Rezultati računalniške tomografije najstarejše domnevne piščali iz Divjih bab I (Slovenija): prispevek k teoriji luknjanja kosti

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Izvleček

Domnevno piščal iz musterjenskega najdišča Divje babe I v Sloveniji smo analizirali s pomočjo večrezinskega računalniškega tomografa (MSCT) in jo ponovno interpretirali v luči dveh hipotez, od katerih ena predvideva umeten nastanek lukenj in druga naraven. Ugotovili smo, da so bile na diafizi 4 luknje, da sta bili vsaj dve narejeni pred poškodbo proksimalnega in distalnega konca diafize, da zveri niso mogle narediti vseh lukenj, ampak kvečjemu eno. Luknje so zelo verjetno umetne, narejene s kombinirano uporabo kamnitih in preprostih koščenih orodij, najdenih v najdišču Divje babe I. Večina, laho pa tudi vse poškodbe, ki so jih na domnevni piščali naredile zveri, so drugotnega nastanka. Zato ne moremo na podlagi poškodb sklepati o izvoru lukenj in zavrniti hipotezo, ki predvideva njihov umeten nastanek.

Ključne besede: jama Divje babe I, Slovenija, musterjen, "piščal", večrezinska računalniška tomografija (MSCT)

Abstract

The suspected flute from the Mousterian site Divje babe I in Slovenia was analysed with the aid of multi-slice computed tomography (MSCT) and reinterpreted in the light of two hypotheses, one of which envisages an artificial origin of the holes and the other a natural one. It was found that there were four holes on the diaphysis; that at least two were made prior to the damage to the proximal and distal ends of the diaphysis; and that carnivores could not have made all the holes, but one at most. The holes are very probably artificial, made by the combined use of stone and simple bone tools found at the Divje babe I site. The majority, and probably all the damage made by carnivores on the suspected flute, are of secondary origin. Conclusions about the origin of the holes cannot therefore be reached only on the basis of the damage, and the hypothesis of an artificial origin cannot be rejected.

Keywords: Divje babe I cave, Slovenia, Mousterian, "flute", multi-slice computed tomography (MSCT)

1. UVOD

Letos mineva deseto leto od odkritja t. i. musterjenske piščali v srednjepaleolitski plasti najdišča Divje babe I (Turk et al. 1997). V tem času se je zgodilo dvoje: natančneje je bila določena starost najdbe (Lau et al. 1997; Turk et al. 2001; 2002, v tisku), v paleolitski arheologiji pa je delno prevladalo mnenje, da najdba ne predstavlja piščali (glej Chase, Nowell, 1998; Albrecht et al. 1998; d'Errico et al. 1998; 2003; Nowell, Chase v tisku), vendar se takšno mišljenje ni moglo dokončno uveljaviti niti v arheologiji niti na drugih znanstvenih področjih (glej Horusitzky 2003).

Starost je bila določena kronometrično in kronostratigrafsko, in sicer v najdaljši in najtoplejši interstadial kisikove stopnje 3 (MIS 3) oz. srednjega virma (Middle Würm), ali natančneje, 46.000 let pred sedanjostjo (Turk et al. 2001). Ta interstadial, ki ga v Sloveniji označuje zelo vlažna klima (Turk et al. 2002; v tisku), se vzporeja s severnoevropskim interstadialom Moershoofd oz. Glinde po pelodni kronologiji. Po splošnem prepričanju je bil tedaj v Evropi musterjen, edina živeča človeška vrsta pa neandertalec (*Homo sapiens neanderthalensis*). Mlajši paleolitik in anatomsko moderni človek (*Homo sapiens sapiens*) sta v Evropi nastopila šele v naslednjem pelodnem interstadialu, tj. Hengelu, ki ga je od prejšnjega interstadiala ločila globalno hladnejša in aridnejša klimataska faza ali stadial. Neandertalec je izumrl in musterjen se je končal še pozneje, v pelodnem interstadialu Denekamp, ki je verjetno zastopan pri vrhu profila Divjih bab I, tako da ga od "piščali" ločijo 2 m debele in v predelu s "piščaljo" cementirane plasti sedimentov, ki odslikavajo bolj suho klimo. Glede na te ugotovitve je najdba, kolikor dejansko predstavlja piščal, nesporno najstarejša te vrste, ker jo od drugih podobnih najdb, ki trenutno veljajo za najstarejše (glej Hein 1998, 127; Auffermann, Orschiedt 2002, 69; Conrad et al. 2004), loči vsaj en stadial, v večini primerov pa vsaj dva in en interstadial (Leocata 2000-2001, sl. 2; d'Errico et al. 2003, sl. 10; 11) ali 10 do 15 tisoč let. Najdbo, ki je kronološko bolje opredeljena od vseh podobnih najdb, lahko na podlagi datacij skeletnih najdb človeške vrste v Evropi z večjo verjetnostjo pripišemo neandertalcu kot anatomsko modernemu človeku (glej tudi Nowell, Chase v tisku). Slednjemu jo zaenkrat pripisuje samo M. Brodar (1999), in sicer na podlagi precej mlajših domnevno umetno naluknjanih kosti v orinjasjenskih najdiščih Slovenije (glej M. Brodar 1985). Pri tem se ne ozira na skeletne najdbe.

Pri najdbi je bila od vsega začetka sporna edino njena interpretacija, ki je odvisna predvsem od vprašanja, kako so nastale luknje. Ker se je, kot rečeno, uveljavilo mnenje, da so luknje v "piščali" naravne (Chase, Nowell 1998; Albrecht et al. 1998; d'Errico et al. 1998; 2003; Nowell, Chase v tisku), in ker mislimo, da takšno mnenje ni najbolje utemeljeno (Kunej, Turk 2000; Turk et al. 2001; 2003), smo se odločili za še eno analizo sporne najdbe, tokrat s pomočjo večrezinske računalniške tomografije (odslej CT).

Raziskavo smo naredili s pomočjo večrezinskega (16-rezinskega) računalniškega tomografa (MSCT - 16 multi slice computed tomography) na Inštitutu za radiologijo Kliničnega centra v Ljubljani[1]. Tehnični podatki so naslednji:

1. Topogram
kV-180
mA 50
debelina rezine: 1 mm
dolžina topograma: 256 mm

2. Slikovni del - spirala
kV 120
eff.mAs 90
čas skeniranja: 7,49
debelina rezine: 1.0 mm, kolimacija rezine: 0,75 mm
pomik/obrat: 18,0
konstrukcijski algoritem B31s srednje rahel, 0,75
rekonstrukcijski inkriment 7
FOV 250

Vzdolž diafize smo posneli 228 rezin v segmentalni ravnini, debelih 1,00 mm. Vsaka rezina se s predhodnjo prekriva v dolžini 0,25 mm. Rezine so oštevilčene tako, da se tekoče številke začnejo na skrajnem proksimalnem delu diafize (štev. 58) in končajo na skrajnem distalnem (štev. 285) (*sl. 1*).

Za lociranje rezin na levem femurju juvenilnega jamskega medveda bomo uporabljali anatomske oznake in imena, kot so epifiza, metafiza in diafiza. Obe epifizi, tj. sklepa, na t. i. piščali manjkata, ker še nista bili priraščeni. Metafizi, dela med epifizo in diafizo, sta odstranjeni oz. močno poškodovani. Diafiza, osrednji del cevaste kosti, ki je tudi poškodovana, ima proksimalni in distalni konec, medialno in lateralno ter anteriorno in posteriorno stran. Proksimalni konec je bliže trupu, distalni pa je od trupa bolj oddaljen. Medialna stran je obrnjena navznoter oz. proti sredini trupa, lateralna navzven oz. vstran od sredine trupa. Anteriorna stran je obrnjena naprej v smeri glave, posteriorna nazaj v smeri repa (*sl. 1*).

Za številne luknje in izjede zaradi lažjega sporazumevanja uporabljamo številke od 1 do 5 (*sl. 1*) (glej tudi Turk et al. 2001, sl. 8).

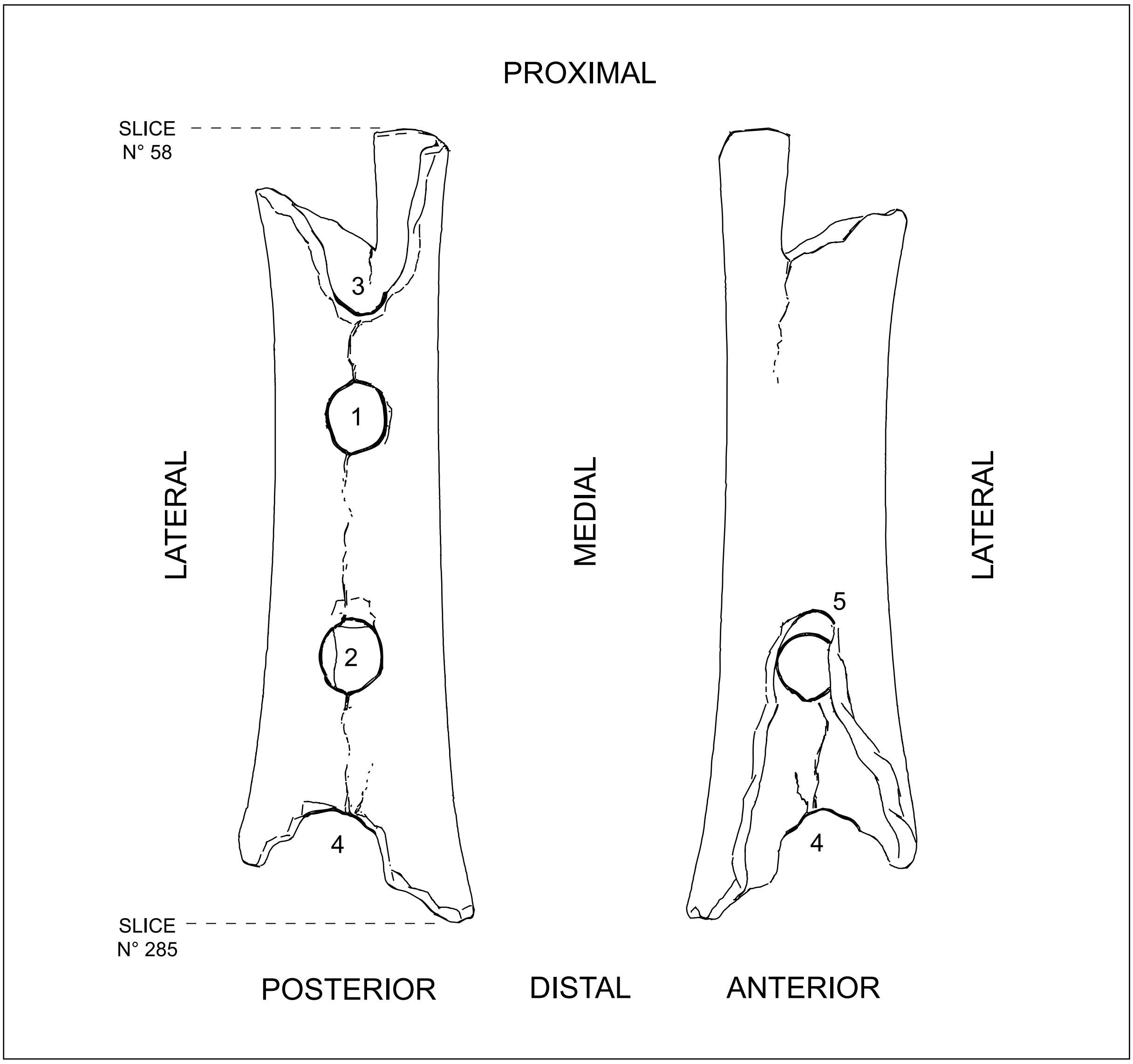
Prvoten namen analize je bil ugotoviti, ali obstaja povezava med debelino kostne lupine in lokacijo lukenj. Pri prediranju z zobmi bi se lupina predrla prej tam, kjer je tanjša, saj zveri z zobmi preizkušajo trdnost kosti in iščejo njihove šibke točke. Človek bi se pri prediranju z orodjem domnevno ne oziral na debelino kostne lupine ali pa bi jo poskušal stanjšati. Želeli smo tudi preveriti, ali sta obe manjši izjedi na anteriorni in posteriorni strani ostanek luknje ali samo del odloma, ki spominja na luknjo. Pozneje smo si izbrali dodatne cilje. Tako smo hoteli ponovno preveriti, kako so lahko nastale posamezne luknje in poškodbe ter ali obstaja med enimi in drugimi povezava, kot trdijo nekateri (Chase, Nowell 1998; Albrecht et al. 1998; d'Errico et al. 1998; 2003; Nowell, Chase v tisku). Zato smo želeli ugotoviti časovno zaporedje lukenj in poškodb. To je vprašanje, s katerim se nihče ni podrobneje ukvarjal, je pa pomembno za preverjanje postavljenih hipotez (glej Nowell, Chase v tisku). Te so lahko močne v teoriji in šibke v praksi. Slednje posebej velja za hipotezo Albrechta, Chaseja in d'Errica, ki se zavzemajo za zverski izvor lukenj (glej nadaljevanje).

2. REZULTATI ANALIZE IN RAZLAGA REZULTATOV

Fragmentacija proksimalne diafize

Lateralno je lupina debelejša (5,4 mm) kot medialno (4,0 mm). Debelino smo določili s pomočjo CT rezine (*sl. 2*). Medialna lupina skrajne-

[1] Topogram je prispeval radiolog Dean Pekarovič. Podatke sta računalniško obdelala Dean Pekarovič in Miran Pflaum.



