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ORIGINAL PAPER

Human teeth pendants from the Mid-Upper Paleolithic sites Pavlov I and Dolní Věstonice I, Czech Republic

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Abstract

This paper focuses on a special case of mortuary habit in the treatment of human bodies during the Upper Paleolithic. Human teeth present a good available raw material source; however, until now, 12 Czech and French sites have been identified with human teeth pendants dated from the Aurignacian to the Magdalenian. Our study investigates four human teeth (Pav 15, Pav 25, Pav 39, and DV 8) from Pavlov I and Dolní Věstonice I that display perforations in the root area. This paper aims at distinguishing traces of human manipulation and perforation activities from traces caused by non-human depositional and post-depositional processes. Furthermore, broad paleoanthropological and archeological approaches were undertaken to understand the possible functional and symbolic meaning of these objects. The habit of functional usage and wearing human remains encompasses a comprehensive spectrum of analogies in human prehistory and recent ethnology.

Keywords Gravettian · Human remains · Body ornamentation · Central Europe · Perforation technique · Mortuary practice

Introduction

Pierced natural objects such as animal teeth, ostrich eggs, and marine shells were used as body decoration items already by early modern humans in Africa, and later by Neanderthals in Europe (Henshilwood et al. 2004; Zilhão et al. 2010; Miller and Willoughby 2014; Steele et al. 2019; Vanhaeren et al. 2019). During the Aurignacian and Gravettian, a broader variety of forms were carved from ivory, bone, and soft stones and polished (Taborin 1993; Vanhaeren et al. 2006; Vanhaeren and d'Errico 2006; White 2007; Wolf and Conard 2015; White and Normand 2015; Heckel and Wolf 2014; Vercoutère and Wolf 2018). Pierced animal teeth, mostly from wolf, fox, cervid, and bovid teeth, are common in Mid-Upper Paleolithic sites in Eurasia and appear to have been used as pendants, amulets, or necklaces. Body ornamentation clearly indicates diversity in personal and social identities (White 2007); some ornaments are thus found either directly associated with human bodies or dispersed within the surrounding settlement area. The intentional ante- and postmortem human manipulation with complete deceased bodies and/or scattered cranial and postcranial remains represents a broadly discussed topic (e.g., Gambier 2000; Henry - Gambier and White 2006; Vercoutère et al. 2008; Pettitt 2011; Sázelová et al. 2018; Trinkaus et al. 2019). In terms of raw material exploitation, human teeth present an available source for ornament production. Nevertheless, only 12 sites dated from the Aurignacian to Magdalenian in southern and southwestern France and the southern Moravia, Czech Republic, have provided human teeth pendants (Vlček 1991; Trinkaus and Svoboda 2006; Vanhaeren and d'Errico 2006; Vercoutère et al. 2008).

Little attention has been paid to the complex analysis of intentionally modified human teeth due to (a) the spatial isolation of individual human teeth pendants, (b) their scarcity compared with animal teeth pendants, and (c) differences in description of the surrounding archeological context. Except for few cases, we lack information concerning used perforation techniques, and thus it is almost impossible to identify this from the

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published drawings and photos if they are not supported by additional visual analysis, for example, with a stereomicroscope or 3D models produced from micro computed tomography (micro-CT) scans. Furthermore, the individual and detailed analyses (e.g., Henry - Gambier et al. 2004; Henry - Gambier and White 2006; Vercoutère et al. 2008) do not allow us to make broader conclusions about trends in human teeth modifications, although it has been repeatedly accentuated that the perforation and decoration techniques represent important cultural markers (Taborin 2004). The comparison with animal teeth modifications could be used as an auxiliary tool, by which the spectrum of stable practice in tooth selection and modification is presented (repeating laterality, raw material selection, used technology). Similarly, preference for a certain human tooth type, such as permanent over deciduous teeth and molars and premolars over the incisors and canines, is being observed.

This paper aimed at developing complex paleoanthropological and technological approaches for the study of pierced human teeth from southern Moravia for which information about the archeological context is provided to improve the interpretations of the intentional modification and wearing of human remains. Our paper combines dental anatomical description of four pierced human teeth from Pavlov I and Dolní Věstonice I (Pav 15, Pav 25, Pav 39, and DV 8) together with detailed analyses of the human modifications of the dental roots (e.g., Barge-Mahieu 1991; Barge-Mahieu and Taborin 1991; Vanhaeren and d'Errico 2003; Goutas 2004; Taborin 2004). Such approach would enhance the determination of the used perforation techniques and help distinguishing them from traces left by non-human depositional and post-depositional processes. Finally, the pierced human teeth were interpreted in the broad paleoanthropological, archeological, and ethnological context used to understand the possible functional and symbolic usage of these pendants.

Pavlov hills: sites, paleoanthropology, and context

The microregion Dolní Věstonice-Pavlov-Milovice (southern Moravia, Czech Republic), with a main cultural layer dated by charcoals and bones between 31 and 27 ka cal BC (Table 1), displays the hierarchical pattern of site complexes with different lengths of human occupation and connected settlement and hunting activities. The site elevation is 200–220 a.s.l., except at the Milovice IV site and in the MIS 3 environment, which likely provided optimal conditions for hunter-gatherer adaptations. For example: (a) the microclimate was favorable to variable faunal and plant resources; (b) the overall geomorphology provided locations for hunting settlements higher on the slopes with a dominant overview of the Dyje river and its valley, which would have been useful for hunting large herbivore herds and fur-bearing animals; and (c) the human stations sat next to the side gullies and ravines, in which freshwater springs or shallow water basins sometimes occurred (Absolon 1945; Klíma 1959, 1963, 1981, 1995; West 2001; Svoboda 2005; Oliva 2009; Beresford-Jones et al. 2010, 2011; Svoboda 1994, 2005, 2011, 2016; Svoboda et al. 2019). In this microregion, four sites—Dolní Věstonice I, Dolní Věstonice II, Pavlov I, and Milovice I—have yielded a total of 55 isolated human teeth. The number represents 22.0% of all teeth if calculated together with complete skulls in the human burials. The ratio between the permanent teeth of juveniles and adults to the deciduous teeth of children is 30:25. Four isolated human teeth (7.2%) from Pavlov I and Dolní Věstonice I showed perforations of the roots.

Detailed analyses of dental wear were performed by Hillson (2006) and Willman (2016), who divided irregularities as follows: (a) occlusal attrition facets with slight asymmetry in dental wear between frontal and distal teeth together with teeth scratches (connected to food processing or artifact manufacture); (b) approximal grooving reflecting usage of toothpicks or thread or fiber processing; and (c) buccal wear, which creates unusual attrition facets occurring on the buccal side of first molars, second and first premolars, and sometimes on second molars and canines. The facets on adjacent teeth create a slightly curved wear plane and include both upper and lower teeth and occur on the left or right side or on both sides. Such an unusual pattern could reflect wearing of labrets (lip plugs; Hillson 2006; Willman 2016) or holding pebbles behind the cheek (Vlček 1997).

