Buccal striations on fossil human anterior teeth: evidence of handedness in the middle and early Upper Pleistocene

The presence of gross preferentially distributed striations on the buccal surfaces of permanent anterior teeth of Neandertal individuals from La Quina, Hortus and Angles-sur-l'Anglin (France), Saint Brais (Switzerland) and Shanidar (Iraq) has led some authors to hypothesize that Neandertals used stone tools to cut something held between the anterior teeth, inadvertently scratching the enamel at the same time. We also observe these striations on the anterior teeth of Middle Pleistocene hominids from Atapuerca/Ibeas, Spain, on the incisors of La Quina 5, and on one isolated I1 from Cova Negra, Spain. Macro- and microscopic studies of these striations, together with those striations produced in an experimental study suggest that scratching of these hominid anterior teeth was indeed the result of ante-mortem tool use, producing striations indicating right- (normally) or left-handedness (rarely). These results provide indirect evidence for lateralization of the brain of Middle and early Upper Pleistocene hominids.

Introduction

During the last 60 years several authors have noted the presence of distinct striations on the buccal surfaces of the upper permanent anterior teeth of certain Neandertal specimens (Martin, 1923; Koby, 1956; Patte, 1960; de Lumley, 1973; Trinkaus, 1983). In a preliminary report (Fernández Jalvo & Bermúdez de Castro, in press) evidence was presented of similar striations on the buccal faces of 14 permanent upper and lower anterior teeth, and on one deciduous lower canine of the Middle Pleistocene hominids from the Sima de los Huesos site (Ibeas de Juarros, Burgos) in the Sierra de Atapuerca, Spain (Aguirre & de Lumley, 1977; Aguirre & Rosas, 1985; Aguirre et al., 1986; Bermúdez de Castro, 1986).

Inspection of these striations by eye or by light binocular microscopy led Martin (1923), de Lumley (1973) and Trinkaus (1983) to hypothesize that Neandertals cut pieces of meat or other matter held between the maxillary and the mandibular incisors with a stone tool, inadvertently scratching the enamel at the same time. To date this hypothesis has yet to be examined further.

The aim of the present study is to further examine the stated hypothesis by making both a macro- and microscopic study of striations observed on the anterior teeth of some fossil hominids, and of striations produced during a simulated cutting experiment. It was hoped that in so doing we would learn something more of the origin of the hominid striations and that criteria for the determination of handedness of the tool-user could be applied. We operated on the assumption that the tool-user scratched his/her own teeth, thus presenting the unique situation (in the sense of hominid cutmark studies) whereby the anatomical relation between the cutmark (teeth) and the hand (stone tool) are known.
The sample

The human fossil material examined consists of 19 specimens from Atapuerca/Ibeas (Table 1), which, after the 1987 season, constitute the sample of anterior teeth of this Anteneanderntal site showing buccal striations. The right I\(^1\) and left I\(^1\) of the La Quina 5 hominid (France), and one isolated right upper central incisor from Cova Negra (Valencia, Spain)* were also investigated. Moreover, we have had the opportunity to examine the anterior teeth of the individuals VII, VIII, IX, XI and XII from the Hortus site (France), which also show buccal striations (de Lumley, 1973).

Table 1

<table>
<thead>
<tr>
<th>Individual*</th>
<th>Inventory number</th>
<th>Tooth</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>AT-27 I(^1)</td>
<td>Upper</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>AT-42 I(^1)</td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>AT-55 I(_2)</td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>AT-162 I(_1)</td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>III</td>
<td>AT-67 C</td>
<td>Upper</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>AT-103 I(_2)</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>AT-104 I(_1)</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>VII</td>
<td>AT-145 C</td>
<td>Upper</td>
<td>L</td>
</tr>
<tr>
<td>X</td>
<td>AT-90 dc</td>
<td>Upper</td>
<td>L</td>
</tr>
</tbody>
</table>

Teeth not assigned to individuals:

