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New Evidence of Dental Pathology in 40,000-year-old Neandertals

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INTRODUCTION

Unlike modern urban humans with a soft refined diet and consequent rampant dental pathology, especially dental caries and periodontal disease, dental and alveolar pathology was relatively rare in Pleistocene humans. This holds true for the Neandertals, who were contemporaneous with and immediately preceded modern humans in western Eurasia, between ~200,000 and ~35,000 years ago. Among Neandertals, the most general observations of the dentition are a high level of occlusal and interproximal attrition. The wear tended to be greater on the anterior teeth, frequently resulting in complete crown removal of some teeth by the fifth decade of life, and was accompanied by supereruption of the teeth (Trinkaus, 1983). Caries lesions have been documented (Lebel and Trinkaus, 2001), but they were extremely rare (4 out of > 1250 teeth, or ≈ 0.3%). *Ante mortem* tooth loss was present but rare, even in cases of marked occlusal attrition (Heim, 1976; Trinkaus, 1983, 1985). The few known alveolar abscesses were associated with severe attrition and/or *ante mortem* tooth loss (Heim, 1976; Trinkaus, 1985), and pathology of the mandibular body beyond alveolar lesions is unknown. Orthodontic problems included only premolar rotations (Rougier *et al*., 2006). It is in this context that we present dental pathological lesions in two Neandertal fossils from the Sima de las Palomas del Cabezo Gordo, southeastern Spain.

This paper is not intended to be a conceptual advance, but it presents new data regarding the antiquity of human caries lesions and an unusual case of oral pathology.

MATERIALS

The Palomas Neandertal Sample

The Neandertal specimens described were found at the Sima de las Palomas in southeastern Spain. The site is a vertical karstic shaft in an isolated massif of Mesozoic marble (Cabezo Gordo) arising out of the coastal plain near the town of Torre Pacheco. The shaft is 18 m deep and retains a sediment column on one side. Since 1991, systematic excavations of the column by Walker and colleagues have yielded ≈ 250 Neandertal fossils, including three associated partial skeletons, 10 incomplete mandibles, 3 partial maxillae, and 106 teeth (Walker *et al*., 2008, 2010; Walker, 2009). Excavation is ongoing and continues to yield human skeletal material, Late Pleistocene faunal remains, and stone tools.

The two specimens of interest with regard to dental pathology are a lower right first deciduous molar lacking any of the adjacent alveolar bone (Palomas

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25) and a partial left mandibular corpus with 5 teeth in place (Palomas 59). They were excavated in 1995 and 1998, respectively, from Level 2f of the Upper Cutting. The Upper Cutting is at the top of the sediment column and is composed of three components that have yielded Middle Paleolithic (Mousterian) lithics, faunal remains, and isolated Neandertal cranial, mandibular, dental, and post-cranial elements, as well as the three associated skeletons. A combination of radiometric dating techniques and paleoclimatic correlation places the Palomas 25 and 59 remains at ≈ 40,000 years ago, making them among the most recent of the known Neandertal remains. Detailed descriptions of the geology of the site, its paleoecology, the fossil remains, and dating methods can be found in previous publications (Carrión *et al*., 2003; Walker *et al*., 2008; Walker, 2009).

The Palomas 25 Deciduous Molar

Palomas 25 is a lower right first deciduous molar (dm1; US, S; FDI, 84) consisting of the crown and a portion of the broken roots (Figs. 1C, 1D). There is occlusal attrition, with dentin exposure along the buccal side, combined with mesial and distal interproximal facets (Fig. 1A). Both the tooth and its adjacent second deciduous molar (dm2; US, T; FDI, 85) had therefore been in occlusion for some period of time, which indicates a minimum age of 3 years post-natal (Liversidge and Molleson, 2004). The root is broken and not resorbed (Figs. 1C, 1D), indicating that it was still in occlusion at the time of death, sometime prior to a normal age of exfoliation ≈ 10 yrs post-natal (Smith, 1991).

The Palomas 59 Mandibular Dentition

Palomas 59 consists of the body of a left mandible extending from the I2 (US, 23; FDI, 32) alveolus to the alveolar bone mesial to the M3 (US, 17; FDI, 38). Complete teeth are present from C to M2 (US, 18-22; FDI, 33-37). The individual was mature at death, since an M2 distal interproximal facet indicates the *ante mortem* presence of an occlusal M3. The degree of occlusal wear approximates Smith's (1984) stage 2 for P3, stage 3 for C, P4, and M1, and stage 4 for M2. Compared with modern foraging populations and Late Pleistocene humans (Davies and Pedersen, 1955; Moorrees, 1957; Trinkaus, 1995; Hillson *et al*., 2006), this level of attrition indicates a young adult at the time of death.