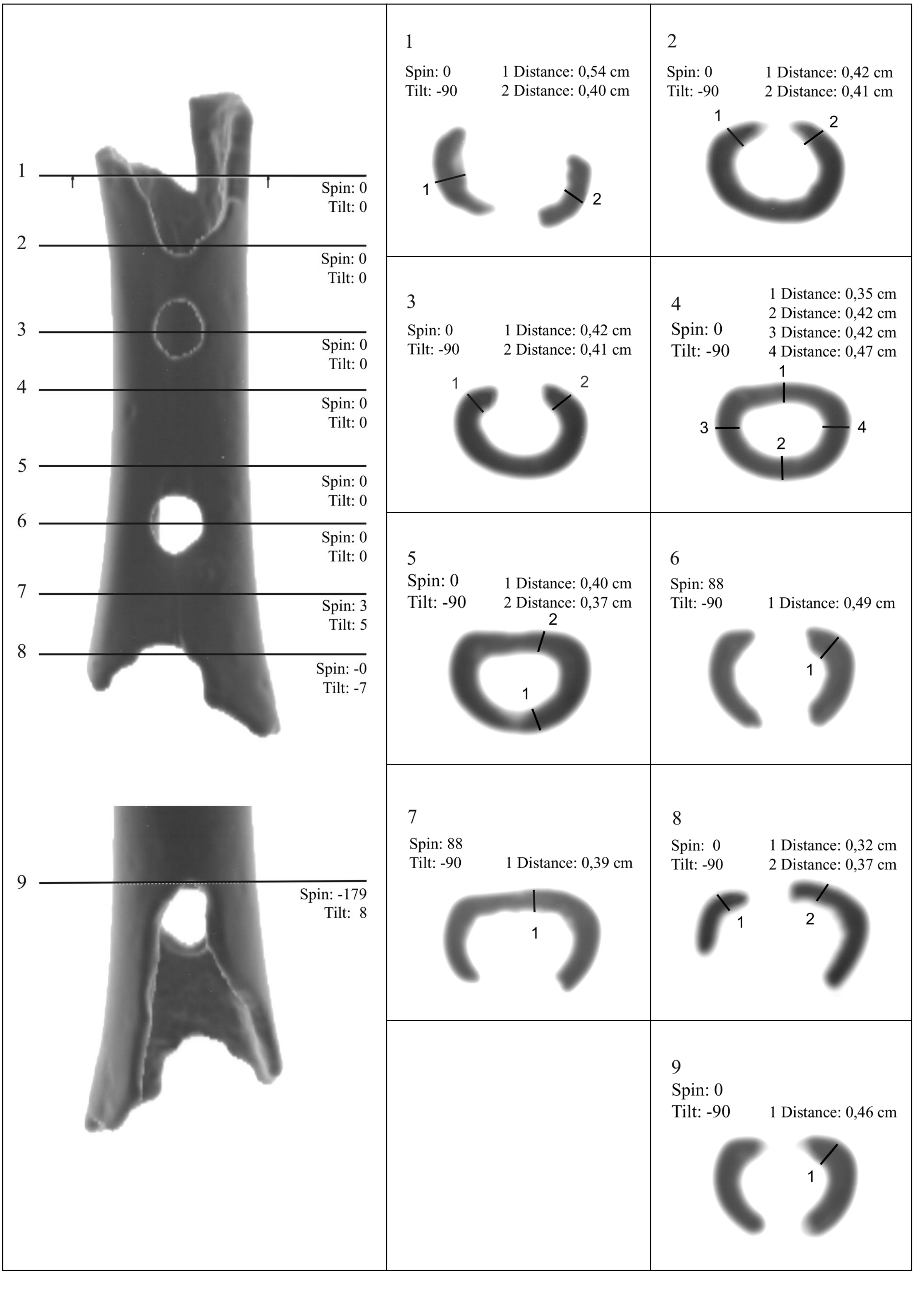
Sl. 1: Terminološke oznake, uporabljene v tekstu ter prva in zadnja rezina. M. = 1:1. Risba D. Knific Lunder.
Fig. 1: Terminology used in the text and first and last slices. Scale = 1:1. Drawing D. Knific Lunder.

ga proksimalnega dela odlomljene diafize je stanjšana na najmanj 3 rezinah. Vsi robovi so zaobljeni.

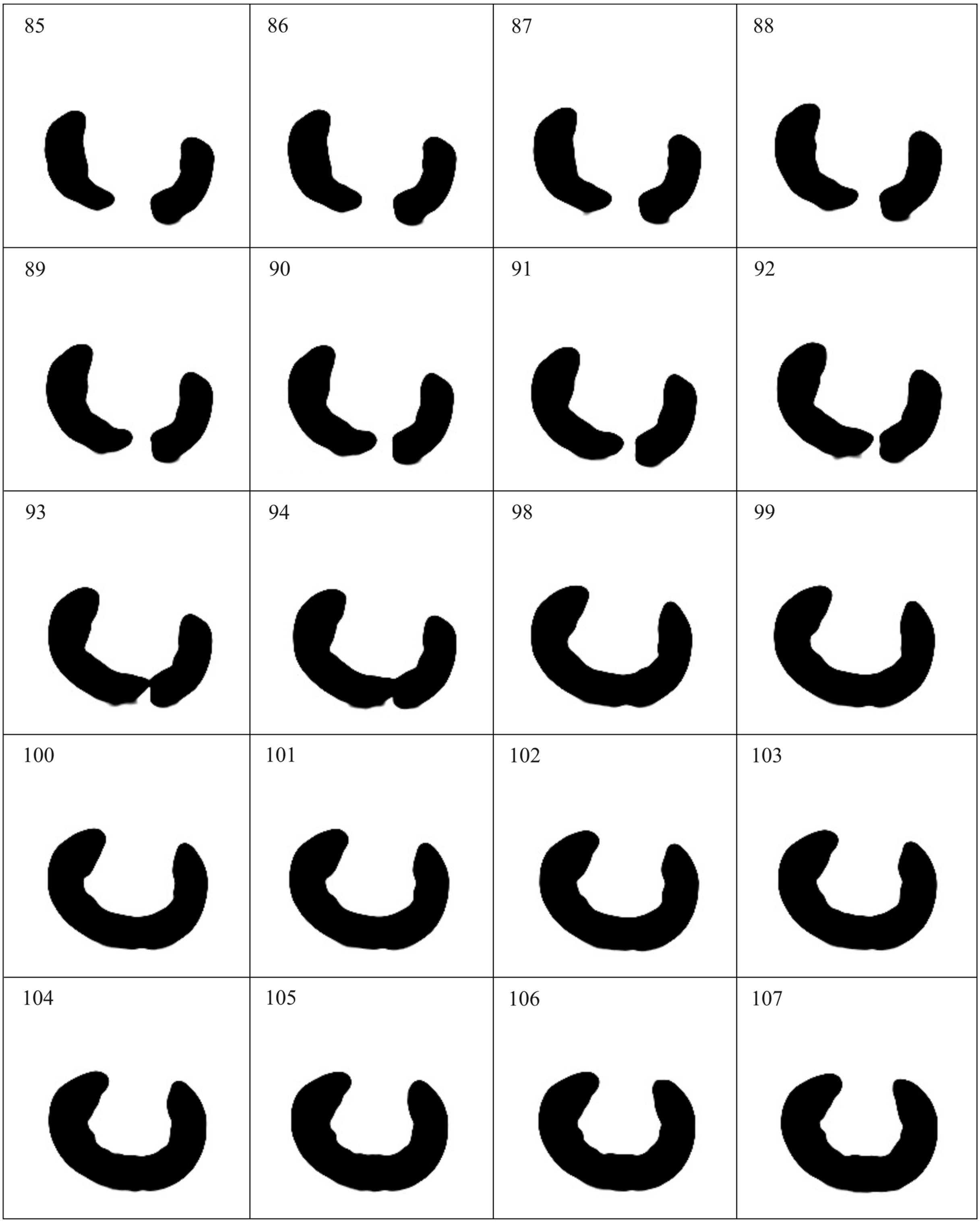
Prav tako je stanjšan skrajni del lateralne lupine odlomljene diafize na najmanj 3 rezinah. Robovi so zaobljeni.

Stanjšanje lahko razložimo z grizenjem (glej Chase, Nowell, 1998; d'Errico 2003) ali močnejšim kemičnim preperevanjem zaradi večje površine na prostorninsko maso.

Fragmentacija je bila dvofazna. Najprej se je v obliki črke U odlomil posteriorni del lupine, ki je bil oslabljen zaradi luknje 3. Sila je delovala v anteriorni smeri. To dokazuje izrazito poševen lateralni rob odloma, ki je obrnjen navznoter (*sl. 3:* rezine 98-107). Nato se je v obliki črke V odlomil še anteriorni del lupine. Tik pred tem ali pri tem je nastala tudi razpoka v podaljšku vzdolžnega roba odloma na anteriorni strani. Da gre za drugo fazo, sklepamo na podlagi sile, ki je tudi tokrat delovala v anteriorni smeri. Precejšen del roba odloma, ki je v bližini razpoke, je namreč močno poševen in obrnjen navzven (*sl. 3:* rezine 85-93) oz. v isto smer kot rob odloma na anteriorni strani v bližini luknje 3. Zato domnevamo, da se je proksimalni del diafize zaradi stiskanja z zobmi najprej odlomil na posteriorni strani. Odlom se je razletel na dvoje in omogočil, da je spodnji zob udaril ob medularno površino anteriornega dela lupine, ki se je nato odlomila zaradi strižne sile, ki sta jo povzročila zgornji in spodnji zob. Pred



Sl. 2: Mesta, na katerih smo izmerili debelino kostne lupine. M. = 1:1.
Fig. 2: Places at which the thickness of the bone cortex was measured. Scale = 1:1.



Sl. 3: Izbor prečnih (segmentalnih) rezin proksimalnega dela epifize, distalno od luknje 3. M. = 1:1.
Fig. 3: Selection of transverse (segmental) slices of the proximal part of the epiphysis, distally from Hole 3. Scale = 1:1.

tem je domnevna zver večkrat obrnila kost med zobmi in pustila sledi, ki jih navaja d'Errico s sodelavci (2003, sl. 9).

Chase in Nowellova (1998, 551) imata za odlom na anteriorni strani drugačno razlago. Nastal naj bi zaradi teptanja ali pritiska v sedimentu na že prepereli kosti. Odlom na posteriorni strani razlagata kot obgrizen rob (Nowell, Chase v tisku).

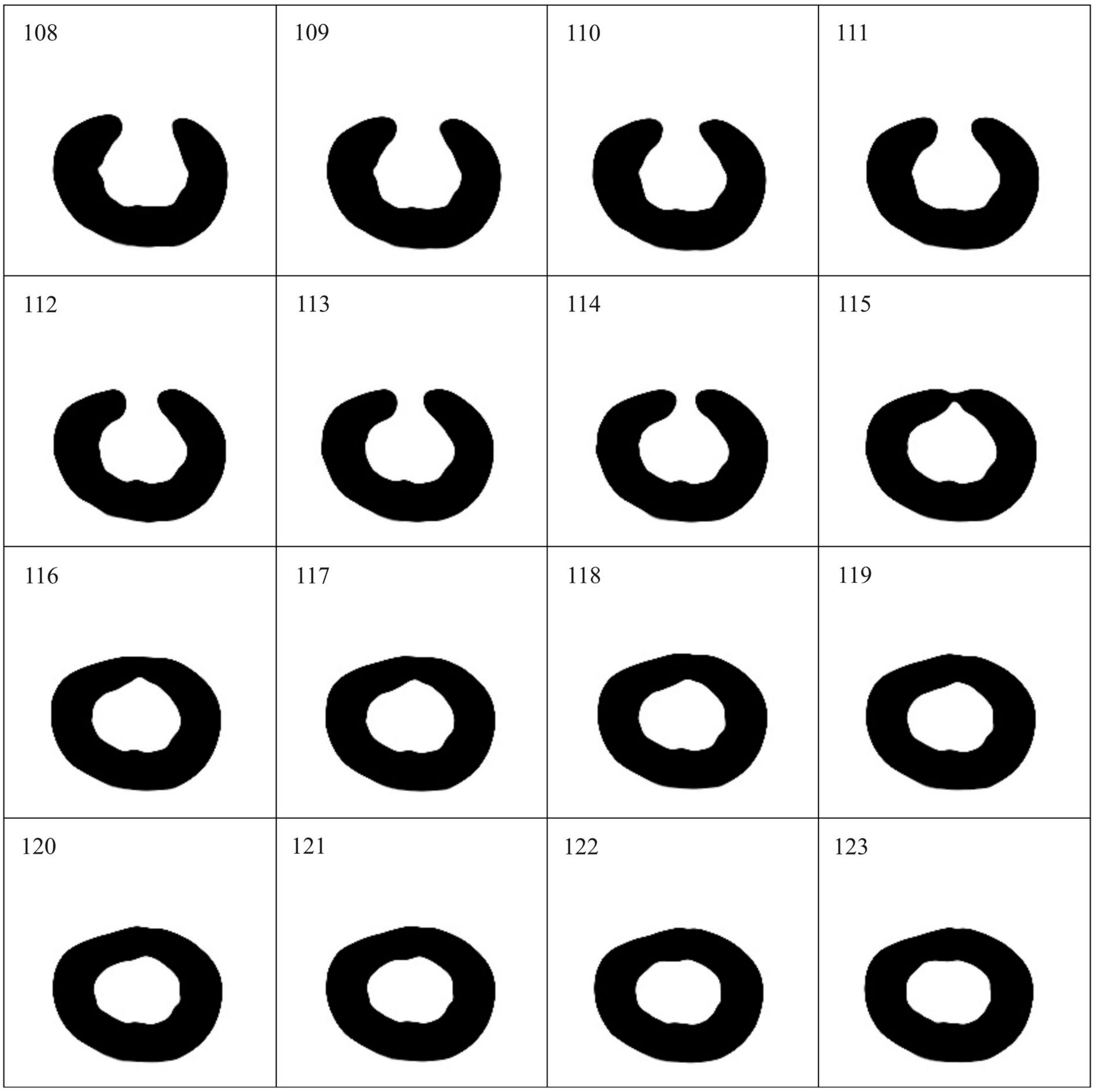
Izjeda 3 na proksimalnem delu diafize (= ostanek luknje 3)

Izjeda 3 je dejansko ostanek luknje. Zato jo bomo odslej imenovali luknja 3. Kot luknjo smo jo obravnavali že v prvi objavi (Turk et al. 1997), vendar smo jo pozneje označili za izjedo (Turk et al. 2001). Nowellova in Chase (2000) jo razlagata kot neko vrsto vdolbine, narejene z zobom.

Največji ohranjeni premer luknje je 7,6 mm, debelina lupine na mestu luknje pa je 4,2 mm. Debelino smo določili s pomočjo CT rezine (*sl. 2*). Premer, določen s CT, je večji za 1,1 mm od premera, ki smo ga izmerili s kljunastim merilom (glej Turk et al. 1997, 161).