<table>
<thead>
<tr>
<th></th>
<th>Tooth</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT-6</td>
<td>C</td>
<td>L</td>
</tr>
<tr>
<td>AT-7</td>
<td>I(_2)</td>
<td>L</td>
</tr>
<tr>
<td>AT-8</td>
<td>I(_1)</td>
<td>L</td>
</tr>
<tr>
<td>AT-29</td>
<td>I(_2)</td>
<td>R</td>
</tr>
<tr>
<td>AT-54</td>
<td>I(_1)</td>
<td>L</td>
</tr>
<tr>
<td>AT-146</td>
<td>I(_1)</td>
<td>R</td>
</tr>
<tr>
<td>AT-165</td>
<td>I(_1)</td>
<td>R</td>
</tr>
<tr>
<td>AT-5</td>
<td>I(_2)</td>
<td>R</td>
</tr>
<tr>
<td>AT-166</td>
<td>I(_1)</td>
<td>R</td>
</tr>
<tr>
<td>AT-167</td>
<td>I(_2)</td>
<td>L</td>
</tr>
</tbody>
</table>

* After the 1987 season, a minimum number of 11 individuals have been identified in the Atapuerca hypodigm.

The striations observed by us on the anterior teeth from Atapuerca/Ibeas, La Quina 5, Cova Negra, and Hortus, as well as those noted by Koby (1956) on one isolated I\(^1\) from Saint Brais (Switzerland), by Patte (1960) on one isolated I\(^1\) from Angles-sur-l’Anglin (France), and by Trinkaus (1983) on the left I\(^1\) and I\(^2\) of the Shanidar 2 hominid (Iraq), are located only on the buccal face and they are not present on the post-canine teeth. Furthermore, the striations of the specimens that we have examined personally are observed to be more frequent on the central area of the buccal face, and more scarce on the mesial and distal aspects of this face. They are not present on the mesial and distal margins near the interproximal contact with the adjacent tooth, and on the area which is near the enamel–cementum junction. That is to say, the striations are located on the zones more

* In a paper in preparation, the first author has attributed this specimen to the European Neandertal group.
forward on the buccal face. The deciduous right lower canine AT-90 shows an interproximal wear facet situated on its lingual face produced by the contact with the lateral incisor. AT-90 seems to have been rotated with respect to its usual position in the jaw. In this way, the mesial face of AT-90 is located at the same level of the buccal face of the incisors. Striations are exclusively distributed on the mesial face of AT-90. On the other hand, the permanent right lower canines AT-67 and AT-145 and the permanent left upper canine AT-6 show striations only on the mesial aspect of the buccal face. The central and distal aspects of the buccal face of these teeth are laterally positioned in the mouth.

The striations of the Angles-sur-l’Anglin incisor are parallel to the incisal border (Patte, 1960), but on the anterior teeth of Atapuerca/Ibeas, Hortus, Saint Brais, La Quina 5 and Shanidar 2 most of the striations are oblique and run according to the following orientations (Figure 1):

Right I₁, I₂, left I₁, I₂ and AT-67: from the mesial cervical corner to the distal occlusal one. Left I₁, I₂, right I₁, I₂, AT-6 and AT-90: from the distal cervical corner to the mesial occlusal one.

The individual VIII from Hortus is an exception, because the striations of their anterior teeth have an inverse orientation to those above. That is, on the right incisors and canine the striations run from the distal cervical corner to the mesial occlusal one, and on the left upper incisors and canine the striations run from the mesial cervical corner to the distal occlusal one.

![Diagram](https://example.com/diagram.png)

Figure 1. Disposition and orientation of the striations on the anterior teeth (general scheme).

### Methods and results

The striations on seven Atapuerca/Ibeas anterior teeth (AT-5, AT-42, AT-55, AT-67, AT-104 and AT-146), the I₁ from Cova Negra and the right I₁ and left I₂ of La Quina 5 hominid were examined by scanning electron microscopy (SEM). These specimens were indirectly observed by means of positive replicas made from RS Quick-Set Epoxy Adhesive (RS Components, London) taken from a negative replica cast in Exaflex (G-C Dental...
Indust. Corp., Scottsdale, AZ) material. The replication method used was an adaptation of Bromage (1985, 1987). The replicas were mounted on SEM stubs with carbon conductive paint, sputter coated with gold, and observed either with a Cambridge S4-10 SEM, an ISI-60A SEM and a Jeol JXA-840 SEM.