PATHOLOGICAL LESIONS

Palomas 25 Dental Caries Lesion

Visual examination of the Palomas 25 deciduous molar revealed a deep pit within the occlusal surface just interior to the distobuccal cusp (Figs. 1A, 1B; the extensive mineralization of the tooth prevented us from obtaining usable radiographs). The pit extends through the exposed dentin mesially and the worn enamel distally. The pit is 1.2 mm in maximum diameter and passes through the occlusal surface to form a cavity within the crown. Although there is a fossilization crack through the pit and the adjacent crown, and there has been some etching of the external crown surface, the distolingual and mesiobuccal sides of the pit exhibit smooth *ante mortem* rounding into the depression. The exposed edges of the hole are smooth, suggesting cavity initiation, possibly within a developmental pit. The floor of the cavity has some hard sediment encrustations, but the exposed dentin surface appears roughened, similar to the eroded surfaces found within caries lesions.

Palomas 59 Second Molar Abnormalities

As measured by the degree of dentin exposure, the Palomas 59 M2 has greater occlusal attrition than the M1 (Fig. 2A). The greater wear is evident in the crown heights of the two molars (Fig. 2B): The buccal crown height (4.9 mm) of the M2 is 86% of that on the M1 (5.7 mm). Assuming that the M2 erupts six years after the M1, and estimating that the individual lived until age 25, the M1 should have been in functional occlusion ≈ 50% longer than the M2, with correspondingly greater wear. The Palomas 59 M2 then would be expected to have less occlusal wear than the M1, rather than the reverse. Among Neandertals in whom both molars were preserved (N = 16), 81% had greater M1 wear, 19% had equivalent wear, and none had greater M2 wear. Among Late Pleistocene early modern humans (contemporaneous with or immediately following the Neandertals in time; N = 32), 87% had greater M1 wear, and the remainder had similar M1 and M2 wear.

As best we could determine given the irregularity of and minor damage to the buccal alveolar crest, the two molars have similar cervix-to-alveolar crest heights. The occlusal surfaces of the two molars remain on the same plane and follow a smoothly curving arc from C to M2. In the context of differential occlusal attrition and similar cervix-to-alveolar crest heights, marked supereruption of M2 is not apparent, yet some degree of supereruption seems likely.

The greater wear of the M2 may be related to radiographic changes in and near its root apices, which manifest thickening of the root walls, as well as a periapical abnormality that appears as a radiopaque mass between and adjacent to the root apices (Fig. 2C). The mass is traversed by a radiolucent gap 1 mm wide. The overall radiographic form of the root is due to its taurodontism, a non-pathological enlargement of the pulp chamber and root canals with a low root bifurcation commonly found in Neandertals (Trinkaus, 1983).

Palomas 59 Dental Caries Lesions

The adherence of hard cemented sediment (breccia) in the interproximal areas of Palomas 59, which cannot be removed without risk of further damage to the fossil, makes definitive diagnosis of dental caries difficult. This is complicated by the need to discriminate between the effects of *ante mortem* processes, such as dental caries, and changes incurred during fossilization. Radiographic examination, CT scans, and careful surface examination were applied, but a degree of uncertainty remains, especially given the radiopacity of the heavily mineralized bone and teeth. The ambiguity was apparent when a conspicuous and apparent defect was found on a lateral radiograph, an ovoid radiolucency near the mesial cervix of the M2 (Fig. 2C). However, this apparent defect is the result of a *post mortem* gap in the adherent breccia (Fig. 3A). Yet, slightly superior to the gap there is a concave notch on the buccal aspect of the mesial surface of the M2, whose edges round into a concavity filled with sediment. This notch corresponds to a clear but faint radiolucency on the lateral radiograph (Fig. 2C), and it is apparent as a notch in the CT image (Fig. 3B). This is presumed to be a caries lesion.

In addition, there are radiolucencies on the distal and mesial surfaces of the M1 crown. Both areas are buried in breccia. The CT image shows irregularities on the M1 distal surface that correspond to the radiolucencies, supporting the view that they represent *ante mortem* defects caused by dental caries. The mesial translucency is not detectable on the CT scan and may be an artifact. The mesiobuccal defect on the M2 and the interproximal surface radiolucencies on the M1 therefore strongly suggest caries lesions.

