N. T. W., 1980: Dental destruction in Broken Hill Man. *J. of Hum. Evol.* 9: 33–39.

PUECH P. F., PANT R., 1980: Un modèle d'étude de l'alimentation des hommes fossiles. *Bulletin et mémoires de la Société d'anthropologie de Paris* 7(13): 61–64.

RYAN A. A., 1979: A preliminary scanning electron microscope examination of wear striation direction on primate teeth. *J. of Dental Research* 58: 525–530.

TEAFORD M. F., 1988: Scanning electron microscope diagnosis of wear patterns versus artifacts. *Scanning Microscopy* 2: 1167–1175.

TEAFORD M. F., LYTLE L. J., 1996: Brief communication: diet-induced changes in rates of human tooth microwear: a case study involving stone-ground maize *Amer. J. of Phys. Anthrop.* 100: 143–147.

TEAFORD M. F., RUNESTAD J. A., 1992: Dental microwear and diet in Venezuelan primates. *Amer. J. of Phys. Anthrop.* 88: 347–364.

UNGAR P., 1992: Feeding behaviour and dental microwear in Sumatran Anthropoids. *Amer. J. of Phys. Anthrop.* S14: 165–165.

UNGAR P., 1994: Incisor microwear of Sumatran Anthropoid primates. *Amer. J. of Phys. Anthrop.* 94: 339–363.

UNGAR P., TEAFORD M. F., GLANDER K. E., PASTOR R. F., 1995: Dust accumulation in the canopy: a potential cause of dental microwear in primates. *Amer. J. of Phys. Anthrop.* 97: 93–99.

WALKER A., 1979: SEM analysis of microwear and its correlation with patterns. *Amer. J. of Phys. Anthrop.* 50: 489–489.
WALKER A., 1981: Diet and teeth. Dietary hypotheses and human evolution. *Philosophical Transactions of the Royal Society of London [Biology]* 292: 57–64.

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