Distalno od luknje je stena medularnega kanala longitudinalno odkrušena na 3 rezinah (*sl. 4:* 116-118; *sl. 6*). Takšna poškodba nastane pri prediranju ali prebijanju in je tudi pri vseh drugih luknjah (glej nadaljevanje). Zato je izjeda ostanek luknje. Pri prediranju ali prebijanju se stena medularnega kanala odkruši v vzdolžni smeri, kakor poteka večina kanalov in kolagenskih vlaken.

Robovi luknje so zaobljeni po celotnem obodu.



Sl. 4: Izbor prečnih (segmentalnih) rezin proksimalno od luknje 3 (108-109), pri luknji 3 (110-115) in distalno od luknje 3 (116-122). M. = 1:1.
Fig. 4: Selection of transverse (segmental) slices proximally from Hole 3 (108–109), by Hole 3 (110–115) and distally from Hole 3 (116–122). Scale = 1:1.

Na mestu, kjer je luknja odlomljena, je navznoter lijasto razširjena (*sl. 4:* rezina 109), distalno pa nič več (*sl. 4:* rezina 113). Tu je rob luknje navpičen. Lijak na medialnem robu luknje je lahko posledica majhne poškodbe, do katere je prišlo med luščenjem kosti iz breče (Turk et al. 1997, 157).

Lupina ni na mestu luknje nič tanjša kot anteriorno, nasprotno, v manjkajočem delu luknje je bila verjetno celo debelejša. Zato debelina lupine ni vplivala na položaj luknje.

Distalno od luknje je lupina zunaj lokalno močno preperela. Rezultat preperevanja je luščenje (eksfoliacija) lupine, ki se konča v razpoki. Eksfoliacija in razpoka sta natančno nad odkrušenim delom medularnega kanala. Razpoka je lahko nastala ali pri prediranju ali kdaj pozneje. Prediranje je mogoče z zobom ali koščenim prebijačem. Ker anteriorno ni najmanjšega odtiska zoba antagonista (glej *sl. 3* in *4:* rezine 106-122), je verjetneje, da je bila luknja umetno prebita tako, kakor smo razložili v našem zadnjem prispevku (Turk et al. 2003). Mikroskopske poškodbe, povzročene z zobom antagonistom, ki jih navaja d'Errico s sodelavci (2003, sl. 9), so nepomembne za razlago nastanka luknje 3. Za luknjanje 3,9 mm debele lupine z zobom je potrebna sila do 4000 N (glej Turk et al. 2001, tab. 4). Zato bi zob antagonist naredil vidno vdolbinico ali pa bi anteriorna lupina vzdolžno počila. Vendar se ni zgodilo ne eno ne drugo.

Diafiza med ostankom luknje 3 in luknjo 1

Na posteriorni strani je lupina na tem mestu nekoliko tanjša kot na anteriorni (*sl. 4:* rezine 119-122). Med obema luknjama je lupina počena. Razpoka je lahko samo površinska in povezana z eksfoliacijo ob distalnem robu luknje 3. Razpoke CT ni zaznal.

Luknja 1

Luknja 1 je nepravilna. V distalnem delu ima na robu majhno izjedo v obliki črke V. Največji premer v medialno-lateralni smeri, določen s pomočjo CT, znaša 8,4 mm, kar je 0,2 mm več, kot smo izmerili s kljunastim merilom, v proksimalno-distalni pa 10,5 mm, kar je 0,8 mm več, kot smo izmerili s kljunastim merilom (glej Turk et al. 1997, 161). Kostna lupina ob luknji je debela 4,2 mm, in sicer tako na lateralni kot medialni strani (*sl. 2*).

Proksimalno od luknje, bliže njej kot vstran od nje, je medularni kanal longitudinalno-lateralno močno odkrušen na 6 rezinah (*sl. 5:* 127-132). V bistvu gre za lijasto odkrušeno lupino (*sl. 6*). Lijak se nadaljuje v proksimalni lateralni obod luknje, medtem ko ga v medialnem ni (*sl. 5:* rezine 135-137). Večji del odkrušene cone je vstran od razpoke, ki povezuje luknji 3 in 1. Medtem ko je odkrušena cona umeščena bolj lateralno, je razpoka bolj medialno. Razpoke CT ni zaznal, zato ne vemo, ali je ta površinska ali globinska, vsekakor pa je zelo ozka.

Obod pri največjem medialno-lateralnem premeru ima navpične stene z zaobljenimi robovi. Lijaka na tem delu ni (*sl. 5:* rezina 140; *sl. 6*).

Oba distalna oboda luknje, medialni in lateralni, sta lijasta navznoter (*sl. 5:* rezine 146-149). Skrajno distalno je lijasta samo medialna stran (*sl. 5:* rezini 150-151). Tu je rahel lijak tudi na zunanji strani.

Lupina je posteriorno in anteriorno enako debela. Zato debelina lupine ni razlog za položaj luknje, kot so domnevali nekateri (glej Nowell, Chase v tisku; Albrecht et al. 2001).

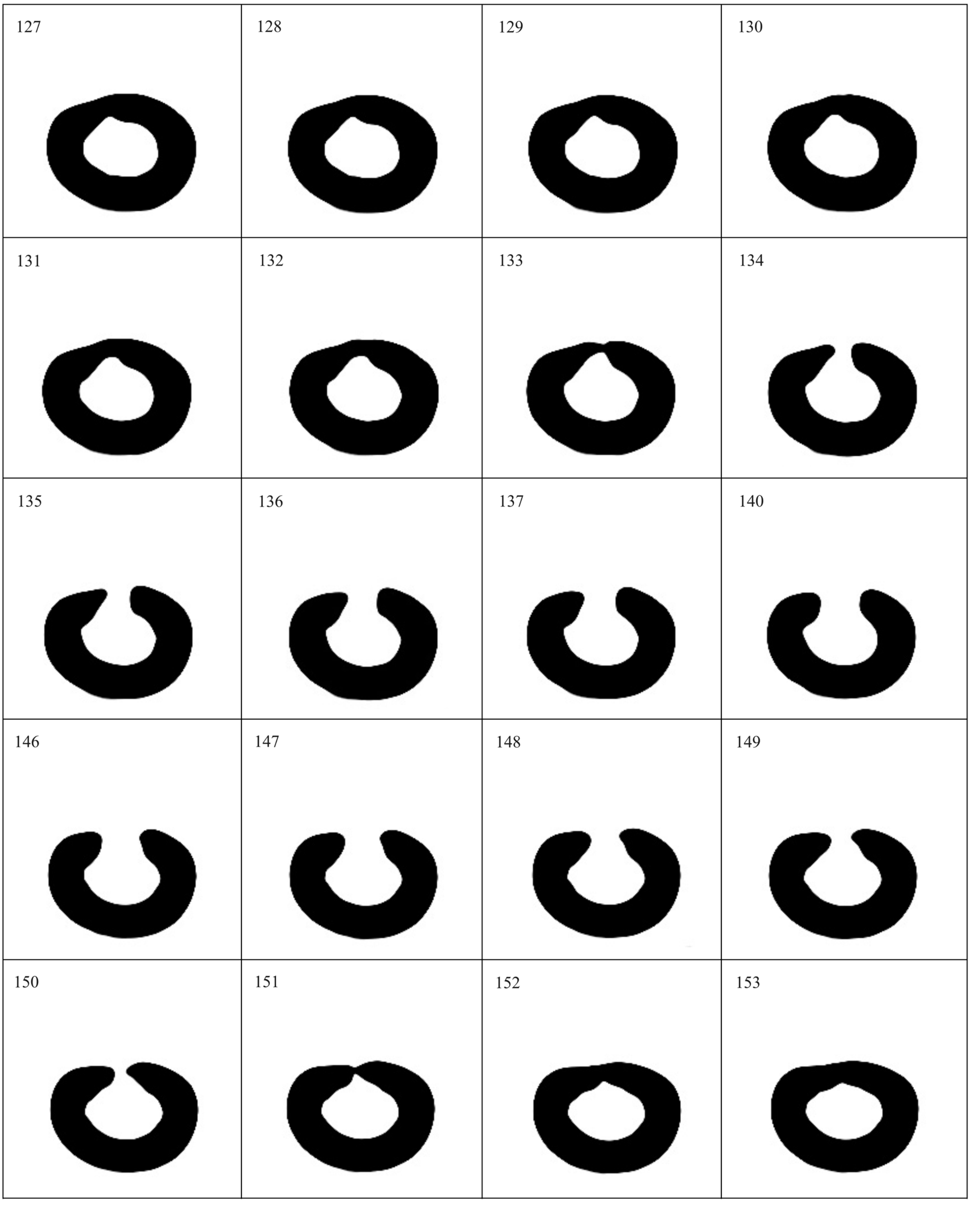
Distalno od luknje je medularni kanal longitudinalno rahlo odkrušen na 2 rezinah (*sl. 5:* 152-153). Poškodba je podobna poškodbi ostanka luknje 3. Na posteriorni, preluknjani strani je lupina na tem mestu nekoliko tanjša kot na anteriorni, kar je enako kot pri ostanku luknje 3. Poškodba je nekoliko medialno od izjede v obliki črke V na obodu luknje in precej vstran od razpoke, ki povezuje luknji 1 in 2.

Velik del oboda luknje 1 ima navpične stene z zaobljenimi robovi. Menjavanje dolgih navpičnih sten na obodu luknje s poševnimi stenami oz. z lijasto oblikovanimi odseki je bolj značilno za klesanje s kamnito konico (glej Turk et al. 2001) kot prediranje z zobom ali koščenim prebijačem (prav tam; Turk et al. 2003). Pri prediranju z zobom je nasproti lijasto odkrušenega roba običajno strm rob, ne pa drug lijasto odkrušen rob kot pri luknji 1.

Podobno velja za nepravilno obliko luknje, ki jo lahko naredimo le s kamnitim ali koščenim orodjem.

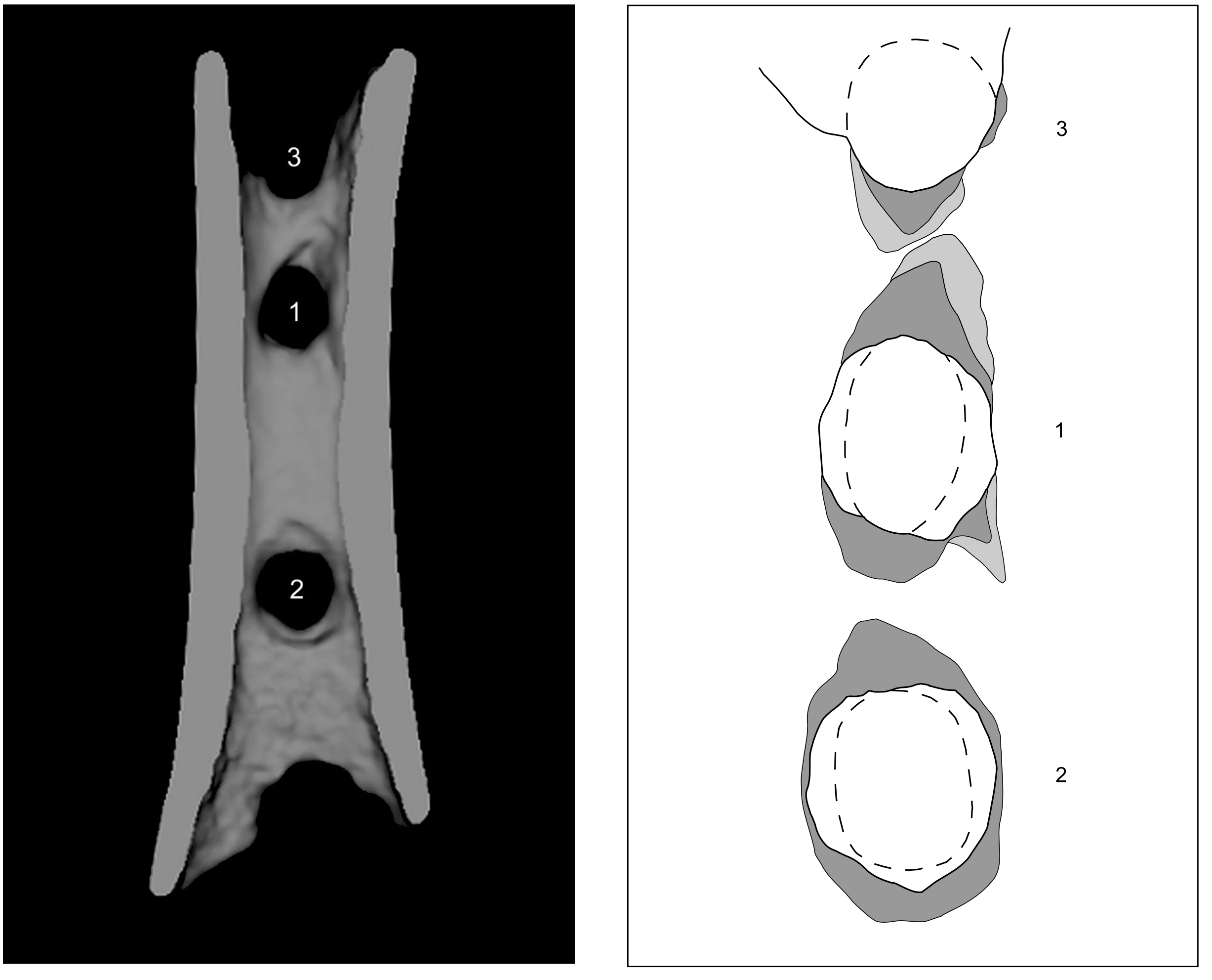
Luknja, ki je v celoti narejena s kamnitim orodjem, ima lahko na zunanji strani le delen in neznaten lijak. Luknja, prebita s koščenim orodjem, se v ničemer ne razlikuje od luknje, ki jo naredi zob (glej Turk et al. 2003, sl. 3).