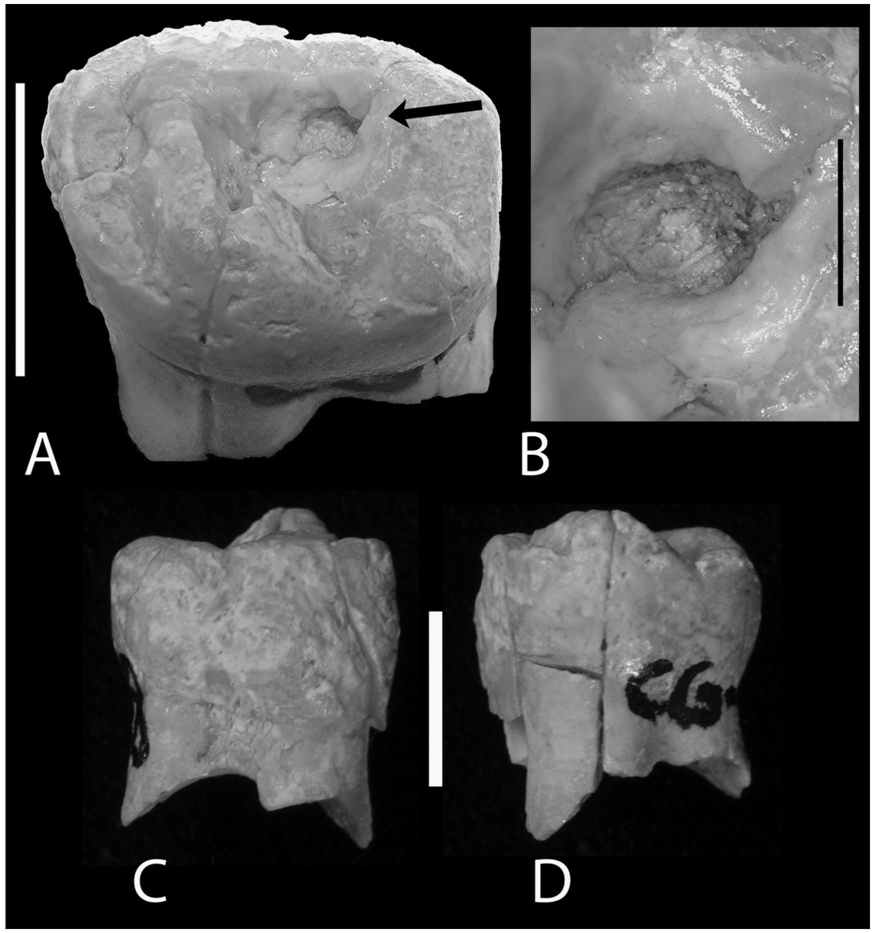

Figure 1. The Palomas 25 mandibular deciduous first molar (dm1; S). **(A)** Bucco-occlusal view of the tooth crown with the lesion indicated. Scale bar: 5 mm. **(B)** Detail of the occlusal lesion. Scale bar: 1mm. **(C, D)** Buccal and lingual views, respectively, of the crown and broken root. Scale bar: 5 mm.

DISCUSSION

Dental Caries

Dental caries lesions have been well-documented in modern non-human primates and in human fossils prior to the Neandertals (Schultz, 1956; Koritzer and St. Hoyme, 1979; Grine *et al.*, 1990), albeit all from low latitudes. Yet, as noted above, they have rarely been documented in western Eurasian Neandertals. They have been identified in remains from northeastern Spain (Banyoles 1), coastal Israel (Kebara 27), and southeastern France (Aubesier 5 and 12) (Lalueza *et al.*, 1993; Tillier *et al.*, 1995; Trinkaus *et al.*, 2000; Lebel and Trinkaus, 2001). Assuming that the occlusal defect on the Palomas 25 deciduous molar and the radiolucencies on the M1/M2 interproximal surfaces of the Palomas 59 molars are indicative of caries, they increase the sample by 50%. Yet, there are > 1250 Neandertal teeth known, including the 106 teeth with largely complete crowns from Sima de las Palomas, indicating a documented incidence of caries lesions of < 0.5% for Neandertal teeth.

These Neandertal caries lesions are joined by 5 additional ones among contemporaneous early modern humans from southwestern Asia (Qafzeh 3 and 4; Skhul 2) (Sognnaes, 1956; Tillier *et al.*, 2004; Trinkaus and Pinilla, 2009). Even when these morphologically different but contemporaneous human fossil samples are pooled, the incidence remains low, 0.7% of > 1500 teeth.