In order to study the cross-section of the striations, the negative replicas were cut transversely, and the sections were observed by means of a light binocular microscope.

The striations are clearly visible to the naked eye and further examination using a light microscope reveals that they have an oblique arrangement (Figure 1). The SEM examination shows that the striations are very long (generally from 1 to 4 mm), rectilinear or with a gentle curvature and generally have a width of more than 20 μm (Figure 2), reaching in some cases up to 100 μm. The width of most of the striations range from 40 to 60 μm. Furthermore, there are also shorter and narrower striations (1–5 μm) with an irregular arrangement, that can be attributed to the action of abrasive inorganic particles incorporated in food (Figure 3). These particles produce striations whose width range from 1 to 20 μm (Puech, 1982), and whose arrangement corresponds to characteristic patterns on the postcanine teeth in relation to mastication (Puech et al., 1980; Puech, 1982; Walker, 1981). The buccal faces of the Atapuerca/Ibeas postcanine teeth show striations of this nature.

Figure 2. Replica of the buccal face of AT-104, a left lower central incisor (incisal edge at top), showing a wide striation (on the left side of the photograph) presumably produced by a stone tool. Note the Hertzian fracture cones on the lateral margin (medial for the hominid that created it). There are also narrower striations (on the right side) that can be attributed to the action of abrasive inorganic particles incorporated in food.
Figure 3. Hertzian fracture cones produced on glass by a right handed operator using a flint tool. Directionality is from top to bottom. Note the rough lateral (right) margin (field width equals 580 microns).

Figure 4. Replica of the buccal face of AT-55, a right lower lateral incisor (cervix at top). Directionality, in this instance, is from cervix to the incisal edge; handedness is shown by a rough lateral (medial for the hominin that created it) margin. Hertzian cones are illustrated. (Field width equals 690 microns).
Comparative data and interpretation

Martin (1923) considers that the striations which he observed on the upper incisors and canine of La Quina 5 hominid could have been caused during the mastication of hard substances containing silica, perhaps gnawing on a bone or a root. On the other hand, de Lumley (1973) and Trinkaus (1983) suggest that hominids from Hortus and Shanidar could have cut materials held between the anterior teeth with a stone knife and inadvertently scratching the enamel at the same time.

This hypothesis implies that the buccal striations of the anterior teeth were produced *ante-mortem*. Taking the Atapuerca/Ibeas teeth as a reference sample, we must prove that taphonomic agents, which can produce striations on bone with similar features to cutmarks (Andrews & Cook, 1985; Behrensmeyer et al., 1986), are not responsible for the formation of their buccal striations. The Sima de los Huesos site contains derived material (Aguirre & Rosas, 1985). The human and faunal remains were transported by a mud flow and, therefore, they could have been scratched through this process. If the striations were made *post-mortem*, then both human and mammalian dental remains should have been affected in a similar way and on the mesial, distal, lingual and buccal faces. We looked for similar striations on the human postcanine teeth (17 pre-molars and 34 molars), and on a tooth sample of Ursus deningeri (57 incisors, 26 canines, 40 premolars and 110 molars), which was the most abundant species at the Sima de los Huesos site. Using a light binocular microscope, we found no striations similar to those found on the human anterior teeth.

If we then accept an *ante-mortem* origin for the striations observed on the anterior teeth of Atapuerca/Ibeas and of the Neandertal specimens, we must ask how they were produced. If La Quina 5 or other hominids engaged in gnawing bones or roots impregnated with inorganic particles, as Martin suggests (1923), these particles would not have left large buccal striations as we have observed and their arrangement would not be so homogeneous.

Shipman (1981), Shipman & Rose (1984) and Cook (1986) observed that cutmarks on bone exhibit multiple fine striations closely spaced within the main groove and parallel to its long axis. The presence of these fine striations, which is one of the most distinctive features of cutmarks (Shipman & Rose, 1984), are tracks made by the fine projections that deviate to one side or the other of the edge of the artefact (Shipman, 1981). Two isolated actual human teeth were scratched with a flint flake and the striations produced also show these characteristic fine striations within the main groove. The buccal striations of the Atapuerca/Ibeas, La Quina 5 and Cova Negra anterior teeth are often found to be damaged, and this abrasion does not permit us to study their internal structure in any detail. However, we can sometimes find traces of this feature on the striations of these fossil specimens. Recently, it has been shown that cutmarks can be mimicked by scrapes produced by trampling (Andrews & Cook, 1985; Behrensmeyer et al., 1986). Although trampling marks show similar features to cutmarks, they can be differentiated from those produced by stone tools (Cook, 1986).