Izrazite vdolbine na zunanjem lateralnem proksimalnem robu (*sl. 7*) lahko kažejo na uporabo kamnitega orodja. Razpoka v kosti bi lahko nastala pri prebijanju s koščenim prebijačem ali pri prediranju z zobom. Prediranje z zobom je malo verjetno, ker na anteriorni strani ni vidne nobene vdolbinice oz. odtiska zoba antagonista pri rezinah 125-170 (glej *sl. 5* in *8* za del rezin in sl. 21a v: Turk et al. 2001), ker oblika luknje in morfologija robov slabo



Sl. 5: Izbor prečnih (segmentalnih) rezin med luknjama 3 in 1 (127-132), pri luknji 1 (133-151) in distalno od luknje 1 (152-153). M. = 1:1.
Fig. 5: Selection of transverse (segmental) slices between Holes 3 and 1 (127–132), at Hole 1 (133–151) and distally from Hole 1 (152–153). Scale = 1:1.

ustrezajo obliki lukenj, narejenih s kaninom (glej Turk et al. 2001, sl. 16), in ker se počena kost ni razklala. Mikroskopske poškodbe na anteriorni strani, ki jih je ugotovil d'Errico s sodelavci (2003, sl. 9) in domnevno razložil kot zverske, so nepomembne za razlago nastanka luknje. Kot pri luknji 3 bi tudi



Sl. 6: Tomograf medularnega kanala z luknjami 3, 1 in 2. Vidijo se mesta, kjer je kost odkrušena. M. = 1:1.
Fig. 6: Tomograph of medullary cavity with Holes 3, 1 and 2. Places where the bone has crumbled can be seen. Scale = 1:1.

tu potrebovali za potrditev takšne razlage bolj prepričljivo sled zoba antagonista. Trditev Albrechta s sodelavci (2001), da je nasproti luknje 1 našel odtisek zoba, se ne ujema z dejanskim stanjem. Prav tako trditev d'Errica s sodelavci (2003, 37), da je nasproti te luknje in luknje 2 jasen odtis zoba. Da odtisa ni, sta ugotovila tudi Nowellova in Chase (2000).

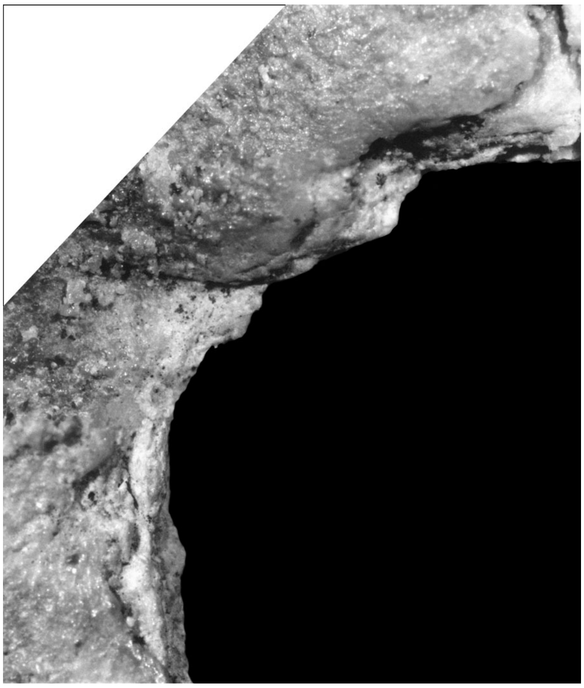
Chase in Nowellova (1998, 552) sta v svoji kritiki razlage umetnega nastanka lukenj domnevala, da so imele te prvotno lijaste odprtine nepravilne oblike (glej tudi Nowell, Chase v tisku). Robovi odprtine so se pozneje poškodovali oz. prepereli in se spremenili v navpične, sama odprtina pa se je povečala za 3-4 oz. 1,5-2 mm in dobila okroglo obliko.

Takšna domneva o drobljenju robov lijastih lukenj ni možna pri luknji 1, saj bi bila ta pred preperevanjem izrazito ovalne oblike namesto okrogle (glej *sl. 6*). Tako oblikovana odprtina ne nastane s prediranjem s kaninom, medtem ko drugi zobje zaradi lege luknje ne pridejo v poštev (glej Turk et al. 2001, sl. 10). Z zadnjim se strinja večina, ki je sodelovala v razpravi o nastanku lukenj v t. i. musterjenski piščali (Albrecht et al. 1998; d'Errico et al. 2003). Poleg tega bi bila luknja ovalna v proksimalno-distalni smeri, medtem ko bi zveri lahko naredile z derači ovalno luknjo samo v medialno-lateralni smeri (glej Turk et al. 2001, sl. 10). Enako velja tudi za luknji 3 in 5.

Domneva Chaseja in Nowellove je zato mogoča samo pri luknji 2, ki ima na notranji strani skoraj popoln lijak.

Diafiza med luknjama 1 in 2

Bliže luknji 1 je lupina na anteriorni strani debela 3,5 mm, na posteriorni pa 4,2 mm. Bliže luknji 2 je lupina anteriorno debela 3,7 mm in posteriorno 4,0 mm. Vse debeline smo določili s pomočjo CT rezin (*sl. 2*).



Sl. 7: Detajl zunanjega proksimalnega lateralnega roba luknje 1 z vidnimi sledmi klesanja. Foto F. Cimerman. Močno povečano.
Fig. 7: Detail of the outside proximal lateral edge of Hole 1 with visible traces of chiselling. Photo F. Cimerman. Greatly enlarged.

Naluknjana posteriorna lupina je povprečno tanjša proksimalno- in distalno-medialno od luknje 1 (*sl. 4:* rezini 121-122; *sl. 8:* rezine 154-158). Zato bi v primeru grizenja pričakovali luknjo prej na delu s stanjšano lupino, kot je to napačno dokazoval Albrecht s sodelavci (2001), ko je na podlagi lege lukenj na tanjšem delu lupine zagovarjal hipotezo o njihovem živalskem izvoru. Enak dokaz navajata tudi Nowellova in Chase (2000).

Med obema luknjama je rahla razpoka, ki jo CT ni zaznal. Zato ni jasno, ali je razpoka površinska ali globinska, je pa vsekakor zelo ozka.

Distalno od luknje 2 je bila površina lupine poškodovana v dolžini slabega centimetra, tako da se vidijo strukturna vlakna (Turk et al. 1997, sl. 11.1: 4). Poškodba je zelo verjetno nastala z brušenjem z namenom stanjšati lupino, ki je na mestu luknje 2 najdebelejša (*sl. 11:* rezina 218).

Na anteriorni površini lupine ni nobene vdolbinice zoba antigonista (*sl. 8:* rezine 170-188), ki bi jo pričakovali pri luknjanju z zobmi.

D'Errico s sodelavci (2003, sl. 9) navaja na tem odseku samo nekaj mikroskopskih poškodb, osredotočenih distalno od luknje 1. Razlaga poškodb je lahko vprašljiva. Vsekakor pa je močno vprašljivo povezovanje poškodb z luknjo.

Izjeda 5 na distalnem delu diafize (= ostanek luknje 5)

Izjeda 5 je dejansko ostanek edine luknje na anteriorni strani diafize. O njenem obstoju smo sprva dvomili (Turk et al. 1997), pozneje smo jo na podlagi poskusov opredelili kot možno (Turk et al. 2001). Rezultat CT nas je dokončno prepričal, da je bila izjeda 5 nekoč luknja.

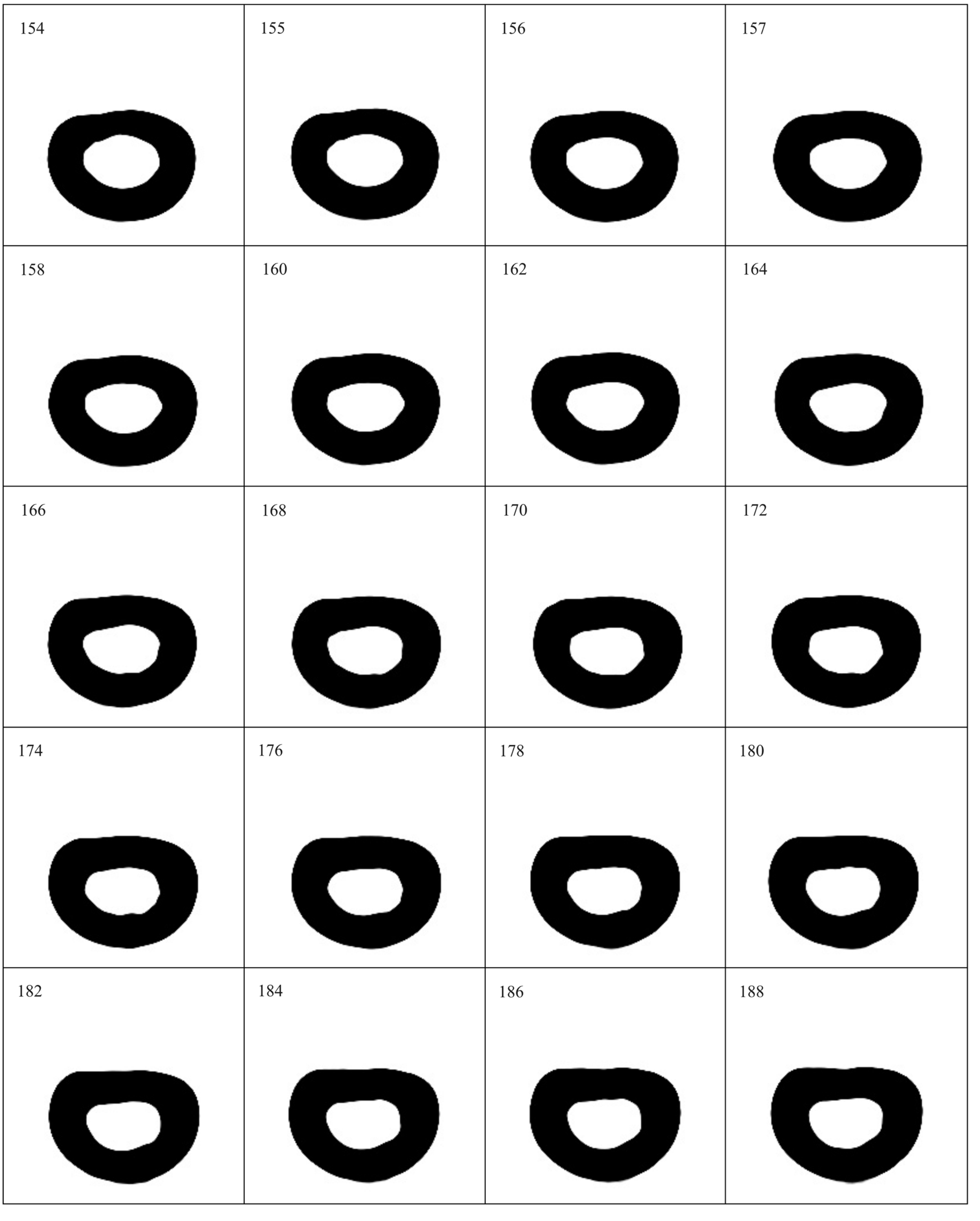
Luknja 5 je brez razpoke. Največji ohranjeni premer, določen s pomočjo CT, je 6,2 mm, debelina lupine na mestu luknje pa je ob lateralnem robu 4,6 mm (*sl. 2*). Robovi luknje so zaobljeni po celotnem obodu.

Proksimalno od luknje je medularni kanal *longitudinalno* močno odkrušen na 4-5 rezinah (*sl. 9:* 191-195; *sl. 12*), bliže luknji kot stran od nje. Takšna poškodba v obliki lijaka nastane pri prediranju ali prebijanju luknje. Zato ne dvomimo več, da je izjeda ostanek luknje.

Na zunanji strani lupine je na tem mestu plitka vdolbinica (*sl. 9:* rezine 193-195), ki postaja globlja, bolj ko se bliža luknji. Na zadnjih dveh rezinah (*sl. 9:* rezini 194-195) pred skrajnim proksimalnim delom luknje je plitka vdolbinica tudi medularno na posteriornem delu lupine nasproti luknje 5. Ta vdolbinica se nadaljuje tudi v naslednji dveh rezinah (*sl. 9:* 196-197), tako da se delno prekrije s skrajnim proksimalnim robom luknje 5, nato pa izgine. Hkrati se pojavi vdolbinica na zunanji strani (*sl. 9:* rezine 196-197), ki je povezana z zbrušeno posteriorno površino. Vdolbinica postaja vse večja in globlja, dokler nazadnje ne preide v luknjo 2 (*sl. 9:* rezine 198-202).

Skrajni proksimalni del luknje 5 ima na lateralnem robu na zunanji površini lijak, na medialnem pa je lijak na notranji (medularni) površini (*sl. 9:* rezini 196-197). Del zunanjega lijaka je povezan z omenjeno vdolbinico, kar naj bi kazalo, da je bila luknja izklesana. Vendar bi vdolbinico lahko naredil tudi zob, preden bi zdrsnil na mesto, kjer je luknja 5. Notranji lijak je prav tako lahko nastal pri klesanju ali pa pri prediranju z zobom. Distalno obeh lijakov ni več. Obod luknje ima na tem odseku vse robove močno zaobljene (*sl. 9:* rezine 198-200), kar daje vtis izklesane luknje. Odsotnost razpoke, značilne za prediranje z zobom ali za prebijanje s koščenim prebijačem, ta vtis samo še podkrepi.