All of the currently identified Neandertal (and early modern human) caries lesions, with the exception of Palomas 59, have been found on occlusal surfaces or in isolated teeth, so it is likely that systematic radiographic analysis of their dentitions would reveal heretofore undetected interproximal caries lesions, given the predominance of interproximal ones among prehistoric populations with high levels of occlusal attrition and consequent supereruption (Hillson, 2008). Still, the prevalence is very low, even compared with that in high-latitude recent populations living on pre-industrial unrefined diets (Pedersen, 1966; Mayhall, 1978; Costa, 1980; Hillson, 2008).

It may be significant that the Neandertal teeth with carious defects, as well as the early modern human ones, come from sites near the Mediterranean. The area of the Sima de las Palomas experienced a relatively warm climate through the Late Pleistocene, especially when the sediments of the Upper Cutting were deposited (Carrión *et al.*, 2003). The presence of these lesions among the southerly, but apparently not among more northerly, Late Pleistocene Neandertals and Middle Paleolithic modern humans suggests a climatic correlation. Perhaps the greater availability in warmer climates of fruits and sugar-rich plant organs contributed to a higher (but still exceptionally low) prevalence of caries lesions.

Since the oral bacterium *Streptococcus mutans* metabolizes sucrose into lactic acid, thereby producing caries lesions, it is conceivable that the caries lesions present in the Palomas 25 and

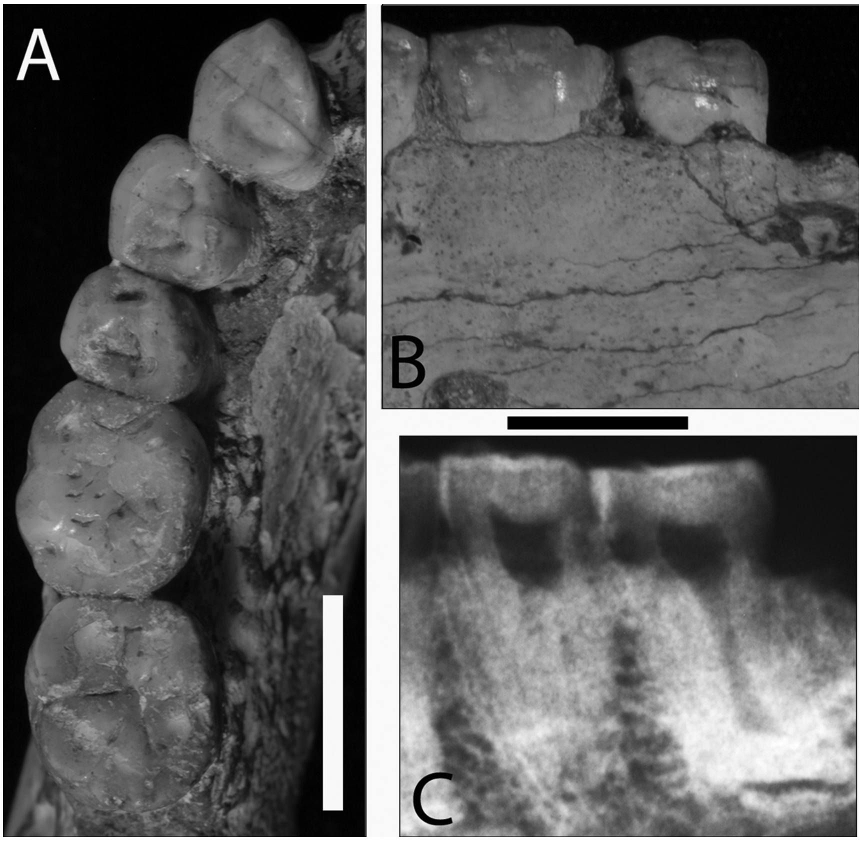

Figure 2. The Palomas 59 mandibular dentition. **(A)** Occlusal view of the Palomas 59 preserved dentition. **(B)** Buccal view of the Palomas 59 molars, and **(C)** lateral radiograph of the molars. The changes to the M2 root are apparent as thickening of the root walls and an adjacent radiopaque mass between and adjacent to the root apices. Possible caries defects are evident on the mesial second molar (M2) and the distal first molar (M1). The low resolution of the radiograph is a product of the high degree of mineralization of the specimen. Scale bars: 10 mm.