Dolní Věstonice I

The first isolated human tooth (DV 29, Table 2) was found by K. Absolon in the upper part of Dolní Věstonice I in 1924 (Fig. 1a), followed by permanent premolars in 1927 (DV 7-1 and 7-2) and the pierced permanent incisor DV 8 (Fig. 1b) in the middle part of the site in 1934 (Absolon 1935, 1945). After the Second World War, two permanent incisors, two molars, and a deciduous molar were excavated by B. Klíma, who conducted his field seasons in the upper part of the settlement in 1948 and 1949 (DV 26 and DV 27, DV 9-1-3). Then, a deciduous canine was found in 1951 (DV 10), and after more than 20 years, four permanent molars were discovered in 1974 in the uppermost part of the settlement (DV 31-1 and DV 31-2 and DV 32, recently labeled DV 31-b, DV 37, and DV 38). In total, the site has yielded 14 permanent and deciduous isolated teeth, of which five specimens were recently lost. DV 8 was located approximately 200 m from the female burial DV 3 and cranial vault DV 1, approximately 50 m from the child burial DV 4 and 70 m from the cranial vault DV 2 (Klíma 1963, 1981; Vlček 1971, 1994; Hillson 2006; Hillson et al. 2006; Holliday et al. 2006; Oliva 2014; Svoboda et al. 2018; Trinkaus et al. 2019). The closest archeological context to this pierced tooth includes standard objects that are typical for the

Table 1 Dolní Věstonice I and Pavlov I selected radiocarbon dates originated from the vicinity of human pierced teeth

Site	Laboratory number	Position at site/depth in cm	Result (BP)	Deviation	Calibration (cal BC)	Deviation 2 σ
Pavlov I	GrN-4812	Southeast	26,730	250	29,286–28,586	95.4
Pavlov I	GrN-19539	Southeast	26,650	230	29,229–28,541	95.4
Pavlov I	GrN-1272	Southeast	26,620	230	29,214–28,503	95.4
Pavlov I	KN-1286	Southeast	26,580	460	29,431–27,769	95.4
Pavlov I	GrN-22303	Southeast	26,400	310	29,162–27,932	95.4
Pavlov I	GrN-22305	Southeast	25,840	290	28,811–27,431	95.4
Pavlov I	GrA-192	Southeast	25,530	110	28,152–27,346	95.4
Pavlov I	GrN-22304	Southeast	25,160	170	27,669–26,836	95.4
Pavlov I	GrN-1325	Southeast	25,020	150	27,504–26,760	95.4
Pavlov I	Beta 388403	Southeast object S1/145	26,420	120	29,032–28,507	95.4
Pavlov I	Beta 388404	Southeast object S1/160	28,710	120	31,385–30,418	95.4
Dolní Věstonice I	GrN-1286	Middle	25,820	170	28,629–27,578	95.4

The C14 dates are based on the charcoals (Svoboda et al. 2016, 2018). Dates calibrated in OxCal v.4.2, using IntCal13 (Bronk Ramsey et al. 2013; Reimer et al. 2013)

Dolní Věstonice and Pavlov settlement areas. The thick layer around DV 8 is gray to black and ashy with burned bones. Mammoth bones (e.g., carpals, phalanges, astragals, and scapular fragments) and teeth fragments, faunal remains from smaller species, pieces of burned clay pellets, and a few fragments of zoomorphic and anthropomorphic plastics, grinding stones with ochre, an ivory spatula, and two bone awls were found in the vicinity (Absolon's diaries in Oliva 2014).

Table 2 List of isolated teeth excavated at Dolní Věstonice I during the K. Absolon's and B. Klíma's field seasons in 1924–1938 and 1948–1974. DV 8 marked in italics

Inventory no.	Tooth type	Side
Dolní Věstonice I 7/1^{M}	Permament lower first premolar	n/a
Dolní Věstonice I 7/2^{M}	Permanent lower second premolar	n/a
Dolní Věstonice I 8/1^{M}	*Permanent upper first incisor*	*Right*
Dolní Věstonice I 9/1	Permanent lower molar (third?)	Right
Dolní Věstonice I 9/2	Permanent lower molar (third?)	Left
Dolní Věstonice I 9/3	Permanent upper first incisor	Left?
Dolní Věstonice I 10/1	Deciduous upper canine	Left?
Dolní Věstonice I 26/1^{M}	Permanent upper second incisor	n/a
Dolní Věstonice I 27/1	Deciduous upper first molar	Left
Dolní Věstonice I 29/1^{M}	Deciduous incisor	n/a
Dolní Věstonice I 31/a	Permanent lower third molar	Right
Dolní Věstonice I 31/b	Permanent lower third molar	Right
Dolní Věstonice I 32/1	Permanent lower third? molar	Left
Dolní Věstonice I 37/1	Permanent lower second molar	Left
Dolní Věstonice I 38/1	Permanent lower third molar	Right

Data based on Absolon (1945), Klíma (1963), Vlček (1971), Sládek et al. (2000), and Hillson et al. (2006). Superscript "^{M}" indicates recently missing teeth, *n/a* siding not available

Pavlov I

The majority of the 29 human isolated teeth from Pavlov I (Table 3) were found during B. Klíma's excavations in the southeastern part of the site. In 1953, the permanent lower incisor Pav 26 was discovered, followed by the deciduous lower molar Pav 9 and two deciduous upper molars Pav 6-1 and Pav 11 in 1954. The majority of the human teeth were excavated in the 1956's field season, namely, five permanent lower incisors (Pav 5-1 and 5-2 and Pav 23–25), a deciduous upper molar (Pav 6-2), two deciduous lower molars (Pav 7 and 8), three deciduous upper canines (Pav 13–15), two deciduous upper incisors (Pav 16 and Pav 19), and a deciduous lower incisor (Pav 17). Although separated by 5 m, Pav 5-1 and Pav 5-2 were confidently attributed to the same individual based on their wear facets. Pav 6-1 and Pav 6-2, discovered within two different field seasons, also belong to one individual.

In 2010, the permanent lower incisor Pav 30 and deciduous upper molar Pav 32 were found by P. Wojtal and J. Wilczyński among the osteological collections from earlier excavations. The last permanent upper premolar, Pav 39, was excavated in settlement unit S1 over the large rescue excavations led by J. Svoboda in 2013–2015 (Hillson 2006; Holliday et al. 2006; Svoboda et al. 2016; Sázelová et al. 2018; Trinkaus et al. 2009, 2019). Most of these isolated teeth overlap with other human scattered cranial and postcranial remains, and their spatial cluster distribution is within 60 m of the Pav 1 male burial in the northwestern part of the site. Some human teeth are within or at the margins of the settlement units, namely, to settlement units K4 (Pav 14 and 30), K6 (Pav 10), K10 (Pav 28), K11 (Pav 6/1–2, Pav 13, and 24), and K11a (Pav 25). The remaining specimens were scattered within the settlement area between these units. The density and overall distribution of