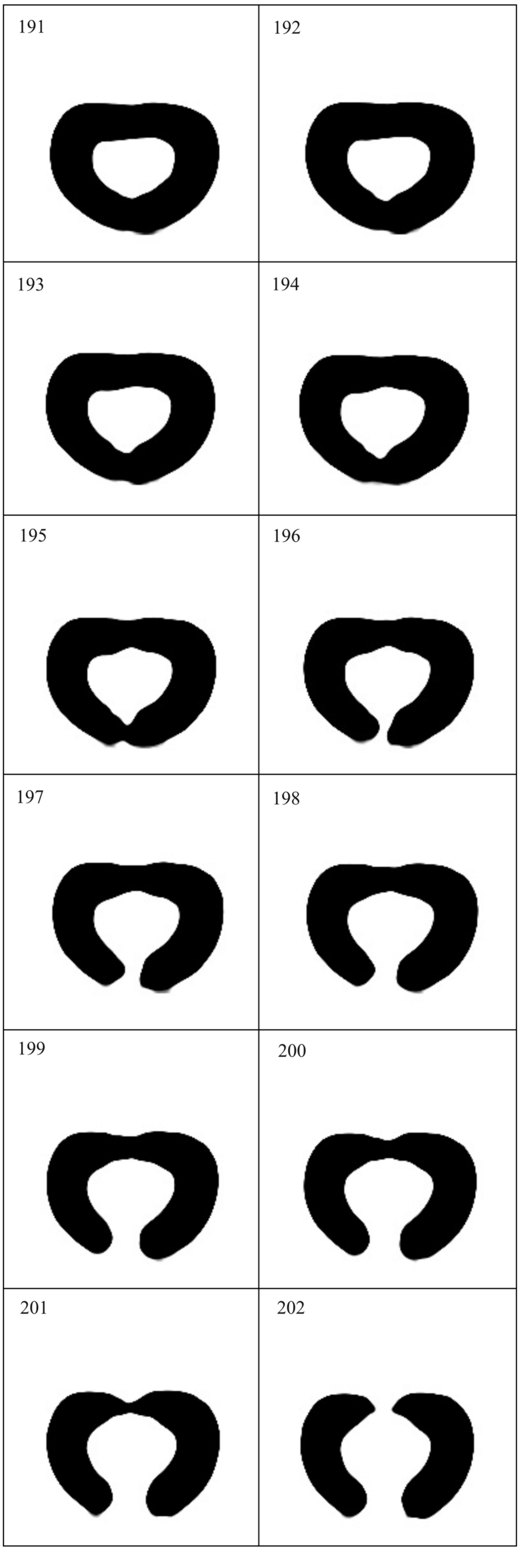
Ostanek luknje 5 nekateri razlagajo kot delo zoba antagonista, zoba, ki je naredil luknjo 2 (Chase, Nowell 1998, 551; d'Errico et al. 1998, 77; Nowell, Chase v tisku). Luknji 2 in 5 sta namreč približno ena pod drugo (*sl. 10*). Da taka razlaga ni mogoča, smo že ugotovili, sklicujoč se predvsem na okluzijo kaninov (Turk et al. 2001). Tokrat dodajamo, da je nemogoče, da bi hkrati z luknjama 2



Sl. 8: Izbor prečnih (segmentalnih) rezin diafize med luknjama 1 in 2. M. = 1:1.
Fig. 8: Selection of transverse (segmental) slices of the diaphysis between Holes 1 and 2. Scale = 1:1.

in 5 nastal odlom, ki je poškodoval luknjo 5.

Dejstvo je, da se kostna lupina lahko odlomi ob luknji v obliki črke U ali V. Take odlome poznamo tudi z drugih najdišča (glej Albrecht et al. 1998, sl. 10: 3). Vendar, kot rečeno, ne moreta hkrati nastati luknja in odlom. Če bi kost pri prediranju kljub vsemu ob luknji počila v obliki črke V, bi razpoka nastala tudi na nasprotnem robu luknje, kar pa se ni zgodilo. Zato menimo, da je odlom v obliki črke V ob luknji 5 mlajši od luknje.



Luknji, ki sta ena pod drugo, sta izjemno redki. Našli smo ju tudi na diafizi femurja juvenilnega jamskega medveda iz plasti 4-5a med paleolitskimi najdbami v Divjih babah I (Turk et al. 1997, sl. 11.15). Po zakonih fizike obeh lukenj ni bilo mogoče narediti z zobmi (toda glej Albrecht et al. 2001), ker sta očitno prebiti oz. predrti tako, da je sila delovala vedno v isti smeri. Zato smo prepričani, da sta bili naenkrat prebiti s koščenim prebijačem (glej Turk et al. 2003). Luknji sta po našem prepričanju umetni kljub nespornim sledovom zob v njuni bližini, ker gre tudi v tem primeru za dve ločeni stvari. Zato sledovi delovanja zob ne morejo biti vzrok, luknji pa posledica.

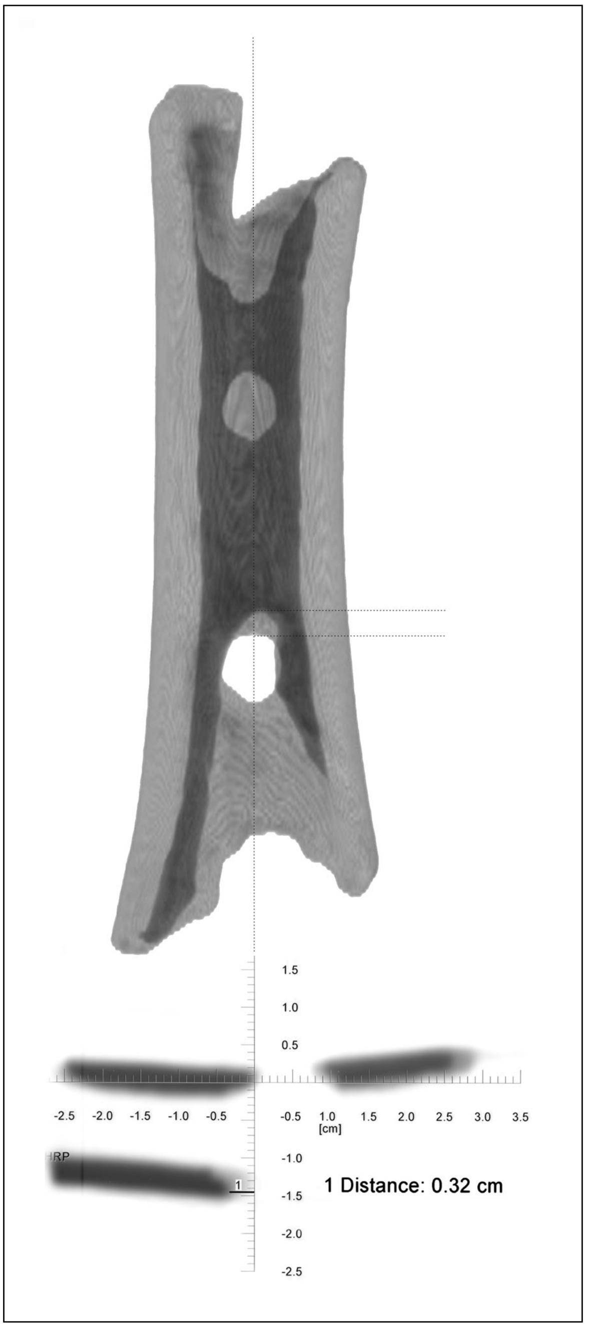
V zvezi z luknjo 5 so najbolj zanimive zgoraj navedene prvič natančno dokumentirane poškodbe v bližini luknje 2: vdolbinica na zunanji in vdolbinica na medularni površini lupine (*sl. 9:* rezine 194-197). Vdolbinici bi lahko nastali skupaj z luknjo 5, če je luknjo 5 naredil en zob in vdolbinico drug zob, kot to predvideva d'Errico s sodelavci (2003). Vendar kako potem na enak način razložiti nastanek luknje 2. Če je zob enkrat naredil luknjo 5, pri ponovnem vgrizu nad njo ni mogel narediti še luknje 2, niti ni mogel hkrati kost odlomiti pri luknji 5 in narediti novo luknjo 2. Še bolj nenavadno je, da se vdolbina, ki bi jo naredil zob anatagonist v trenutku, ko je nastala luknja 5, ne bi pri ponovnem luknjanju zaradi predhodne deformacije lupine vdrla pred ali skupaj z nedeformirano lupino, kjer je nastala nova luknja 2 (glej nadaljevanje).

Luknja 5 je edina luknja, ki jo lahko na podlagi zbranih dokazov razložimo na dva načina: bodisi kot izdelek človeka bodisi kot posledico grizenja z zobmi. Ker kostna lupina pri luknji ni počena, je prediranje z zobom ali prebijanje s prebijačem manj verjetno kot klesanje s kamnito konico.

Luknja 2

Luknja 2 je podobno kot luknja 1 nepravilne oblike. Največji premer v medialno-lateralni smeri, določen s pomočjo CT, znaša 9,2 mm, kar je za 0,5 mm več, kot smo izmerili s kljunastim merilom, v proksimalno-distalni pa 11,1 mm, kar je 2,1 mm več, kot smo izmerili s kljunastim merilom (glej Turk et al. 1997, 161). Luknja 2 je tako nekoliko večja kot luknja 1. Kostna lupina ob luknji je na

Sl. 9: Izbor prečnih (segmentalnih) rezin proksimalno od luknenj 2 in 5 (191-195 oz. 201) ter pri luknji 5 (196-200). M. = 1:1.
Fig. 9: Selection of transverse (segmental) slices proximally from Holes 2 and 5 (191–195 or 201) and Hole 5 (196–200). Scale = 1:1.



Sl. 10: Anteriorna stran, preslikana navpično na posteriorno in sagitalni prerez po sredini luknje 2. Preslikava in prerez kažeta odmik proksimalnega roba luknje 5 od proksimalnega roba luknje 2. M. = 1:1.
Fig. 10: Anterior side, depicted perpendicularly on the posterior and sagital section through the centre of Hole 2. The depiction and cross-section show the deviation of the proximal edge of Hole 5 from the proximal edge of Hole 2. Scale = 1:1.

medialni strani debela 4,9 mm (*sl. 2*), kar je 0,9 mm več, kot smo prvotno mislili (glej prav tam).

Proksimalno od luknje je medularni kanal skoraj nedotanjen (*sl. 9:* rezine 198-201), kar pomeni, da se tu lupina ni lijasto odlomila. Preostali obod luknje ima skoraj v celoti izrazit lijak na notranji strani (*sl. 6*) in manj izrazit na zunanji, ki je lahko tudi posledica preperevanja robov (*sl. 11:* rezine 203, 208, 214). Značilno za robove je, da so zelo močno zaobljeni.

Notranji lijak je bolj izrazit v distalnem delu kot v proksimalnem, in sicer v medialni in lateralni smeri (*sl. 11:* rezine 214-219; *sl. 6*). Kostna lupina je enako debela na anteriorni in posteriorni strani.

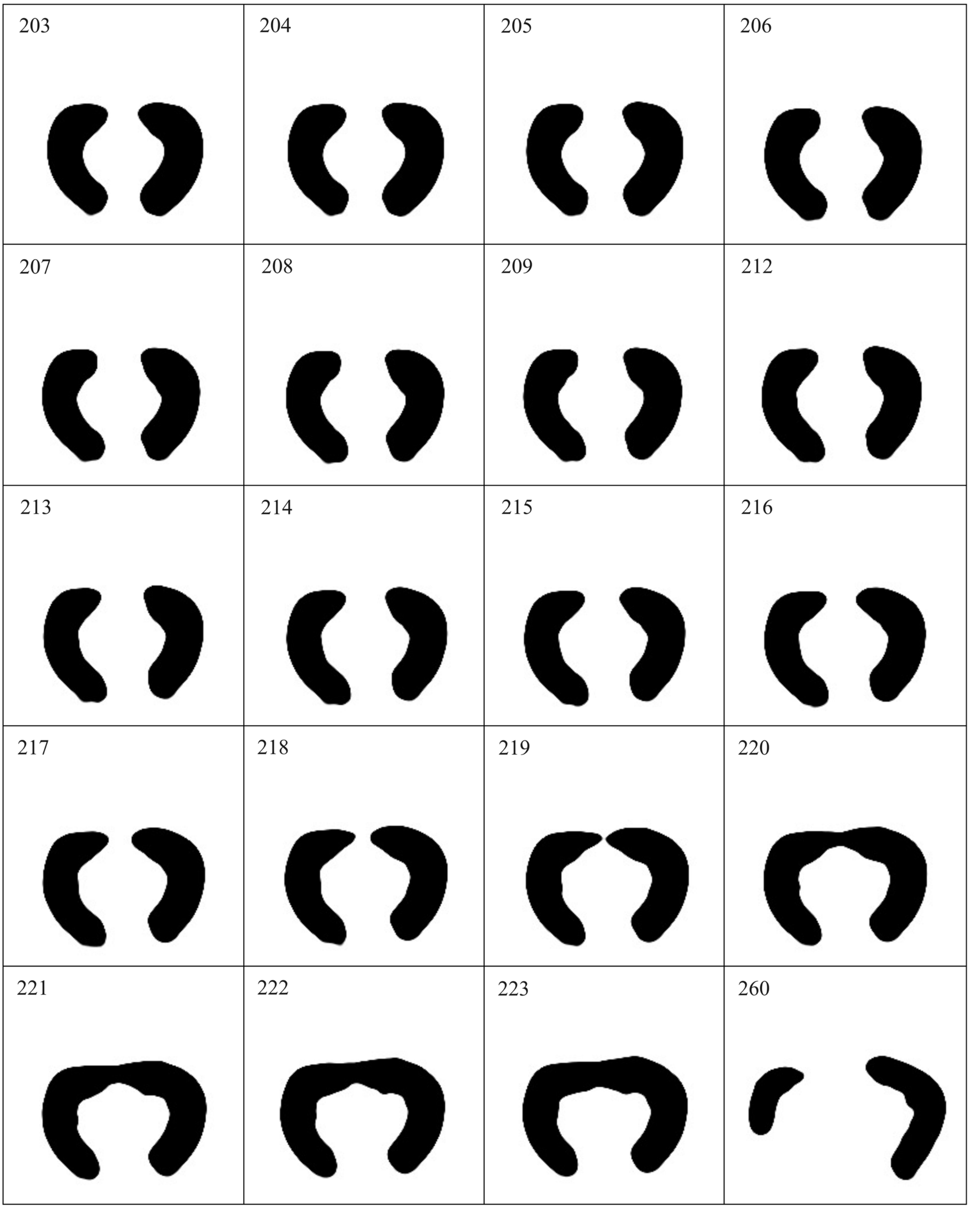
Distalno od luknje je medularni kanal longitudinalno močno odkrušen, kar dokazuje obstoj lijaka tudi v tem delu. Poškodba obsega 4 rezine (*sl. 11:* 220-223). Posteriorna stran kostne lupine je tu 1 mm tanjša kot v predelu luknje 2 (*sl. 2*). Zato bi v primeru grizenja pričakovali luknjo prej na tem mestu, tj. bolj distalno od sedanje. Razpoka, ki poteka od luknje 2 do izjede 4, se začne točno v sredini luknje 2. CT razpoke ni zaznal, zato ni jasno, ali je razpoka površinska ali globinska, je pa vsekakor zelo ozka.

Luknja 2 je bila nedvomno predrta. Razpoka v lupini je lahko nastala pri prediranju. Vprašanje je, kako je bila predrta: naravno z zobom ali umetno z orodjem.

Če je bila narejena z zobom, je luknja 5 umetna. Če je bila luknja 5 narejena z zobom je umetna luknja 2. V nobenem primeru nista bili narejeni z zobom obe luknji, lahko pa sta obe umetni.