59 teeth and those of other Neandertals were caused by bacteria, of which *S. mutans* is the most commonly associated. Limited data on bacteria in the dental calculus of Neandertals have identified primarily cocci forms in a Mediterranean Neandertal, whereas only the filamentous form was present in one further north in Europe (Vandermeersch *et al*., 1994; Pap *et al*., 1995).

Palomas 59 M2 Abnormalities

The simultaneous occurrence of unusual occlusal attrition and periapical pathology in Palomas 59 is suggestive of, but does not prove, a causal relationship. The radiopaque mass adjacent to the root apices may be a cementoma, a benign fibrous tumor of unknown etiology that arises from cementoblasts in the periodontal ligament and often becomes mineralized (Resnick and Novelline, 2008). It is possible that expansion of such a tumor caused slight supereruption of the M2, which in turn subjected it to greater occlusal forces and increased wear. Alternatively, the radiopaque mass may be a calcified periapical abscess (Schulz *et al.*, 2009), which would also put eruptive pressures on the molar. Given the absence of lesions breaching the pulp chamber or evidence of severe periodontal infection, this seems less likely. It is also possible that the periapical mass may be a reactive lesion to increased occlusal forces imposed by changes in the opposing teeth (Corruccini *et al*., 1987), but since the opposing dentition has not been found, this can only be speculated. Unfortunately, it is not possible to test these alternatives, or to seriously evaluate others with the preserved remains.

A question arises as to whether the mutans streptococci (the biological basis of dental caries) existed in the times of the Neandertals (between ~200,000 and 35,000 years ago). Coykendall suggested that because the DNA base sequences of the mutans species are so disparate, the group did not evolve recently and could be as old as 1 million years (Coykendall, 1976). Therefore, there is a possibility that the mutans streptococci could have been related to the Neandertal lesions.

SUMMARY

The fossil remains from the Sima de las Palomas add to the small sample of caries lesions affecting Neandertals and reinforce the pattern of oral pathology that has been emerging for these late archaic humans. Alveolar lesions, *ante mortem* tooth loss, and orthodontic problems, as well as caries lesions, remain rare, in the context of high levels of occlusal and interproximal attrition, dental supereruption, and calculus accumulation. This implies a level of oral health rarely seen in more recent, sedentary human populations without routine dental care. As such, the Neandertal pattern, reinforced by the Palomas specimens, may provide a framework against which to view the abundant dento-alveolar abnormalities of recent human populations.

This oral health pattern is accompanied by the abnormalities of the Palomas 59 second molar. As with a number of both Neandertal (Trinkaus, 1983; Fennell and Trinkaus, 1997) and early modern human (Formicola and Buzhilova, 2004; Trinkaus *et al*., 2006; Shang and Trinkaus, 2010) sets of lesions, the abnormalities are obvious, the proximate causes are sometimes apparent, but the ultimate etiologies remain obscure. Diagnosis is inhibited by incomplete fossil preservation, as with Palomas 59. Yet, these lesion patterns raise the issue of changing developmental and degenerative pathological patterns through human evolution.

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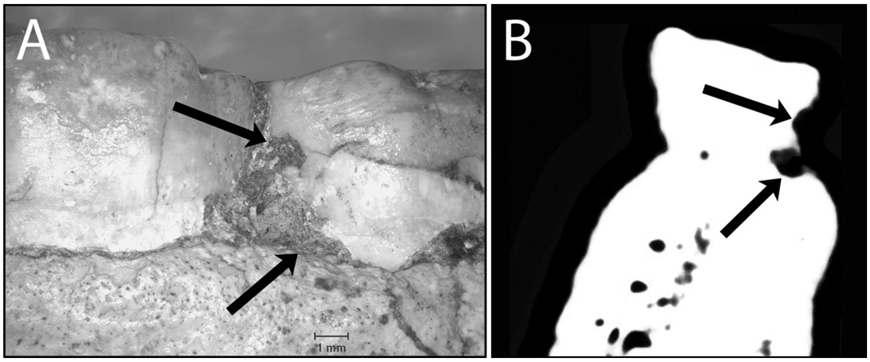

Figure 3. Abnormalities of the Palomas mandibular molars. **(A)** Detail of the Palomas 59 buccal first (M1) and second (M2) molars. **(B)** CT slice through the mesial M2. The lower arrows indicate the fossilization defect; the upper arrows indicate the probable caries lesion.

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