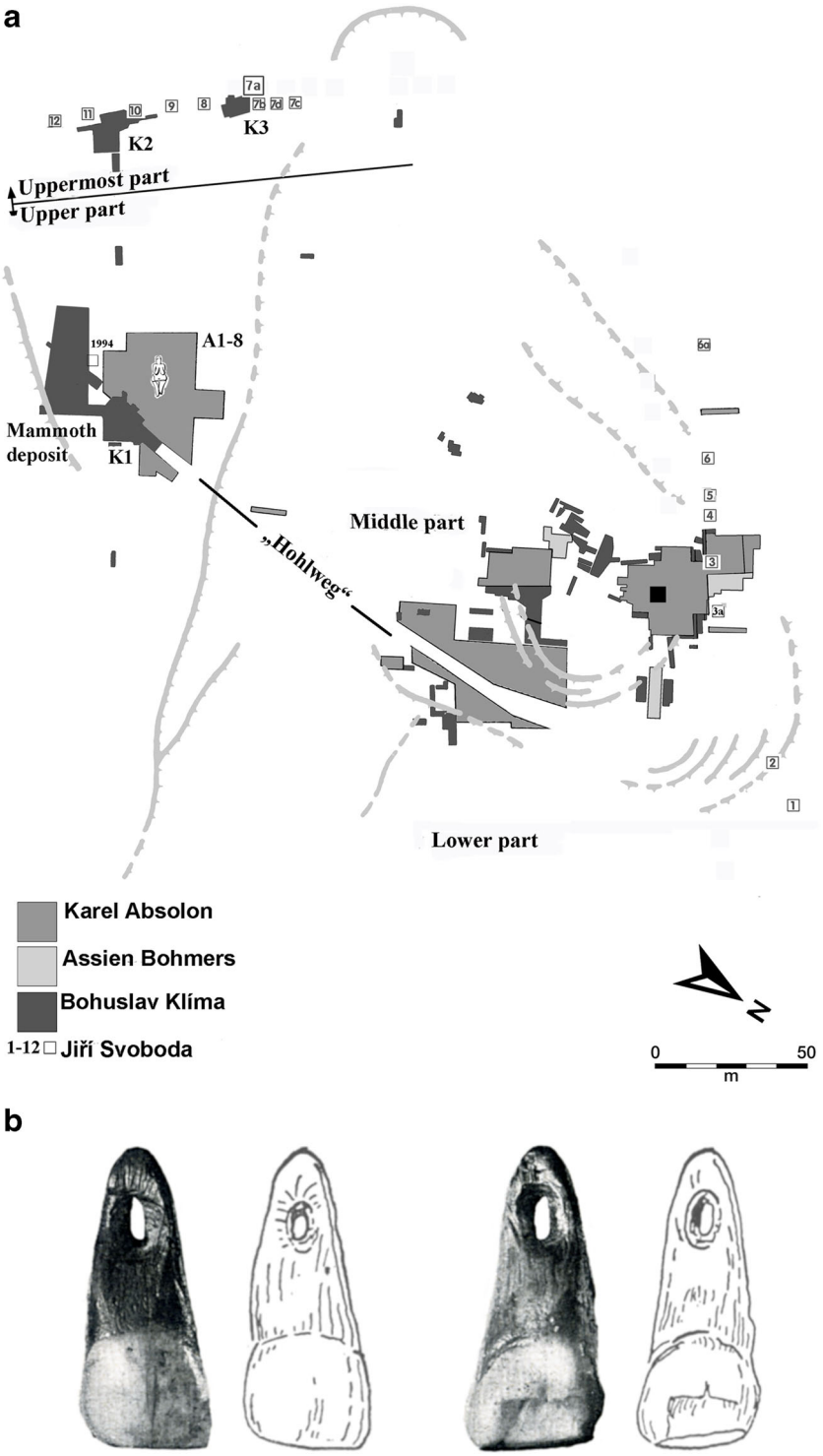

Fig. 1 a, b Site plan of Dolní Věstonice I. **a** The square shows the possible position of a human pierced tooth within the settlement excavated by Karel Absolon in 1934. Figure modified after Svoboda et al. (2018, p. 28). **b** The photographic documentation of the recently lost tooth DV 8 was based after Absolon (1935, p. 317) and drawings by Vlček (1991, p. 7). Scale: not provided

these teeth reflect the patterns of other findings, such as lithic artifacts, animal hard tissue artifacts and pendants, Tertiary shells, mineral dyes, and burned clay pellets. The major concentrations lie between unit K7 and K11 and then run centripetally to the accumulations (a) between unit K10 and K10a, (b) around unit K9 and in the southeastern periphery of the site creating a concentration on the margin of unit K6, and (c) distinct smaller concentrations were within and around the units K3, K4, and K5 (Novák 2005).

The K4 unit layer is composed of an accumulation of hearths, with clay-like inclusions at the base, and extensive dark ashy deposits permeated with white ash. Pav 15 was found in the profile next to hearth H38, which is clearly separated into three microstratigraphic events,

Table 3 List of isolated teeth excavated at Pavlov I during the B. Klíma's and J. Svoboda's field seasons in 1952–1975 and 2013–2015. Pav 15, Pav 25, and Pav 39 marked in italics

Inventory no.	Tooth type	Side
Pavlov 5/1	Permanent lower first incisor	Right
Pavlov 5/2	Permanent lower first incisor	Left
Pavlov 6/1	Deciduous upper first molar	Left
Pavlov 6/2	Deciduous upper second molar	Left
Pavlov 7/1	Deciduous lower second molar	Left
Pavlov 8/1	Deciduous lower second molar	Right
Pavlov 9/1	Deciduous lower second molar	Right
Pavlov 10/1	Deciduous lower second molar	Right
Pavlov 11/1	Deciduous upper first molar	Right
Pavlov 12/1	Deciduous upper second molar	Right
Pavlov 13/1	Deciduous upper canine	Right?
Pavlov 14/1	Deciduous upper canine	Left
Pavlov 15/1	*Deciduous upper canine*	*Left*?
Pavlov 16/1	Deciduous upper second incisor	Right
Pavlov 17/1	Deciduous lower second incisor	Right
Pavlov 18/1	Deciduous lower second incisor	Left
Pavlov 19/1	Deciduous upper first incisor	Left
Pavlov 20/1	Permanent upper third molar	Left
Pavlov 21/1	Permanent lower first premolar/paramolar	n/a
Pavlov 22/1	Permanent upper second incisor	Left?
Pavlov 23/1	Permanent lower first incisor	Left
Pavlov 24/1	Permanent lower first incisor	n/a
Pavlov 25/1	*Permanent lower first incisor*	*Right*
Pavlov 26/1	Permanent lower incisor	n/a
Pavlov 27/1	Permanent post canine tooth	n/a
Pavlov 28/1	Permanent lower third molar	Left
Pavlov 30/1	Permanent first lower incisor	Left
Pavlov 32/1	Deciduous lower second molar	Right
Pavlov 39/1	*Permanent upper premolar*	*n/a*

Data collected based on Klíma (1959), Svoboda (2005), Sládek et al. (2000), Hillson et al. (2006), Trinkaus et al. (2009), and Sázelová et al. (2018). *n/a* siding not available

each divided by loess (Svoboda 2005). Pav 25 lies on the southwestern margin of the K11a unit, approximately 2 m from hearth H42 in the lower part of the unit with two fine microstratigraphically superimposed phases separated by thin loess layers. Each phase has a red-burn concave base with ashy filling, together with charcoals, burned bones, and limestone blocks. The distance from circular hearth H46 is approximately 1.5 m. The fireplace is in the upper part of the unit, delineated by limestone blocks on its western peripheral side, and surrounded by several kettle-like pits. Towards the western periphery of K11a, a nearly complete lion skeleton was found, and its anatomic position was partially disturbed by post-depositional processes (Svoboda 2005). Several pierced wolf and fox teeth and Tertiary shells (*Dentalium* sp., *Pirenella* sp., *Terebralia bidentata margaritifera*, and *Cardites partschi*), a reindeer skull fragment, a deciduous mammoth molar, two broken antler branch tips, a bone awl, ivory needles, beads and modified pieces with cuts, microlithics, backed blades, end scrapers, burins and their spalls, chisels, and sandstone and quartz rubbles were found in the close vicinity of Pav 25. The Pav 39 specimen lay in the S1 settlement unit, which creates a shallow circular depression with a diameter of 5.0–6.0 m and strong anthropogenic filling. In the middle of the depression, a bowl-like fireplace with a diameter of 0.7 m was surrounded by a higher concentration of lithics, faunal remains, and widespread charcoal and burned bones (the archeological and osteological material is still being processed). The unit's vicinity is patterned by frost polygons (Svoboda et al. 2016).