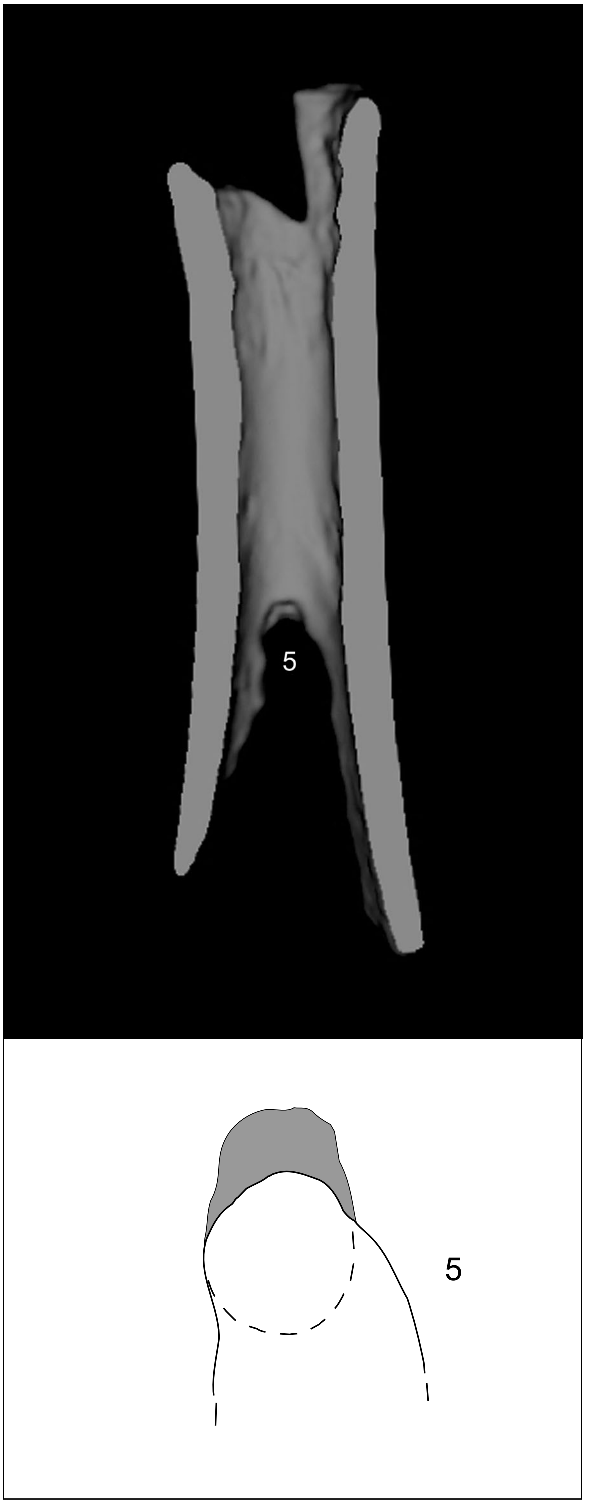
Za razlago nastanka lukenj 2 in 5 je pomembna poškodba v obliki vdolbinice proksimalno ob luknji 2, na katero smo opozorili že v prvi izčrpni objavi o "piščali" (Turk et al. 1997, 160). Vdolbinica, ki je obrobljena z dvema vzdolžnima razpokama in eno prečno, doslej ni bila ustrezno razložena. D'Errico s sodelavci (2003) jo v svoji kritiki "piščali" razlaga kot odtis zoba.

Poskusi so potrdili, da je pri grizenju velika verjetnost, da luknja nastane na anteriorni strani (Turk et al. 2001). Zato je luknjo 5 kljub nekaterim zgoraj navedenim pomislekom lahko naredil zob. Zob (antagonist) je nedvomno deformiral lupino tik ob bodoči luknji 2. Pri tem je nastala poškodba v obliki majhne vdolbinice na zunanji in medularni površini lupine. Zunanjo vdolbinico glavni kritiki "piščali" navajajo kot dokaz za to, da je luknje naredila zver (d'Errico et al. 2003). Hkrati govorijo o drugih mikroskopskih poškodbah med luknjo 2 in izjedo 4, ki naj bi jih naredila zver skupaj z luknjami. Vdolbinica in druge poškodbe so lahko povezane bodisi z nastankom luknje 5 bodisi z odlomom anteriornega dela distalne diafize in metafize, ne pa tudi z luknjo 2. Z zobmi se namreč ne da narediti vdolbinice in obeh lukenj. Zato mislimo, da je bila luknja 2 prebita pozneje, in



Sl. 11: Izbor prečnih (segmentalnih) rezin pri luknji 1 (203-219), distalno od nje (220-223) in pri izjedi 4 (260) na distalni metafizi. M. = 1:1.
Fig. 11: Selection of transverse (segmental) slices at Hole 1 (203–219), distally from it (220–223) and at Notch 4 (260) on the distal metaphysis. Scale = 1:1.

sicer na način, kot smo ga razložili v našem zadnjem članku (Turk et al. 2003). Pred tem je bila zelo debela lupina v območju luknje rahlo stanjšana. Mogoče zato, ker se je izdelovalec preveč namučil pri luknji 1, kjer je bila lupina tudi približno enako debela. Pri prebijanju s koščenim prebijačem



Sl. 12: Tomograf medularnega kanala z luknjo 5. Vidi se mesto, kjer je kost odkrušena. M. = 1:1.
Fig. 12: Tomograph of the medullary cavity with Hole 5. The place where the bone has crumbled can be seen. Scale = 1:1.

je lupina počila. Poleg tega se je udrl koščček kosti na proksimalnem obodu luknje, kjer je bila lupina deformirana zaradi pritiska zoba. Pri tem se je sprostila sila, ki je sicer drugje po obodu luknje ustvarila na notranji strani izrazit lijak (*sl. 11:* rezine 212-221). Na udrtem delu lupine in lateralno v njeni bližini zato ni izrazitega lijaka (*sl. 9* in *11:* rezine 200-209). Nepravilno obliko luknje lahko povežemo z obliko prebijača.

Fragmentacija diafize med luknjo 2 in izjedo 4

Debelina lupine na posteriorni strani, določena s pomočjo CT rezine, je 3,9 mm (*sl. 2*). Manjkajoči anteriorni del ni mogel biti bistveno tanjši.

Robovi odloma v obliki črke V na anteriorni strani so bolj ali manj zaobljeni. Kostna lupina se je odlomila potem, ko je bila tam že luknja 5. Odlom in luknja 5 nikakor nista mogla nastati hkrati, kot predvidevata Chase in Nowellova (1998, 550). Prav tako je napačna razlaga (prav tam), da gre za nekakšno dolbljenje ("scooping") z zobmi, ker je medialni rob očitno odlomljen. Medialni del odloma ima namreč skoraj po celi dolžini poševen rob, ki je obrnjen navznoter. To kaže, da je sila delovala od zunaj navznoter. Lateralni del odloma ima rob raznolikejši in večinoma bolj zaobljen, kar lahko povežemo z grizenjem, ki je sledilo odlomu.

Domnevni mikroskopski sledovi grizenja, ki jih je našel d'Errico s sodelavci (2003, sl. 9), se ujemajo z našo razlago. Nastali so, ko je zver vrtela kost med zobmi.

Pri stiskanju z zobmi je lupina popustila tam, kjer je bila najšibkejša oz. bolj deformirana zaradi luknjanja. Da se je diafiza kljub anteriorni in posteriorni luknji odlomila samo anteriorno, lahko razložimo z večjo pogostnostjo predrtja diafize femorja prav na tej strani (glej Turk et al. 2001). Poleg tega je večina izjed v obliki črke U na distalni metafizi (glej nadaljevanje) juvenilnih femurjev jamskega medveda prav tako na anteriorni strani. To pomeni, da je verjetnost poškodbe z zobmi večja distalno anteriorno kot distalno posteriorno, kar bi se morda dalo razložiti z izbočenostjo oz. ploskostjo kostne lupine.

Izjeda 4 na metafizi

Izjeda 4 ni bila nikoli luknja, saj na zaobljenih robovih ni sledi o lijaku. Na najširšem delu meri 9,4 mm. Premer, ki smo ga določili s pomočjo CT, je za 3,6 mm manjši od največjega premera, ki smo ga izmerili s kljunastim merilom (glej Turk et al. 1997, 161). Velika razlika je posledica tega, kje merimo. Lupina najširšega dela izjede je lateralno debela 3,2 mm, medialno pa 3,7 mm (*sl. 2*).

Proksimalno se oba dela lupine hitro zadebelita za dober milimeter.

Lateralni in medialni del metafize se distalno končata v topo špico. Vsi robovi so močno zaobljeni. Domnevamo, da zaradi večjega kemičnega preperevanja oz. raztapljanja.

Strinjamo se s kritiki, da je distalni posteriorni rob metafize domnevne piščali, vključno z izjedo 4, lahko oblikovala zver med grizenjem (glej Chase, Nowell 1998, 550; d'Errico et al. 2003). Ne strinjamo pa se s tem, da ga je tudi zaoblila (prav tam). Zaobljene robove imajo namreč vsi kostni fragmenti, od najmanjših do največjih. Zato sklepamo, da je zaobljanje povezano predvsem s kemičnim preperevanjem, ki je lepo vidno tudi na dolomitnih klastih (glej Turk et al. 2002).

Vprašanje je, kdaj in kako je nastala izjeda. Da jo je naredila zver, je vsekakor zelo verjetno. Vendar je večina podobnih izjed, ki so jih dejansko naredile zveri, verjetno volkovi, na distalnih metafizah juvenilnih femurjev na izbočeni anteriorni strani. Ne glede na to, kdo je naredil izjedo 4, je ta zelo verjetno nastala pred velikim odlomom v obliki črke V na anteriorni strani, ki se konča v luknji 5. Tako izjedene cevaste kosti so na najdišču in tudi drugje pogoste, vendar je nasproti izjede vedno ohranjena kostna lupina, ki je dajala enemu zobu oporo, medtem ko je drugi dolbel izjedo (glej Turk et al. 1997, sl. 11.19). Brez anteriorne lupine bi zobje posteriorno lupino samo zmečkali, pri strižni obremenitvi pa bi se odlomil večji kos lupine, tako kot na proksimalnem koncu "piščali". Zato sklepamo, da je izjeda 4 starejša od anteriornega odloma. Ker je odlom mlajši od luknje 5 in ker luknja 2 ne more biti starejša od luknje 5, je bila izjeda 4 verjetno narejena pred luknjami. Zato je lahko služila kot ustnik domnevne piščali ne glede na to, kdo jo je naredil. Vendar so lahko zveri poškodovale in preoblikovale njen lateralni del, ki jim je bil skupaj z nepoškodvanim medialnim normalno dostopen tudi po velikem odlomu na anteriorni strani metafize.

3. RAZPRAVA IN SKLEPI

Kritiki t. i. musterjenske piščali so vprašanje nastanka lukenj neutemeljeno poenostavili. Bili so prepričani, da so se problema lotili na višji znanstveni stopnji, z več prakse in z boljšimi metodami kot najditelji "piščali" (Chase, Nowell 1998, 550; d'Errico et al. 2003). Med njimi po konstruktivnosti in nepristranosti stališč izstopata Chase in Nowellova, saj dopuščata možnost, da sta obe hipotezi enako verjetni (Nowell, Chase v tisku). Najbolj pristranski in tendenciozen je d'Errico s sodelavci (1998; 2003), saj se je vprašanja izvora "piščali" lotil predvsem z vidika ene hipoteze.

Raziskave najditeljev, vključno s tu predstavljeno, kažejo, da je vprašanje zapleteno in da ne daje enostavnih odgovorov (Turk et al. 2001; 2003). V tem se strinjamo z Nowellovo in Chasejem (2000). Zato je bila zavrnitev hipoteze o umetnem izvoru lukenj prenagljena, alternativna hipoteza pa se je hitro pokazala kot slabo utemeljena (za povzetek dosedanje diskusije o "piščali" glej Horusitzky 2003).

Nova, temeljna ugotovitev večrezinske računalniške tomografije je, da je "piščal" nastala v dveh fazah. Najprej so nastale 4 luknje in šele potem večina poškodb, ki jih lahko pripišemo zverem. Uspelo nam je celo ugotoviti natančnejše zaporedje dogajanj na obeh koncih diafize in distalni metafizi, kar bo verjetno pripomoglo k pravilnejši razlagi najdbe.

Glavne ugotovitve so naslednje:

CT je potrdila, da je medularni kanal diafize popolnoma brez spongioze. Notranji deli metafiz imajo spongiozo ohranjeno samo v sledovih (*sl. 13*).

Prav tako je bilo z novo raziskavo ponovno potrjeno, da luknje, z morebitno izjemo ene same, niso narejene z zobmi. Za kaj takega je kostna lupina na mestih, kjer so luknje, predebela, in kot vemo, hkrati prekrhka. Zato bi se pri tolikih luknjah zanesljivo razklala na dvoje (glej Turk et al. 2001). Pri stiskanju z zobmi bi luknje nastale na mestih, kjer je lupina dejansko tanjša, predvsem pa na izbočeni anteriorni strani namesto na ravni posteriorni (prav tam). Posteriorni del lupine je na mestih z luknjami enako debel kot anteriorni. Zato prvotna domneva o tanjši posteriorni lupini (Turk et al. 1997), ki sta jo prevzela tudi Chase in Nowellova (1998, 551; Nowell, Chase v tisku), ne drži. Prav tako ne drži domneva Albrechta s sodelavci (2001), da so luknje nastale na mestih, kjer je lupina tanjša (glej *sl. 4; 5; 8; 11* in *13*).

Preden je bila kost naluknjana, so zveri lahko naredile t. i. "ustnik piščali" oz. izjedo 4. Luknje je lahko naredil samo človek z določenim namenom. Enako ustnik, če ga niso pred njim naredile zveri in ga je človek samo uporabil. Podobno je s t. i. "luknjo za palec" na anteriorni strani. Njen izvor in pomen ostajata še vedno nejasna. Lahko jo je naredil človek, lahko pa tudi zver. Ko je človek nehal uporabljati izdelek, so ga na koceh poškodovale zveri, verjetno volkovi. Zveri so lahko tudi preoblikovale t. i. "ustnik piščali", ki je bil že pred tem na voljo človeku. Domnevni potek dogodkov prikazuje *sl. 14*.

