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A reassessment of the presumed Torrener Bärenhöhle's Paleolithic human tooth

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A R T I C L E I N F O

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1. Introduction

Torrener Bärenhöhle's cave is a corridor located about 810 m from Golling an der Salzach (Salzburg, Austria). The cave was discovered in 1924 by Hermann Gruber, an Austrian alpine guide. After the initial speleological survey (carried out by Fritz and Robert Ödl), the cave was the subject of a paleontological excavation commissioned by the newly founded (in 1924) Natural History Museum in Salzburg (now Haus der Natur). The excavation unearthed an enormous amount of animal bones mostly belonging to *Ursus spelaeus*, for a total of more than 90 individuals. Since then, the cave has been called "Torrener Bärenhöhle," meaning "Bear Cave" (Klappacher and Knapczyk, 1979). In 1933, Kurt Ehrenberg identified five hollow bones among the cave findings as possible scrapers and awls (Ehrenberg, 1933, 1938), and in 1972, Ehrenberg identified even more (artificially) modified bones (Ehrenberg, 1972).

Until 1971, the publications about this cave had always mentioned animal bones only, but Gaisberger later reported the presence of a human molar attributed to the 1924 Torrener Bärenhöhle's collection (typescript dated 1971 reporting the finding of the tooth in January 1971, the original was in the archive of the museum Haus der Natur). When Gaisberger identified the tooth among the bones from the "Bärenhöhle," he showed it to the museum geologist, Rudolf Vogeltanz, who verified the identification as a human molar.

In contrast with the 1971 report, an inventory started on January 1, 1968 (starting No. 4000) already listed a "left upper 6th molar of a *Homo sapiens*, leg. H. Gruber" as third entry (No. 4003; Fig. 1), indicating that the tooth had already been identified as human by that year. This inventory was laid out by Gustave Abel, then president of the Speleology Association of Salzburg ("Salzburger Höhlenverein," today "Landesverein für Höhlenkunde in Salzburg"). Abel consigned the inventory to the archive of the "Landesverein für Höhlenkunde;" nevertheless, the museum was not aware of the existence of this document until after Abel's death in 1994, when the list was handed over to the museum. This fact may explain the double "discovery" of the tooth in the museum collection in 1968 and 1971. Anyway, in both cases the finding of the tooth was attributed to the initial discoverer of the cave, H. Gruber, in 1924. In the museum inventory and—as an old label suggests—also in the exhibition of the "Haus der Natur," the tooth was always attributed to *H. sapiens*, with no age given. Moreover, in an old label of the "Haus der Natur" Museum, the tooth is classified as an upper third molar (Supplementary Online Material (SOM) Fig. S1).

Between 1965 and 1984, detailed excavations were carried out in the so called "Schlenkendurchgangshöhle," a cave approximately

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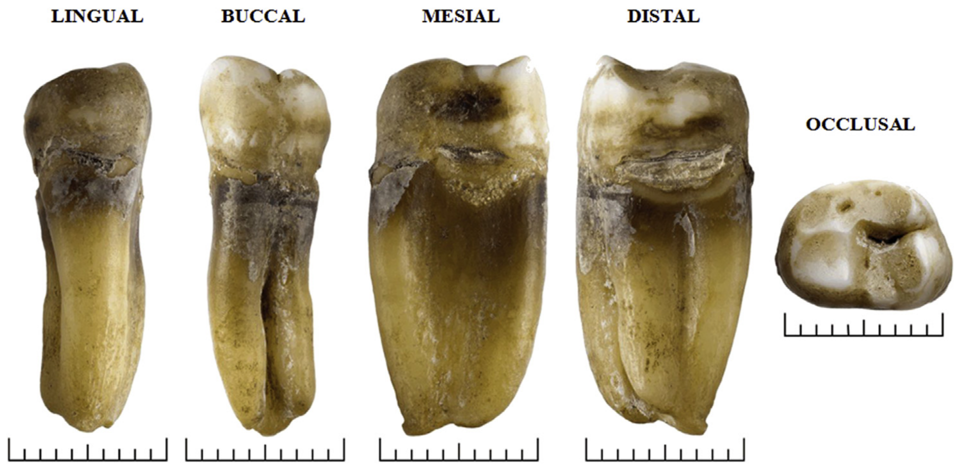

Figure 1. Torrener Bärenhöhle's tooth (Photo: Wolfgang Reichmann/Naturhistorisches Museum Wien).