The I$^1$ of La Quina 5 and the I$^1$ from Cova Negra shows buccal striations accompanied by a parallel, fine and discontinuous scratch. These fine marks are similar to “shoulder effects” that may parallel or diverge from the main groove for part of its length, and that are made with the same stroke as the slicing mark (Shipman & Rose, 1984).

Some of the striations of the Atapuerca/Ibeas, Cova Negra and La Quina 5 anterior teeth show partial Hertzian cones (Figures 2, 3 and 4). These Hertzian cones are caused by
the stress produced on the substrate by the cutting process, and have been described by Lawn (1967) for brittle solids. They have also been observed on glass and on abraded teeth and bones (Gordon, 1984; Bromage & Boyde, 1984). The striations that we have produced experimentally also show these partial Hertzian fracture cones, which are indicators of directionality: the base of the cone faces the cutmark direction (Gordon, 1984; Bromage, 1987).

Cutmarks may be V-shaped in cross-section (Bunn, 1981; Potts & Shipman, 1981). Most of the buccal striations of the Atapuerca/Ibeas, Cova Negra and La Quina 5 anterior teeth are V-shaped in cross-section. However, the cross-sections exhibit considerable variability depending on the edge characteristics of the tool (see Walker & Long, 1977; Shipman, 1981).

It is certainly remarkable that the striations have a similar orientation in all hominid teeth recovered from such different sites (except in Hortus VIII), a fact that argues against trampling or other taphonomic agents as a cause of the striations. This consistent orientation, if the de Lumley (1973) and Trinkaus (1983) hypothesis is true, could be enough to predict that the hominids preferentially used one of their hands when cutting objects held between the incisors. However, it is not enough to know which hand they used; at least, it is not proof by itself.

Bromage (1987) observed that experimental striations on glass made with the right hand showed a rough lateral wall, with oblique faulting and chipping, whereas the medial wall was more or less uniform (in the case of an operator cutting ones own teeth, this would naturally reflect a rough medial wall and smooth lateral wall). When the left hand was used, the opposite condition was observed. Because of slight supination of the hand, the cutting edge does not incise exactly perpendicular to the surface, but cuts with a certain inclination towards the right side (right-handed operator) or towards the left side (left-handed operator) (Bromage, 1987). In the first case, oblique faults and chips are produced in the right side of the striations, where the tool comes into contact with the substrate.

If the hominids from Atapuerca/Ibeas and the Neandertals scratched their teeth with a flint flake, this would be one of the few cases in which handedness criteria may be tested, because the anatomical relation of both the passive object (teeth) and the active object (hand and flint) are known. In order to investigate possible handedness criteria and to test the hypothesis set forth by de Lumley (1973) and Trinkaus (1983), an experimental reproduction of the action proposed by these authors was performed. In order to simulate Neandertal prognathism, a piece of plastic (a mouth-guard used by athletes) was adapted to the mouth of one of us (Y.F.J.). This mouth-guard fitted exactly to the gum and to the maxillary and mandibular teeth. Heated porcelain teeth were then melted onto the plastic guard in their proper anatomical positions. Porcelain teeth were employed because glass has been demonstrated to respond like enamel (both brittle solids) to the cutting process (Bromage, 1987) (the structural anisotropy of surface enamel appears not to result in a differential response to the sort of cutting action employed in this study: see also Maas, 1988). The right-handed operator first gained familiarity with the cutting action and then, while holding pieces of meat by the front teeth, cut off bite-sized pieces with flint flakes prepared for this purpose. The striations produced on the the experimental prosthetic teeth were oriented as in the fossil teeth and illustrated the characteristic oblique faulting on one of their sides according to the pattern A in Figure 5. In the fossil anterior teeth examined here, pattern A was also normally observed, while pattern B was rarely observed, and
pattern C and D not observed. In the experimental study, the action that would produce striations as in the scheme C was uncomfortable and felt less efficient. In the same way, we suppose that the action required to produce striations like those of scheme B would be uncomfortable for a left-handed person. It is important to note in this regard, however, that variations in cutmark patterns (Figure 1) occurs and that this may reflect specific variations in cutting edge morphology or some other variable.