Dolní Věstonice II and Milovice I

Ten isolated teeth were discovered during the rescue excavations by Bohuslav Klíma and Jiří Svoboda in 1985–1987 at Dolní Věstonice II (Table 4). The permanent upper molar or distomolar DV 33 was found directly in settlement unit K4. DV 36 represents nine isolated deciduous teeth from a single child located within the area below the settlement unit S4. Spatially, the isolated teeth create two large clusters with other scattered human cranial and postcranial remains and are located approximately 35 m from the DV 16 male burial and approximately 60 m from the triple male burials DV 13–15 (Svoboda et al. 1991; Hillson et al. 2006; Holliday et al. 2006; Svoboda 2016; Trinkaus 2018; Trinkaus et al. 2009, 2019). Additionally, the upper first and second right molars originating from the same individual were found during the

Table 4 List of isolated teeth excavated at Dolní Věstonice II site during the B. Klíma's and J. Svoboda's field seasons in 1985–1987

Inventory no.	Tooth type	Side
Dolní Věstonice II 33/1	Permanent upper molar/distomolar	Left
Dolní Věstonice II 36/1	Deciduous upper first incisor	Right
Dolní Věstonice II 36/2	Deciduous upper first molar	Left
Dolní Věstonice II 36/3	Deciduous upper second molar	Left
Dolní Věstonice II 36/4	Permanent upper first molar	Left
Dolní Věstonice II 36/5	Deciduous lower first incisor	Left
Dolní Věstonice II 36/6	Deciduous lower second molar	Left
Dolní Věstonice II 36/7	Permanent lower first molar	Left
Dolní Věstonice II 36/8	Permanent lower first molar	Right
Dolní Věstonice II 36/9	Permanent upper first incisor	Right

Data based on Klíma (1995), Svoboda (2016), Sládek et al. (2000), Hillson et al. (2006), and Trinkaus (2018).

revisions of an osteological collection from Milovice I in 2008 in the material from sector B2 excavated in 1986–1990 by M. Oliva. However, the dating of the context remains unclear (Jarošová and Oliva 2009).

Materials and methods

This paper focuses on four isolated human teeth from Dolní Věstonice I and Pavlov I showing perforations in the root area, namely, a permanent upper incisor (DV 8), a deciduous upper canine (Pav 15), a permanent lower incisor (Pav 25), and a permanent upper premolar (Pav 39).

Osteometry and taphonomy

The study material was anatomically and morphologically compared with the upper and lower dentition of the buried individuals Dolní Věstonice 13–15. Then, the isolated teeth Pav 13 and Pav 14 were compared with Pav 15 and Pav 5, while Pav 22–24 and Pav 30 were compared with Pav 25 and Pav 21 as a parallel to Pav 39. Additionally, several diameters were measured on the preserved pierced teeth. The first vertical diameter describes the total length of an object along its longest axis. Due to the wear modifications of the crowns, we naturally followed the methodological recommendations of Goose (1963), Bräuer (1988), Hillson et al. (2005), and Hillson (2006) when linear measurements on teeth were collected in the horizontal planes of the crown and neck: (a) The bucco-lingual crown diameter (B-L CD) presented the greatest distance between the buccal/labial and lingual surfaces of the crown, measured at right angles to the mesio-distal plane. (b) The mesio-distal crown diameter (M-D CD) was measured at the greatest mesial dimension parallel to the occlusal and at a right angle to the bucco-lingual planes. (c) The bucco-lingual cervical diameter (B-L CeD) was measured at the cervical base as a maximum dimension across the crown in the bucco/labio-lingual plane. Incisors, canines, and premolars were defined by the cementum-enamel junction. (d) The latter was the mesio-distal cervical diameter (M-D CeD) at the cement-enamel junction on the mesial and distal sides at the cervical base of the crown. Points for the measurement were located at the apex of the junction curve and were more clearly defined for the incisors and canines than for the premolars.

The traces of biotic and abiotic taphonomic agents affecting the depositional and post-depositional processes were qualitatively studied by the naked eye under a NIKON SMZ 1500 stereomicroscope (Amstelveen, Netherlands) at × 7.5–110.0 magnification (e.g., Dauphin and Denys 1992; Price et al. 1992; Fernández-Jalvo and Andrews 2016; Schmidt et al. 2017).

Virtual reconstruction and visualization

The micro-CT scans of Pav 15 and Pav 25 were obtained in collaboration with the Department of Human Evolution of the Max Planck Institute for Evolutionary Anthropology in Leipzig. Scanning via a transportable, high-resolution CT scanner (Diondo d3 high-resolution micro-CT system, Diondo, Henderson, NV) was conducted at the Institute of Archeology, Czech Academy of Sciences Brno, within the Research Center in Dolní Věstonice in summer 2016. Avizo 9.7.0 software (FEI Visualization Sciences Group, Thermo Fisher Scientific, Hillsboro, OR) was used for visualization and 3D model processing, especially in the process of the surface dentine interpolation for approximation of the missing parts caused by the perforations. Various measurements involved the following: (a) the length and width diameters were measured along the endpoints of the longest midline axes and (b) the area of the perforation was taken as an area measurement along the surface edges of the perforation. There was no need to virtually remove any adhering material (such as calcium concretes) from the tooth surface, because both teeth were cleaned and polished in the 1950s or 1960s. In addition, the 3D models helped in description of depositional and post-depositional processes affecting the inner and outer tooth root structures.

Perforation techniques and production

The approach combined technological and morphometric analyses of human modifications of the dental roots with an emphasis on the determination of the techniques used during the perforation processes (e.g., Barge-Mahieu 1991; Barge-Mahieu and Taborin 1991; Vanhaeren and d'Errico 2003; Goutas 2004; Taborin 2004).

The dental roots were analyzed to assess the techniques used during the perforation processes. An appropriate photographic documentation from the stereomicroscope was then calibrated and analyzed using the NIS-element software (Amstelveen, Netherlands). The image resolution and preservation of dental surface, due to post-depositional changes, precluded deeper use-wear analysis and the identification of microtraces. Broader comparisons can support this important issue in the future.

Results

Dolní Věstonice 8

The tooth represents a permanent upper right incisor with a total length of approximately 16.8** mm. The tooth was lost, most likely burned in an intentional fire set in Mikulov castle at the end of the Second World War, which destroyed other

human fossil specimens from Moravia, such as Předmostí, Mladeč, and Šipka. We were able to evaluate some aspects of this tooth based on the good-quality photographs, which lack a scale indicator, of its labial and lingual sides. The figure possesses three times the size of the original (Fig. 1b). Naturally, such an approach introduces uncertainties in our estimations and measurements (marked with two stars). The robust crown with strong tuberculum and broad marginal ridges was well-preserved, except for two thin cracks on its labial side. The occlusal side displayed moderate dentine exposure, corresponding to Smith stage 3–4 (Smith 1984). The last apical third of the root was perforated with an approximate maximum length of 2.2** mm and width of 0.7** mm. Several cut marks deriving from the perforation processes were presented (Fig. 2).