Skoraj vse poškodbe na naluknjani diafizi, značilne za zveri, so na obeh koncih med luknjama 1 oz. 2 in metafizo (Turk et al. 1997; 2001; Chase, No-

Sl. 13: Vzdolžna (sagitalna) rezina debeline 8 mm. Rezina obsega celotno medialno-lateralno širino lukenj. M. = 1:1.
Fig. 13: Longitudinal (sagital) slice of thickness 8 mm. The slice embraces the entire medial-lateral width of the holes. Scale = 1:1.

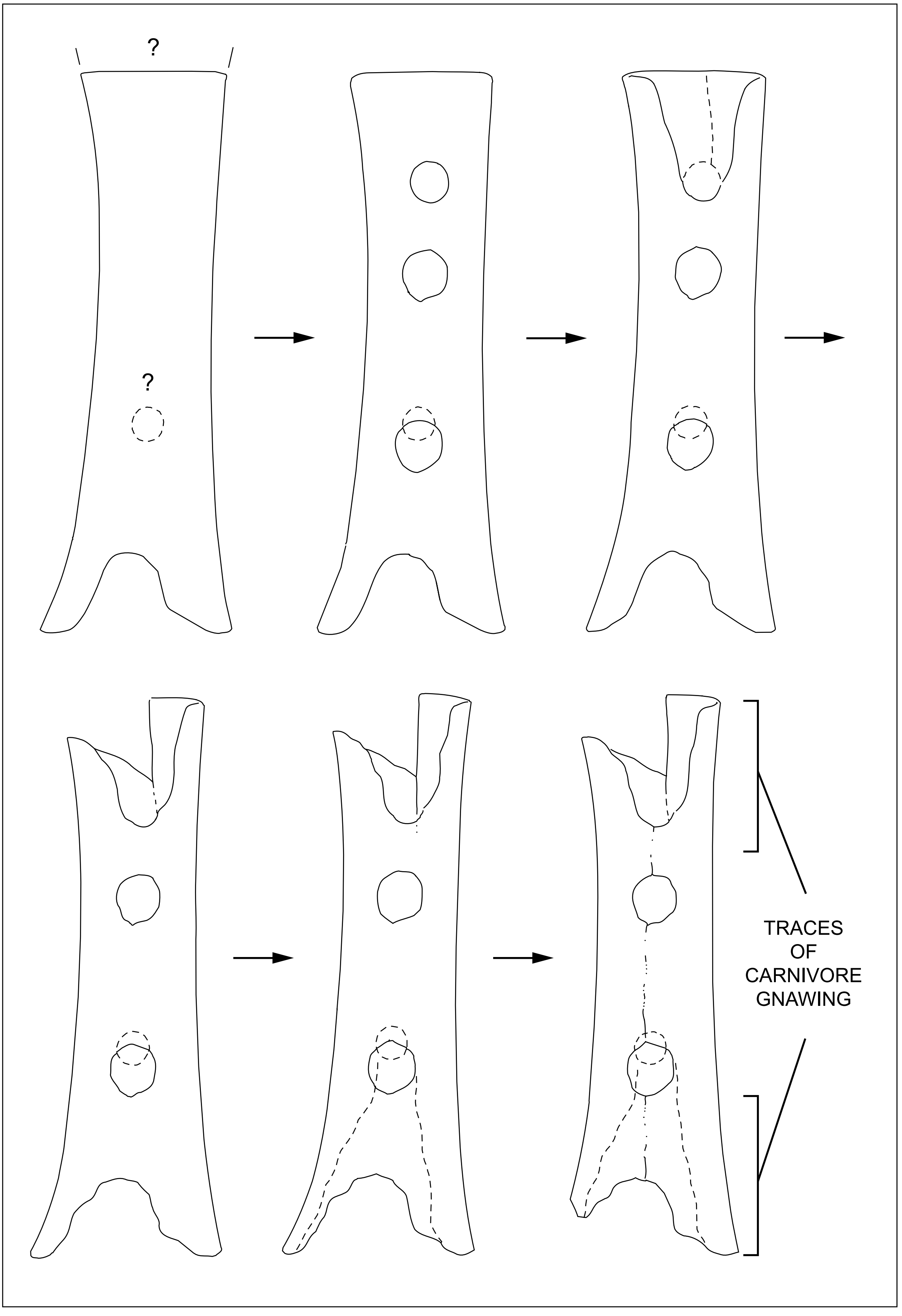
well 1998; d'Errico et al. 2003; Nowell, Chase v tisku). Osrednji del diafize je brez poškodb (glej tudi d'Errico et al. 2003, sl. 9). To pomeni, da so zveri grizle kost s koncev z molarji, za domnevno luknjanje pa bi lahko uporabile kanine. Predvsem luknji 1 in 2 bi bili lahko narejeni, če bi bili, izključno s kanini (toda glej Nowell, Chase v tisku).

Ključni dokaz kritikov stališča, da gre za "piščal", sta lahko po našem mnenju vdrtina z ostankom vdolbinice ob luknji 2 na posteriorni strani in ostanek luknje 5 anteriorno pod luknjo 2. Kritiki menijo, da sta obe luknji ali vdrtina in luknja 5 narejeni z zobmi, natančneje s kanini ali molarji. To je teoretično mogoče, če pri obeh luknjah ne upoštevamo vdrtine (Chase, Nowell 1998, 551; d'Errico et al. 1998, 77) ali če pri vdrtini in luknji 5 ne upoštevamo luknje 2 (d'Errico et al. 2003). Mimogrede omenimo, da je stavek d'Errica in sodelavcev (2003), ki se verjetno nanaša na luknjo 5 in vdrtino ob luknji 2 (za vdrtino glej tudi Turk et al. 1997, 160, sl. 11.2: 3; Chase, Nowell 1998, 552), nenatančen in bi se moral glasiti takole: "A large deep impression found on the anterior (= *posterior*) face near the proximal end (*of the hole*), indicating strong pressure exerted by carnivore teeth, can reasonably be interpreted as the counterbite of the anterior hole (= *semi-hole*)." Netočen in tendenciozen je sklep d'Errica s sodelavci (2003): "The presence of two or possibly three perforations on the suggested flute cannot therefore be considered as evidence of human manufacture, as this is a common feature in the studied sample" Omenjeni vzorec je iz Križne jame (in Mokriške jame?) v Sloveniji in ga je prvi objavil M. Brodar (1985). Te objave in kako je prišel do vzorca, d'Errico s sodelavci ne navaja. Morda zato, ker v Križni jami ni nobene tako in tolikokrat naluknjane diafize, kot je femur iz Divjih bab I. Česa podobnega ni tudi v Mokriški jami, iz katere sicer poznamo šolski primer diafize z izklesano ali prebito luknjo (glej Turk et al. 1997, sl. 11. 12; M. Brodar 1985, t. 5:8). Zanjo žal ni stratigrafskih podtakov (M. Brodar 1985), so pa v najdišču orinjasjenske najdbe v dveh plasteh od desetih in vse vsebujejo ostanke jamskega medveda (M. Brodar 1959).

Če v kontekstu hipoteze, da je luknje naredila zver, upoštevamo obe distalni luknji in vdrtino, pridemo do naslednjega sklepa:

Z zobmi bi se dali izjemoma narediti samo vdolbinica na vdrtem delu kosti in luknja 5 ali samo luknji 2 in 5. Vendar je oboje vprašljivo, ker sta vdolbinica in luknja 5 natančno ena pod drugo, proksimalni rob lukenj 2 in 5 pa je odmaknjen med 3 in 4 mm (*sl. 10*). Konici kaninov odraslega jamskega medveda, ki prideta edini v poštev za luknjanje, sta namreč bolj odmaknjeni druga od druge (minimalno 10 mm) pri skoraj zaprtih čeljustih, kot zahteva majhen anteriorno-posteriorni premer naluknjane diafize.

Če sprejmemo eno od dveh možnosti za naraven nastanek lukenj 2 in 5, ne moremo na enak način razložiti bodisi luknje 2 bodisi vdrtine ob njej, ker pri ponovnem vgrizu oba zoba ali eden od njiju zdrsne v že obstoječi luknji ali vdrtino, zaradi česar drugi zob ne more narediti luknje ali vdrtine. Če bi zver to poskušala, bi se vdrtina ali predrla, ker je kostna lupina tu zaradi deformacije šibkejša, ali bi kost počila pri širjenju obstoječe luknje ali pa bi se razletela. Vendar se ni zgodilo ne prvo ne drugo ne tretje. Dvostranska razpoka pri luknji 2 je lahko nastala hkrati z luknjo 5, enostranska pa ali z odlomom v obliki črke V na distalno-anterioni strani ali pri prediranju luknje 1. Vsekakor razpoka ni mogla nastati pri ponovnem vgrizu s kanini.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Odlom v obliki črke V ob luknji 5 je dokaz, da je zver grizla šele tedaj ali potem, ko je bila luknja že narejena. To pomeni, da je vzročna zveza med luknjami in drugimi zverskimi poškodbami (glej Chase, Nowell 1998; d'Errico et al. 1998; 2003; Nowell, Chase v tisku) vprašljiva. Še bolj problematično je sklepanje o izvoru lukenj na "piščali" na podlagi lukenj, ki so jih dejansko naredile zveri na cevastih kosteh (glej predvsem Albrecht et al. 1998; d'Errico et al. 1998; 2003) v Divjih babah I in drugje (glej Kos 1931; M. Brodar, S. Brodar 1983; Brodar 1985). Te luknje nimajo dosti skupnega z luknjami na "piščali" (glej Turk et al. 2001).

Naši ugovori proti domnevnemu zverskemu izvoru lukenj so zato naslednji:

1. Obe polovično ohranjeni luknji sta bili nekoč luknji, ki sta nastali pred poškobami proksimalnega in distalnega dela diafize oz. pred sicer nespornim posegom zveri.

2. Nemogoče je, da bi se lupina zaradi grizenja hkrati preluknjala in zlomila dvakrat zapored, kot je razvidno iz obeh ostankov lukenj. Še bolj nemogoče je, da se diafiza ne bi razklala, če bi jo zver štirikrat zapored naluknjala z zobmi (glej Turk et al. 2001).

3. Ker zveri grizejo s koncev kosti proti sredini (glej Chase, Nowell 1998), je malo verjetno, da bi najprej s kanini naredile najmanj 2-3 luknje, če ne štiri, v ravni vrsti po sredini diafize in se šele nato lotile koncev z molarji. Ali da bi se po 2-3 luknjah lotile še 1-2 tako, da bi bile vse luknje nazadnje poravnane. Nenavadno je, da ni nobena luknja nastala tam, kjer je kostna lupina diafize najtanjša.

4. Pri luknjanju z zobmi bi pričakovali več lukenj anteriorno kot posteriorno, torej ravno nasprotno kot pri "piščali" (Turk et al. 2001)

5. Sklepati na podlagi drugotnih poškodb, ki so jih domnevno naredile zveri, kako so nastale luknje, je zgrešeno. Zveri grizejo z različnimi nameni: priti do hranljivega mozga je samo eden izmed njih. V paleolitskih zbirkah je kar nekaj koščenih artefaktov, ki so jih naknadno poškodovale zveri, vendar nihče ne pomisli, da so tudi artefakte naredile zveri.

6. Različno velikost, obliko in morfologijo lukenj morda lažje razložimo z uporabo preprostih orodij kot z delovanjem zob. Takšna orodja, kamnita in koščena, z značilnimi poškodbami v najdišču niso neznana (*sl. 15*). Medtem ko so kamnita lepo oblikovana, so koščena manj izdelana. Običajno so to težje prepoznavni *ad hoc* koščeni prebijači, na katere smo postali pozorni šele po zaslugi Z. Horusitzkyega (2003), ki je odkril nov način za izdelavo lukenj. Podobno je bilo z orodji, narejenimi iz dolomita, ki jih dolgo nismo prepoznali, ker nismo predvidevali, da obstajajo. Torej podoben problem kot pri luknjah, kjer ni nihče pričakoval uporabe enostavne tehnike za njihovo izdelavo in so se zato zamenjale z luknjami, predrtimi z zobmi. Ugotovili smo tudi, kako so se lahko uporabljala različna orodja za učinkovito luknjanje cevastih kosti in kako so se pri tem poškodovala (Turk et al. 2001; 2003). Trditve kritikov, da je luknje nemogoče prebiti (Albrecht et al. 1998, 13) in da so preprostejši načini za njihovo izdelavo , pri čemer so mislili na vrtanje ipd. (Chase, Nowell 1998, 552), so neutemeljene. Prav tako ne drži, da se je treba posebej truditi, da orodje ne pusti sledi, kot mislita Nowellova in Chase (2000). Prebijanje oz. klesanje je najpreprostejše in največkrat ne pušča značilnih sledi uporabljega orodja. Klesanje zasledimo tudi v mezolitiku pri luknjah, narejenih v rogovje (Clason 1983, 85) in prstne kosti jelena (Turk 2004), pa tudi pozneje, npr. v eneolitiku na Ljubljanskem barju. Zanimivo, da tudi pri teh luknjah ni nobenih sledi orodij več, če so robovi prepereli.

7. Pri posebni tehniki luknjanja na robovih lukenj samo izjemoma ostanejo (ne)značilne sledi orodja, ki se s preperevanjem hitro zabrišejo. Zato je luknje, narejene s kamnitimi in koščenimi konicami, samo na podlagi morfologije običajno težko ločiti od lukenj, ki so bile narejene z zobmi (glej Brodar 1985). To še posebej velja za luknje, predrte s koščenimi konicami.

Na podlagi dognanj poglobljenih raziskav zadnjih nekaj let izvor lukenj na "piščali" ne more biti več sporen.

Mislimo, da smo dovolj jasno pokazali, da dejansko gre za izjemno najdbo, najstarejši artefakt, ki je podoben piščali, in da se bo treba s tem prej ali slej sprijazniti tudi v paleolitski arheologiji. Lahko pa tudi počakamo, da še kdo odkoplje podobno najdbo v podobnem kontekstu. Seveda pa je vprašanje, kako od tod naprej nadaljevati razpravo. Za njen pravilni potek potrebujemo vsekakor dobre kronološke podatke, ki jih, žal, pogrešamo pri marsikaterem paleolitskem najdišču, vključno s tistimi, ki konkurirajo Divjim babam I.