14 km NE of "Torrener Bärenhöhle." The excavations were financed by the Austrian Academy of Sciences and coordinated by Ehrenberg and his student, Karl Mais. During these excavations, presumed stone artifacts were identified and dated between 40,000 and 30,000 years B.P. (Klappacher, 1992). These simple "Mousterian-type" stone tools gave rise to the assumption that the region was visited by ice-age hunters. Ehrenberg and Mais (1970) wrote that it is most likely "that the maker [of these tools] was the Neanderthal." Consequently, the tooth found in nearby Torrener Bärenhöhle was also attributed to *H. neandertalensis* in a review of local prehistoric findings (Urbanek, 1991). Subsequently, a copy of the tooth was prepared for the Museum Burg Golling (Gollingan der Salzach) and was there exhibited as a Neandertal molar. Obviously, this last classification casts doubt on the real taxonomy of the tooth, an issue that is not restricted to the Torrener Bärenhöhle specimen but that affects several human remains discovered decades ago, for which scanty and ambiguous information are available (Benazzi et al., 2011a, c, 2014a; 2015).

In this contribution, we investigate the tooth from Torrener Bärenhöhle's cave (hereafter called T.B.I). This tooth was microCT-scanned to digitally study its external and internal morphology, and sampled for AMS radiocarbon dating to establish its taxonomy and chronology.

2. Materials and methods

2.1. Morphological description

The evaluation of T.B.I nonmetric traits was done according to standards outlined by the Arizona State University Dental Anthropology System, ASUDAS (Turner et al., 1991).

2.2. Morphometric analysis

High-resolution μCT images of T.B.I were obtained with a GE Phoenix Nanotom® S microtomographic system (University of Applied Sciences, Wels, Austria) using the following scan parameters: 150 kV, 160 μA, 750 ms, and 0.5 mm copper filter. Volume data were reconstructed using isometric voxels of 13.167 μm. The image stacks were segmented with a semiautomatic approach in Avizo 7.0 (Visualization Sciences Group Inc.) in order to separate the enamel from the dentine and to reconstruct a three-dimensional (3D) digital model of the tooth.

The 3D model was optimized and oriented in Rapidform XOR2 (INUS Technology, Inc., Seoul, Korea), aligning the cervical plane (computed as the best-fit plane at the cervical line) parallel to the xy-plane of the Cartesian coordinate system and rotating the tooth around the z-axis according to indications provided by Benazzi and colleagues (2011b; see also Benazzi et al., 2009). The crown outline was projected onto the cervical plane and inscribed in a bounding box tangential to the most extreme points of the crown to identify the MD and BL diameters (Benazzi et al., 2013). In order to quantify two-dimensional (2D) relative cusp area (as a percentage of the total crown base area; see Bailey, 2004), a spline curve was digitized in the fissures that separate the cusps (the digitization of the hypocone is approximate due to Torrener Bärenhöhle's stage of wear) and then orthogonally projected on the cervical plane. The occlusal polygon was obtained connecting the dentine's horn tips, and then projected onto the cervical plane to measure the cusp angles (identified as A = protocone, B = paracone, C = metacone, D = hypocone; Bailey, 2002, 2004; Benazzi et al., 2013).

To calculate the 2D and 3D enamel thickness, we followed the guidelines provided by Benazzi and colleagues (2014b) for molars. In particular, for the 2D enamel thickness, we considered the mesial plane of section, i.e., a plane passing through the mesial cusps and orthogonal to the cervical plane. The measurements recorded from the section were: the area of the enamel cap (mm^2), the area of the coronal dentine that includes the coronal pulp (mm^2), the length of the enamel–dentine junction (EDJ, mm), the 2D average enamel thickness (2D AET, mm), and 2D relative enamel thickness (2D RET, scale-free). To quantify the 3D enamel thickness, the crown was separated by the root using the interpolated surface of the cervical line (Benazzi et al., 2014b). We measured: the enamel volume (mm^3), the coronal dentine volume, which includes the volume of the crown pulp chamber (mm^3), and the EDJ surface (mm^2). These measurements were used for the computation of both 3D average enamel thickness (3D AET, mm) and the 3D relative enamel thickness (3D RET, scale-free) index (SOM Fig. S2).

2.3. Metric comparison

The MD and BL diameters of T.B.I were compared to a Late Pleistocene human sample (Neandertals = N, southwest Asian Middle Paleolithic *H. sapiens* = MPHS, European Upper Paleolithic *H. sapiens* = UPHS, and modern *H. sapiens* = MHS) collected from the literature (SOM Table S1). The comparative dataset for molars'