Pavlov 15

This tooth is a well-preserved deciduous upper left (?) canine (Figs. 3 and 4a–c; Table 5) with a total length of 12.2 mm and advanced occlusal wear at Smith stage 5 (Smith 1984), causing dentine and pulp chamber exposure. The short root is partially affected by resorption, with an open tooth canal, which does not correspond to overall wear traces on the crown; normally, this process should be more advanced. The excessive crown abrasion precludes age determination of this specimen. Large approximal wear facets occur on the mesial and distal sides of the crown. Seemingly, the tooth was retained in the mouth, although other deciduous teeth had already been permanently replaced. The tooth could represent congenital absence of a permanent canine or an extreme in normal dental variation, such as hyperdontia (Sládek et al. 2000; Hillson 2006; Hillson et al. 2006). The occurrence of supernumerary teeth does not present a rare dental abnormality in the Dolní Věstonice-Pavlov population, such as in the case of the deciduous upper left first incisor Pav 19, and among other interpretations, this seems to be the most likely option for paramolar Pav 21 and distomolar or M^4 DV 33 (Trinkaus 2018). From the taphonomic perspective, the crown displays a post-depositional fissure running in the mesio-labial to disto-lingual direction and splitting the crown into nearly identical halves. Disto-lingually, the split runs into a larger perforation, which covers nearly 2/3 of the root and displays wide edges; the enamel color on this side is changed by a large brown patch. Another perforation with thinned edges occurs labially in the upper half of the root. Additionally, disto-lingually, the occlusal side of the enamel is covered by a large brown patch.

Both perforations have an irregular shape and are directly overlapping at an acute angle. The root is notably thinned and flattened. The stage of preservation and post-depositional changes precludes the identification of stigmata related to

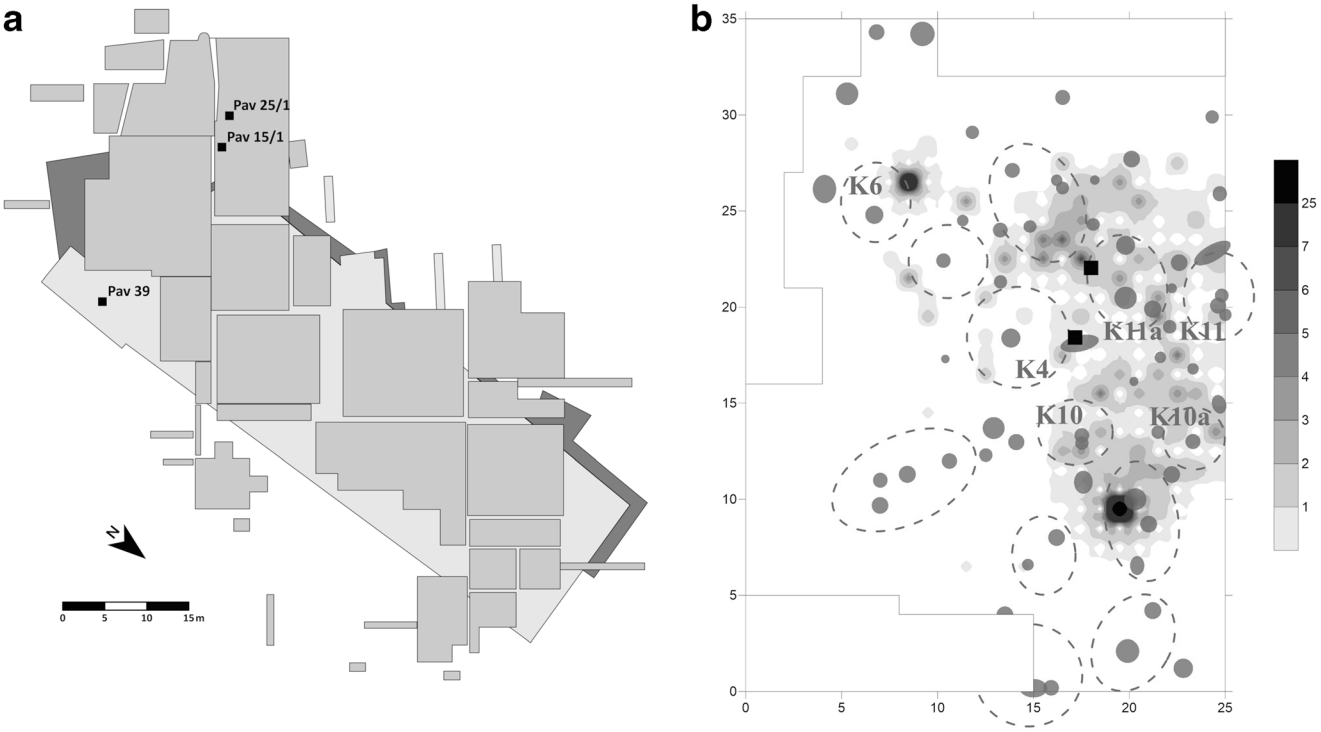

Fig. 2 **a–c** Site plan of Pavlov I. **a** The square shows the positions of the human pierced teeth within the settlement. **b** Human teeth in the context of animal pierced teeth and settlement units excavated by Bohuslav Klíma in 1954–1956. **c** Human tooth in the context of animal pierced teeth (triangles) and settlement unit S1 discovered by Jiří Svoboda in 2013–2015. Figures modified after Novák (2005) and Svoboda et al. (2016, p. 99)

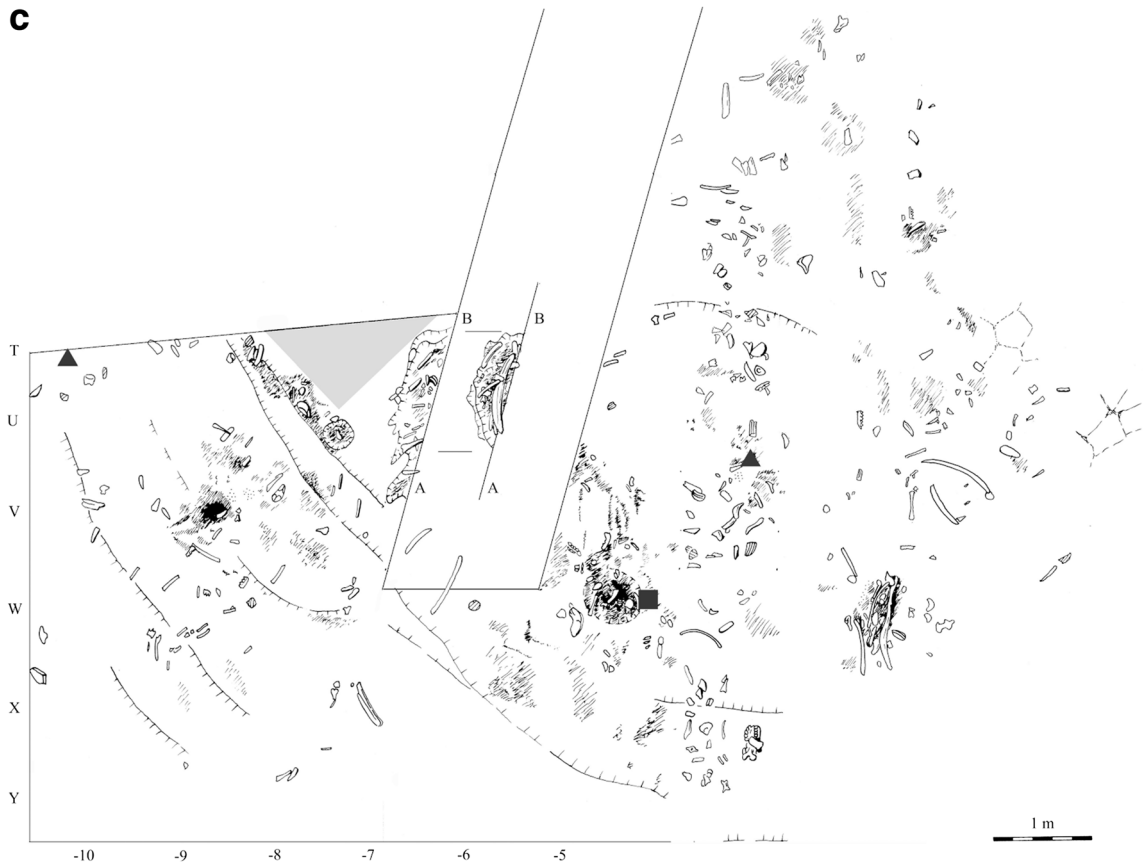

Fig. 2 (continued)

the perforation process. It is apparent that the root surface was flattened by an unidentified wear technique before the perforation by percussion. The overall character and orientation of the sharp and abrupt edges, the saw-tooth morphology, and the direction of tiny incidental cracks support the conclusion that repetitive motion was applied to the tooth, perhaps by indirect