Broader considerations

The orientation of the striations and the criteria for recognising handedness observed in the experimental prosthetic teeth indicate that the striations observed on the Atapuerca/Ibeas, La Quina and Cova Negra anterior teeth were produced by right-handed hominids. This conclusion can be extended to other teeth whose striations have the same orientation. Among the hominids showing buccal striations, Hortus VIII is an exception. We deduce that this individual was probably left-handed. The teeth of Hortus VIII were not available for microscopic (SEM) research.

Hemispheric dominance could have been present in early hominids (Wolpoff, 1983). Several authors have investigated significant asymmetries of the skull and brain of early hominids, which may indicate the development of a profound lateralization of the hominin brain, and which may be related to preferential right-handedness (LeMay, 1976; Holloway, 1980, 1981a,b; Holloway & de la Coste-Lareymondie, 1982; see Falk, 1987, for a recent review). Holloway (1980, 1981a,b), for instance, reported that brain endocasts of certain Middle and early Upper Pleistocene hominids do show evidence of left-occipital, right-frontal petalial patterns, suggesting right-handedness. Furthermore, the preferential direction of core rotation as observed on cortical flakes from Koobi Fora (Kenya) and Ambrona (Spain), led Toth (1985) to conclude that early tool-making hominids from those sites were preferentially right-handed, and that there was a genetic basis for this trait by 1.4-1.9 million years ago. In the same way, and as an important corollary from our investigations of cutmarks, the determination of right or left-handedness could represent indirect evidence for lateralization of the hominin brain at least by the Middle and early Upper Pleistocene.

Summary

Handedness was deduced from the study of striations observed on the buccal surfaces of the anterior teeth of Middle and early Upper Pleistocene hominids from Atapuerca/Ibeas,
Cova Negra and La Quina. These striations are similar to those previously reported in some Neandertal specimens. Three factors were analyzed and compared with observations made from an experimental study: (1) location of the striations; (2) orientation; and (3) microscopic features of the striations. The results of these analyses indicate that the striations were the result of an ante-mortem process, and that they were produced with a sharp flint by hominids who normally preferred to use their right hand. We support the hypothesis that some Neandertals held pieces of meat or other matter between the maxillary and the mandibular anterior teeth, and then inadvertently scratched their teeth while slicing them away with a stone knife. Thus, the buccal striations of the anterior teeth of Atapuerca/Ibeas and some Neandertals may represent additional evidence for lateralization in the hominid brain at least by the Middle and early Upper Pleistocene.

It is of further interest to note that subadults also practised the cutting behaviour reported here, as a left lower deciduous canine is also represented in the study sample (Table 1). The time may also come when the sex distribution of this behaviour can be determined, thus providing new insights into Middle Pleistocene hominid culture.

Acknowledgments

We wish to thank Jean Louis Heim for permission to examine and to obtain replicas of the teeth of La Quina 5 specimen, and Henri and Marie Antoinette de Lumley for permission to examine the human remains from Hortus.

Special thanks are given to Peter Andrews, Emiliano Aguirre, Marta Ceballos, Carlos Diez, Josefa Enamorado, Antonio Sánchez and Begoña Sánchez for their suggestions and critical comments during the course of this work. We are also indebted to the reviewers, who provided important constructive criticisms, to José Luis Monreal, Mark Newcomer and Cottrell & Co. Dental Supply for the experimental materials provided, and to the photography service of the Museo Nacional de Ciencias Naturales. SEM facilities were generously provided to Y.F.J. by M. D. Claugher and Ms S. H. Barnes, to T.G.B. by Prof. Alan Boyle, and to J.M.B.C. by P. Adeva.

This research was supported by a grant from the Comisión Asesora de Investigación Científica y Técnica in relation to the Atapuerca-2 Project (No. 1849/82).

References