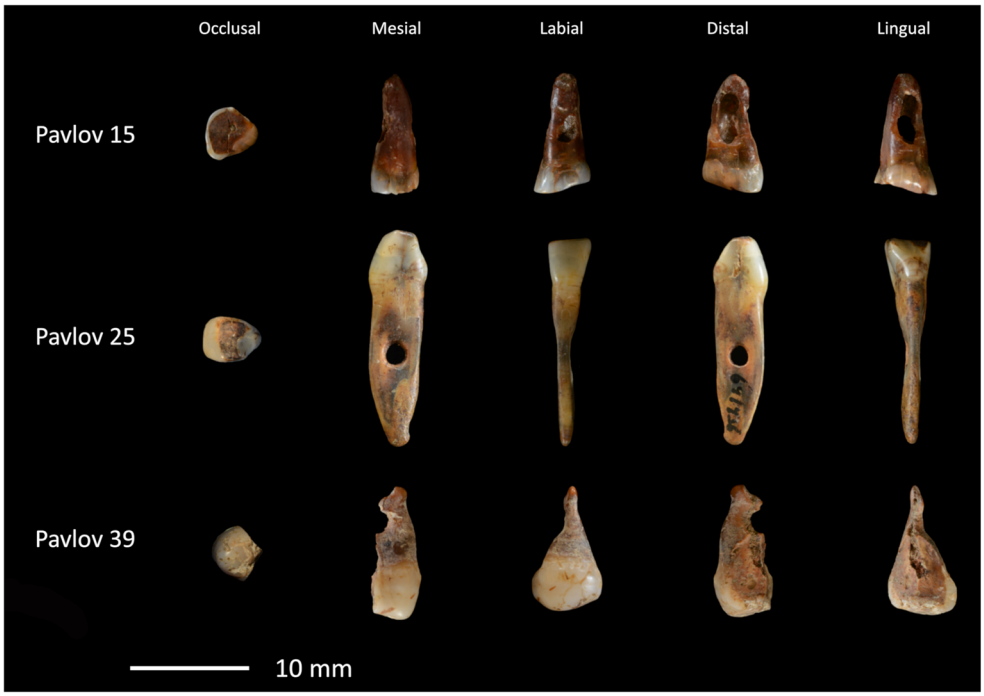

Fig. 3 Pierced human teeth from Pavlov I presented in their anatomic planes. Scale, 10 mm. Photos by S. Sázelová and E. Trinkaus

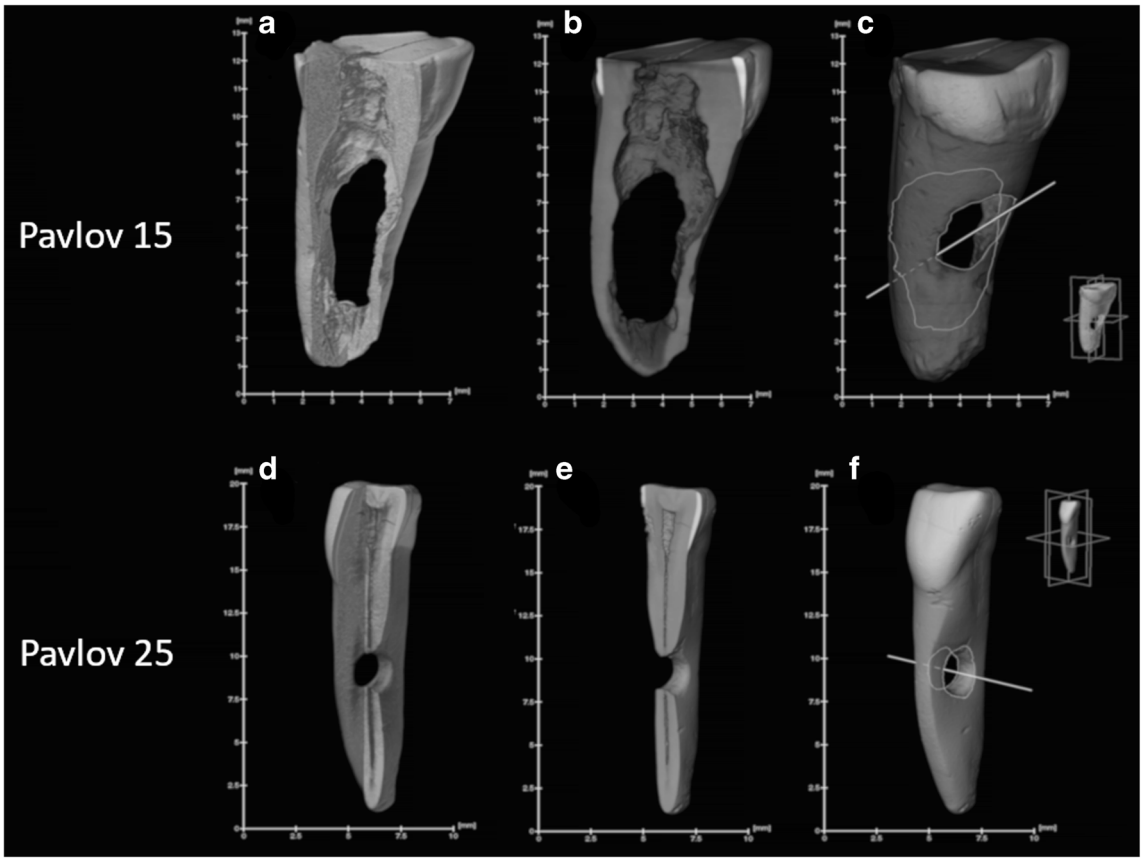

Fig. 4 **a**–**f** Upper: the 3D model based on the micro-CT scans of the Pav 15 tooth. From the left: **a** the 135° section in the tooth with lower grayscale variation in the Avizo Volren module displays the taphonomic modification in the pulp cavity. **b** Longitudinal section with original data. **c** The white contours mark the asymmetric position of both perforations. Lower: the 3D model based on the micro-CT scans of the tooth Pavlov 25. From the left: **d** the 135° section in tooth with lower grayscale variation in the Avizo Volren module displays the pulp cavity. **e** Longitudinal section with original data. **f** The white contours mark the symmetric position of both perforations. The icons display used anatomic planes of the Pav 15 and Pav 25 specimen. Figures based on micro-CT scans from collaboration with EVA MPG, Leipzig

percussion with a pointed object. Other wear or use-wear traces (e.g., glossy surface) have not been observed. Thus, we expect that the tooth remained unused as a result of defective hole orientation caused by an unsuccessful perforation.

Pavlov 25

The tooth represents a well-preserved permanent lower right first incisor (Figs. 3 and 4d–f; Table 5) with a total length of 19.8 mm. The crown is heavily worn at Smith stage 5 (Smith 1984) with a broad area of occlusal exposure of the dentine.

Table 5 Bucco-lingual (B-L) and mesio-distal (M-L) crown (CD) and neck (CeD) diameters of the studied teeth from Pavlov I

Inventory no.	B-L CD	M-D CD	B-L CeD	M-D CeD
Pav 15	-	-	4.9	5.4
Pav 25	5.4	4.0	4.9	2.6
Pav 39	-	6.4*	-	4.3*

*The measurements were approximated

The mesial and distal approximal wear facets are present, and the root is complete with a closed apex at stage Ac (according to Moorrees et al. 1963). The age estimate falls between 26 and 35 years (Sládek et al. 2000; Hillson 2006; Hillson et al. 2006). Again, the crown displays a post-depositional fissure running irregularly through the labial side of the enamel and ending in another deeper fissure-oriented mesio-distally with a prolonged end on the distal side of the tooth. The crown and root are affected by slight traces of post-depositional corrosion and do not bear any traces of plant root etching. The root is covered by several brown patches and achieves a thickness between 1.1 and 1.5 mm due to the thinning on both the mesial and distal sides. The uppermost third of the root is perforated by a nearly regular and rounded perforation with relatively straight sides.

The root surface was prepared and carefully flattened by an unidentified wear technique before the perforation was made. The manufacturing traces are poorly visible because of very glossy surface of the root, which is most likely the result of use wear. The changes in use wear depth are particularly obvious on the lateral parts of the perforation, which caused thinning

of the remaining dentine, and on the labial and lingual root surfaces. The perforation is very regular and rounded with a biconical shape in cross section. Although the manufacturing traces are not well-preserved, their characteristics and features appear by the rotation technique. Moreover, the internal edge of the perforation is covered by several larger facets. We expect that the facets are possibly related to the perforation manufacturing process, given that they are superimposed on other production and use-wear traces. The use-wear traces do not appear in the internal part of the perforation but are present on its edges. All these characteristics suggest the object was carried in intensive contact with other materials, which caused wear of the root surface. Perhaps percussion or a similar type of activity preceded and/or was accompanied by the rotation move. Finally, significant material loss on the root surface indicates intense or long-term use wear of the object as a pendant.

Pavlov 39

This incomplete specimen represents a permanent upper left (?) premolar with nearly half of the tooth preserved (Fig. 3; Table 5) and has a total length of 14.3 mm. The tooth has a rounded and short crown with one smaller intact lingual cusp with its tip positioned slightly to the mesial side. The fossa between the cusps is affected by two stepped cracks running in the enamel with corroded edges, precluding further description. There is a single slightly inclined occlusal wear facet on the cusp above the fossa, which does not cause dentine exposure (Smith stage 2; Smith 1984). The root is relatively short, with an oval cross section in its upper part and slight flattening from the middle part to apex. The tip follows a gently curving path and bends distally (Hillson 1996). The root surface is rough; however, in contrast to Pav 21, Pav 39 lacks other developmental irregularities, so the changes seem to be of post-depositional origin rather than caused by *hypercementosis* or other disease. An additional single large approximal wear facet occurs in the mesial (?) direction below the preserved cusp. From the taphonomic perspective, the crown and root display traces of plant root etching, whereas a brown patch covers the mesial side of the upper root and neck area. Several carbonate concretions occur on the tooth surface. Finally, the lower third of the root is perforated but not thinned, and the surface is rounded and post-depositionally corroded.

The general morphology of the round half notch on the root resembles a perforation made by percussion, and its position roughly corresponds to the usage as the perforated pendant. However, other signs, namely, the character and orientation of the edges, the absence of clear traces after human modification, the saw-toothed but irregular morphology, the skewed and asymmetric orientation of the notch, and the fact that the notch demonstrates the same degree of preservation as the notch surface and remaining root, provide evidence that this notch can be interpreted as a pseudoperforation. Unfortunately, strong post-depositional surface corrosion prevents us from clearly understanding the origin of this phenomenon.

Comparison of perforation techniques and object usage

The direct overlap between both perforations on the Pav 15 root meets at an acute angle (Fig. 4c). The disto-lingual opening has a diameter of 3.6 by 6.2 mm with a total surface area of 19.8 mm^2, and the mesio-labial opening possesses a diameter of 1.9 by 3.45 mm with a total surface area of 5.91 mm^2. The pulp cavity is eroded and enlarged. Both perforations on the Pav 25 root (Fig. 4f) overlap precisely with each other. The mesial opening has a diameter of 2.2 by 3.1 mm with a total surface area of 6.2 mm^2 and a distal opening with a diameter of 2.2 by 2.5 mm and a total surface area of 4.1 mm^2. The greatest axis length of the preserved part of the perforation on the Pav 39 root is 2.2 mm. The stigmata that occurs during the intentional extraction of a tooth from the jaw is lacking, perhaps due to the post-depositional corrosion of the human tooth surface or coverage with another tooth modification (comp. West 2001; Goutas 2004; Lázničková-Galetová 2016). The preparation phase of shaping by surface flattening is presented on the Pav 25 root; however, the specific technique related to this process remains unclear. The perforation techniques are as follows: a bilateral percussion for Pav 15 and a biconical perforation for Pav 25. For obtaining biconical perforation, more than one technique seems to have been used in hole production. If we consider specific facets on the edge of the perforation, the initial phase could have been performed by percussion and then further enlarged and modified by a rotatory movement. The final stages of the production chains of Pav 15 and Pav 25 differ, while Pav 25 was carefully finished and intensively used, and Pav 15 lacks traces of further modifications or usage and was possibly abandoned. The method of object fixation remains unclear.

Discussion

The habits of intentional modification and wearing of human remains find a broad spectrum of analogies in paleoanthropology, archeology, and ethnology. Only complex contextual and analogical approaches allow us to understand the possible symbolic or decorative meanings hidden in pierced human teeth.

Paleoanthropological context

Whether teeth were extracted from the jaws of deceased or alive bodies and whether isolated teeth (or alveolar areas) bear traces after extraction remain persistent questions. The pattern is broadly but still indirectly discussed in the context of the French Aurignacian, such as in the case of a mandible from a child aged 3–5 years from the Fontechevade (Charante) that displayed several cut marks on the mylohyoid line. Most of the pierced teeth from La Combe (Dordogne), Grotte des Hyènes at Brassempouy (Landes), Tarté (Haute-Garonne), Isturitz (Pyrénées-Altantiques), and Les Rois (Charente) lack the striations that occur after removal from the jaw, which could be connected to the state of tooth surface preservation. The molars and premolars prevail between human teeth pendants dated to this period. Parallels from the Gravettian include a permanent molar with a grooved root from Les Vachons (Charente) and a permanent right canine with a pierced root from Abri Pataud (Dordogne). A permanent second right premolar with a pierced root occurs in the Magdalenian layer from Saint-Germain-la Rivière (Gironde), and two incisors and a premolar have been recovered from Bédeilhac (Ariège). Additionally, we should mention the human pierced teeth from Placard (Charente) and Chaffaud (Vienne) recently reported as being lost (Moutton and Joffroy 1958; Le Mort 1985; Gambier 2000; Henry - Gambier et al. 2004; Henry - Gambier and White 2006; White 2007; Vercoutère et al. 2008; Ramirez Rozzi et al. 2009; White and Normand 2015).

Archeological context

The choice of the technological and perforation method, as well as the selection of the morphological tooth type, displays a strong and uniform pattern over the whole Pavlovian. At the same time, the variation in the technology used can provide a sensitive marker of changing cultural traditions, as well as direct evidence about differences in producer habits. The human perforated teeth thus represent a clearly unique find within the rich assemblage of Pavlovian adornments. The whole assemblage of pierced animal teeth (more than 300 specimens; Fig. 2b) from the Pavlov I and Dolní Věstonice II is significantly dominated by fox and wolf canines and incisors (Nývltová Fišáková 2005; Lázničková-Galetová 2016), and the choice of the tooth type does not differ much between animal and human teeth. Unfortunately, the information about the perforation techniques used in the preparation of pierced animal teeth is scant. Based on the description by B. Klíma (1997), some of the animal teeth at Pavlov I were perforated by scraping on both root sides, and alternatively, bifacial rotation was used. Similar techniques were recently identified at Dolní Věstonice II by M. Lázničková-Galetová (2016). However, these techniques differ from those used for Pav 15 and Pav 25. Nevertheless, the use of rotation is not a unique technique for the Pavlov I assemblage because similar cases have been identified in the perforation of bone and ivory objects. From broader analogies, biconical rotation was reported by F. Le Mort for perforated human teeth from the French sites Saint-Germain-La-Rivière and Bédeilhac (Le Mort 1985). Additionally, we cannot distinguish with certainty whether human pierced teeth represent solitary decorative objects or whether they were used as part of broader decoration series, such as necklaces, repetitive pendants, or other types of ornaments sewn onto clothing. The interpretative shortage resulting from our knowledge of only the functional characteristics of these objects can be misleading. For example, in the famous Zaraisk necklace, a series of perforated animal teeth were found in a thread-like structure. However, based on functional analyses, these teeth were previously used in clothing applications (Trusov and Zhitenev 2008).

The contextual analysis presents one of the most important tools for interpretation and helps us to understand some of the taphonomic, technologic, symbolic, and functional aspects of the artifact. Therefore, we studied the individual context of pierced human teeth at both sites—Dolní Věstonice I and Pavlov I (see the "Dolní Věstonice I" and "Pavlov I" sections). Based on the intra- and inter-site spatial distribution comparisons, together with the functional zones of the site, the important role played by the archeological context in the attribution of human pierced teeth from Pavlov and DV is as follows: (1) the association of the teeth with specific objects enables analogies to be found at other parts of the site and (2) the association of the teeth with specific objects shows analogies with other Gravettian sites. Pav 25 has interesting context associations with needles, bone awls, and other patches. We know there is a similar relationship between the pendants and objects typical of clothing production from the Gravettian sites in central Russia, e.g., Gagarino (see Zhitenev 2007, 2011; Trusov and Zhitenev 2008), where pierced animal teeth were discovered in the close vicinity of bone needles and a needle case, and at other sites dated to the Kostienki-Avdeevo culture or Gorodtsovian (Zhitenev 2007, p. 55). A similar context is observed for the tooth DV 8 too, which was associated in close vicinity with a spatula tool, awls, grinding stones, and other symbolic objects.

In addition to individual inventories, the association of pierced animal teeth with isolated human remains is another interesting relationship. In the context of Gorodtsovian, pierced teeth patches, needles, and needle cases were found in the vicinity of a human burial. Thus, a possible interpretation is that these objects were part of the burial rite (Zhitenev 2007, p. 55). However, we cannot confirm this connection at the Pavlov I site with high confidence because the human pierced teeth are several dozen meters from the human burial. Nevertheless, their distribution overlaps with pierced animal teeth, which may present an area of deposition of clothes

constructed from perishable material or a place where the adornments were sewed to a costume. The last contextual association represents the connection between pierced teeth (often in the form of a cache) and shallow depressions, pits and areas around hearths, as in the case of Pav 25 and possibly in the cases of Pav 15 and Pav 39 (the paleopedological aspects and cultural layers have been broadly described previously, e.g., Klíma 1997; Novák 2005; Svoboda 2005; Svoboda et al. 2016). Again, a similar situation is described by Zhitenev (2007, p. 55) for pierced teeth from Kostienki 4, Avdeevo, and Gagarino. The order in the arrangement of the pierced teeth in the cultural layers at Pavlov I seems to have repetitive character and broad analogies in Eastern European Gravettian sites and thus does not represent an accidental phenomenon. It seems that although traditions changed in the lithics, the pierced teeth and hard tissue artifacts did not lose their uniformity and perhaps symbolic function, even when the occupation changed. Similar phenomena were observed at other Gravettian sites in Eastern Europe, especially various sites dated to the Kostienki-Avdeevo culture (Gvozdover 1998). Nevertheless, the contextual association of the human perforated teeth from Pavlov I and Dolní Věstonice I with other Gravettian sites (many belonging to the Willendorf-Kostenkian unity) does not automatically refer to any cultural or technological evolution. We can still accept convergence as a possible explanation for these features.

Ethnological context

The most imaginative ethnological analogies are of course the neck human teeth pendants and necklaces from societies in Polynesia and Melanesia, which combine a single line or cross woven patterns of several dozens of human pierced teeth with beads from marine and coconut shells or glass and declare the wearer's ability to overcome enemies (e.g., Skinner and Phillipps 1953; Emory and Sinoto 1964; Orchiston 1972; Leclerc-Caffarel 2013). In addition, the Maori necklaces *maukaki* are described with a fine woven cord with a series of human teeth pendants, hanging single, or in a group of two or three pieces. The teeth originated from several individuals and present *maioha*, tokens as a memento of the deceased. Pierced human teeth can also be used as ear pendants or plugs. Additionally, the models of human teeth with a considerably larger than natural size could be produced from the whale and moa bones, shells, or aphanite (Fairfield 1937; Orchiston 1972). Similar traditions are documented, for example, in Australia (Balme and O'Connor 2019) and Latin America (Saunders 1998). In Artic Siberia and North America, hunters preferred to wear a piece of human viscera or a finger from the deceased body of their ancestors as an amulet to secure luck in hunting or family welfare (e.g., Bogoras 1904–1909; Jochelson 1905–1908; Diószegi 1968; Diószegi and Hoppál 1978).

Some recent societies favor tooth avulsion when one or more teeth, typically maxillary incisors, are intentionally removed for aesthetic, ritual, or group affiliation reasons (Singer 1953; Taylor 1963; Stojanowski et al. 2016). However, we cannot confirm this hypothesis in our material because various types of teeth occur among the isolated human teeth. Additionally, ethnology can provide further examples of artificial and deliberate ante-mortem dental modifications, such as (a) inlaying, when a cavity is bored or drilled in the enamel for inserting additional material, such as jade, pyrite, or gold; (b) filling connected to reshaping of the anterior teeth into points, or removal of the incisor edges; (c) scoring the tooth enamel to create patterns; and (d) coloring and/or discoloring the teeth via blackening or bleaching with a desire to distinguish humans from animals (Alt and Pichler 1998; Mower 1999). However, none of these habits match the situation observed on the pierced human teeth from Dolní Věstonice I and Pavlov I.

Conclusion

As part of the analysis of the variability of mortuary habits during the Upper Paleolithic, this paper focuses on a special type of treatment of dead bodies. Although we do not have enough evidence to indicate whether teeth were extracted from jaws or found in isolation, we can document intentional perforations of the roots. Possible use-wear traces were documented in the case of Pav 25. Several questions of the interpretation and symbolic meaning of these perforated teeth remain unanswered; the main question is whether the teeth were from a living or dead person (e.g., Vanhaeren and d'Errico 2006; Pettitt 2011) and/or whether the person was a dreaded enemy or reputable ancestor. The combination of human pierced teeth with animal teeth or other remains, such as Tertiary and Quaternary mollusc shells, represents an interesting relationship in which specific symbolic value is added. The broader systematic comparison between pierced human and animal teeth and their site contexts promises interesting results regarding the distribution of techniques used in the production of these ornaments and the transfer of knowledge or symbolic traditions.

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