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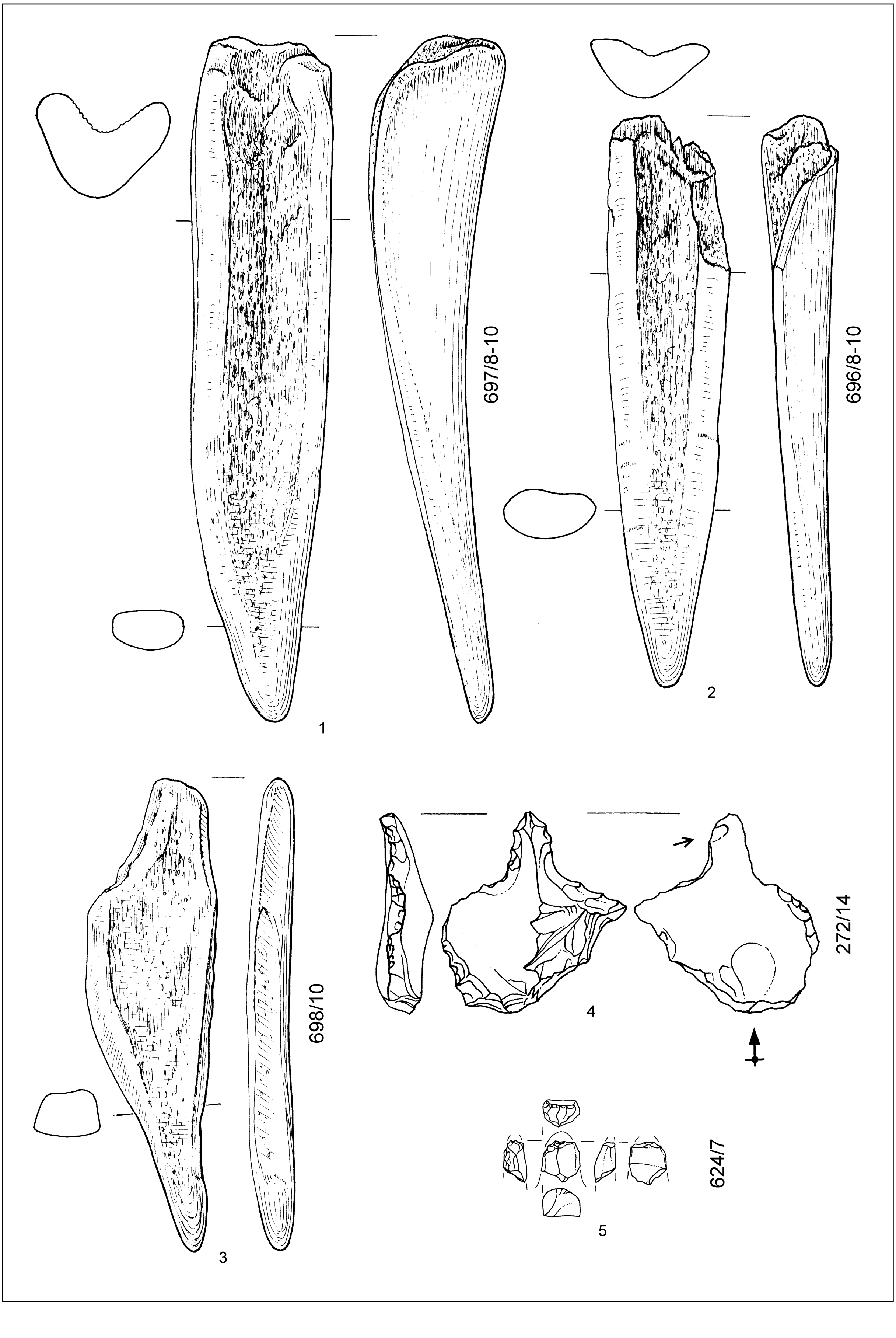
Sl. 14: Kronološke faze preoblikovanja diafize. Risba D. Knific Lunder.
Fig. 14: Chronological phases of transformation of the diaphysis. Drawing D. Knific Lunder.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Sl. 15: Divje babe I, koščeno in kamnito orodje, ki je bilo domnevno primerno za luknjanje kosti. Številka 5 je pri domnevnem luknjanju odlomljena konica orodja številka 4. Ob strani so izpisane inventarne številke in plasti. M. = 1:1. Risba D. Knific Lunder.

Fig. 15: Divje babe I, bone and stone tools which are thought to be suitable for making holes in bones. Number 5 is the tip of tool type number 4 suspected of being detached in making a hole. The inventory number and the layer are noted at the side. Scale = 1:1. Drawing D. Knific Lunder.

Results of computer tomography of the oldest suspected flute from Divje babe I (Slovenia): contribution to the theory of making holes in bones

Translation

1. INTRODUCTION

This year marks a decade since the discovery of a Mousterian "flute" in the Middle Palaeolithic layer of the Divje babe I site (Turk et al. 1997). Two things have happened in that time: the age of the find has been determined more exactly (Lau et al. 1997; Turk et al. 2001, 2002, in print), and among Palaeolithic archaeologists, the opinion has partially prevailed that the find is not in fact a flute (see Chase, Nowell, 1998; Albrecht et al. 1998; d'Errico et al. 1998, 2003; Nowell, Chase 2000), but such an opinion has not been able to establish itself conclusively in archaeology or in other scientific fields (see Horusitzky 2003).

It was dated chronometrically and chronostratigraphically to the longest and warmest interstadial of oxygen isotope stage 3 (MIS 3) or the Middle Würm of Alpine glaciation, or more exactly, 46,000 years BP (Turk et al. 2001). This interstadial, which was marked in Slovenia by a very humid climate (Turk et al. 2002; in print), corresponds to the northern European Moershoofd or Glinde interstadial by pollen chronology. The general conviction is that it was then the Mousterian in Europe, and the only living human species Neanderthal man (*Homo sapiens neanderthalensis*). The Upper Palaeolithic and anatomically modern man (*Homo sapiens sapiens*) only appeared in Europe in the following pollen interstadial, i.e., the Hengelo interstadial, which is separated from the previous one by a globally colder and more arid climate phase or stadial. Neanderthal man died out and the Mousterian ended even later, in the Denekamp pollen interstadial, which is probably represented at the top of the Divje babe I profile, so that it is separated from the »flute« by a 2 m thick, and, in the part with the »flute« ,cemented sediments that depict a drier climate. In view of these findings, insofar as the find actually represents a flute, is undoubtedly the oldest such find made of bone, since it is separated from other similar finds that are currently considered the oldest (see Hein 1998, 127; Auffermann, Orschiedt 2002, 69; Conard et al. 2004) by at least one stadial and one interstadial, and in most cases at least two stadials (Leocata 2000–2001, Fig. 2; d'Errico et al. 2003, Fig. 10–11) or 10 to 15 thousand years. The find, which is chronologically better determined than any similar find, can be ascribed on the basis of dating of skeletal finds of human species in Europe with a higher degree of probability to Neanderthal than anatomically modern man (see also Nowell, Chase 2000). For the moment, only M. Brodar (1999) ascribes it to the latter, on the basis of considerably later suspected artificially pierced bones in Aurignacian sites in Slovenia (see M. Brodar 1985). This opinion disregards skeletal finds.

From the very start, only the interpretation of the find has been in dispute, which depends mainly on the question of how the holes were made. Since, as has been said, the opinion prevailed that the holes in the »flute« are natural (Chase, Nowell 1998; Albrecht et al. 1998; d'Errico et al. 1998, 2003; Nowell, Chase 2000), and because we believe that such an opinion is not soundly based (Kunej, Turk 2000; Turk et al. 2001, 2003), we decided on yet another analysis of the disputed find, this time with the aid of multi-slice computed tomography (CT).

The research was carried out with 16 multi-slice computed tomography (MSCT) at the Institute for Radiology of the University Clinical Centre in Ljubljana[1]. Technical data are the following:

1. Topogram
kV-180
mA 50
slice width 1 mm
topogram length 256 mm

2. Acquisition
kV 120
eff.mAs 90
scan time 7.49
slice width 1.0 mm with collimation 0.75 mm
feed/rotation 18.0
kernel B31s medium soft
reconstruction increment 7
FOV 250

Along the length of the diaphysis, we recorded 228 slices on the segmental plane, with a width of 1 mm. Each slice overlaps the previous to a width of 0.25 mm. Slices are numbered with consecutive numbers starting at the extreme proximal part of the diaphysis (no. 58) and ending at the extreme distal part (no. 285) (*Fig. 1*).

In order to distinguish slices on the left femur of the juvenile cave bear, anatomic characterisations and names will be used, such as epiphysis, metaphysis and diaphysis. Both epiphyses, i.e., the joints, are missing on the "flute" because they had not yet been fused. The metaphysis, the transitional region between the epiphysis and the diaphysis, is removed or greatly damaged. The diaphysis, the central part of the limb bone, which is also damaged, has proximal and distal ends, medial and lateral, and anterior and posterior sides. The proximal end is closer to the body and the distal end further from it. The medial side is turned inwards or towards the centre of the body and the lateral outwards or away from the centre of the body. The anterior side is turned forwards towards the head and the posterior backwards towards the tail (*Fig. 1*).

Numbers 1 to 5 (*Fig. 1*) (see also Turk et al. 2001, Fig. 8) have been used for easier understanding of the various holes and notches.

The original purpose of the analysis was to discover whether there is any link between the thickness of the bone cortex and the location of the holes. With piercing by teeth, the cortex is pierced first where it is thinner, since carnivores with teeth test the hardness of the bone and seek its weakest point. A person piercing with a tool presumably pays no regard to the thickness of the bone cortex or tries to make it thinner. We also wanted to check whether the two smaller notches on the anterior and posterior side are the remains of holes or just parts of the fracture which are reminiscent of a hole. We later chose additional aims. We thus wanted to recheck how individual holes and damage could be made and whether there is a connection between one and the other, as some researchers have claimed (Chase, Nowell 1998; Albrecht et al. 1998; d'Errico et al. 1998, 2003; Nowell, Chase 2000). We therefore wished to establish the chronology of the holes and damage. This is a question with which nobody has dealt in detail, but it is important for verifying the hypoth-

[1] The topogram was contributed by radiologist Dean Pekarovič. Data were computer processed by Dean Pekarovič and Miran Pflaum.

eses put forward (see Nowell, Chase 2000). These can be strong in theory and weak in practice. The latter applies in particular to the hypothesis of Albrecht, Chase and d'Errico, who are committed to a carnivore origin of the holes (see below).

2. RESULTS OF ANALYSIS AND INTERPRETATION OF RESULTS

Fragmentation of the proximal diaphysis

The cortex (including medulla) is thicker laterally (5.4 mm) than medially (4.0 mm). The thickness was determined by means of CT slices (*Fig. 2*). The medial cortex of the short proximal part of the fractured diaphysis is thinned on at least three slices. All the edges are rounded.

Similarly, the extreme part of the lateral cortex of the fractured diaphysis is thinned on at least three slices. The edges are rounded.

The thinning can be explained by gnawing (see Chase, Nowell, 1998; d'Errico, 2003) or powerful chemical weathering because of greater area to volumetric mass.

The fragmentation was two phase. The posterior part of the cortex, which had been weakened because of Hole 3, was first broken in a U shape, with the force operating in the anterior direction. This is indicated by the explicitly oblique lateral edge of the break, which is turned inwards (*Fig. 3:* slices 98–107). The anterior part of the cortex was then broken in the shape of a V. Immediately prior to that, or simultaneously, a crack was created as an extension of the longitudinal edge of the break on the anterior side. That this is a second phase can be concluded on the basis of the force, which also this time acted in an anterior direction. A considerable part of the edge of the break, which is in the vicinity of the crack is strongly oblique and turned outwards (*Fig. 3:* slices 85–93) or in the same direction as the edge of the break on the anterior side in the vicinity of Hole 3. We therefore suspect that the proximal part of the diaphysis was first broken on the posterior side by the pressure of teeth. The fracture is splintered in two and enabled the lower teeth to strike along the medullar surface of the anterior part of the cortex, which then fractured because of the biting force exerted by the upper and lower teeth. Prior to this, the presumed carnivore turned the bone several times between the teeth and left the traces mentioned by d'Errico et al. (2003, Fig. 9).

Chase and Nowell (1998, 551) have a different explanation for the fracture on the anterior side. It is supposed to have been created by trampling or pressure in the sediment on already weathered bone. They explain the fracture on the posterior side as a gnawed edge (Nowell, Chase, 2000).

Notch 3 on the proximal part of the diaphysis (= remnant of Hole 3)

Notch 3 is actually the remnant of a hole. It will therefore be called Hole 3 from now on. It was already treated as a hole in the first publication (Turk et al. 1997), but was later characterised as a notch (Turk et al. 2001). Nowell and Chase (2000) explain it as a kind of indentation made by teeth.

The largest preserved diameter of the hole is 7.6 mm, and the thickness of the cortex at the site of the hole is 4.2 mm. We determined the thickness with the aid of CT slices (*Fig. 2*). The diameter, determined by CT, is 1.1 mm larger than the diameter we measured with calipers (see Turk et al. 1997, 161).

Distally from the hole, the cortex of the medullar cavity is longitudinally crumbled in 3 slices (*Fig. 4:* 116–118; *Fig. 6*). Such damage is created by punching or piercing and is also present with all the other holes (see below). The notch is therefore the remnant of a hole. With punching or piercing, the cortex of the medullar cavity crumbles in a longitudinal direction, as the majority of vascular canals and collagenous fibres are oriented.

The edges of the holes are rounded throughout the entire rim. At the place where the hole is fractured, it is extended inwards in a funnel shape (*Fig. 4:* slice 109), but no longer distally (*Fig. 4:* slice 113). The edge of the hole here is perpendicular. The funnel on the medial edge of the hole may be the result of minor damage that occurred during the 'peeling' of the bone from the *breccia* (Turk et al. 1997, 157).

The cortex is no thinner at the site of the hole than on the anterior side; on the contrary, it was probably even thicker at the missing part of the hole. The thickness of the cortex did not therefore influence the position of the hole.

Distally from the hole, the cortex is locally strongly weathered. The result of the weathering is exfoliation of the cortex, which ends at the crack. The exfoliation and the crack are exactly above the crumbled part of the medullar channel. The crack may have been created either during the piercing or sometime later. The piercing may have been with teeth or a bone punch. Since there is not the slightest impression of an opposing tooth on the anterior side (see *Fig. 3* and *4*: slices 106–122), it is more likely that the hole was pierced artificially, as we explained in our last contribution (Turk et al. 2003). The microscopic damage caused by the opposing teeth mentioned by d'Errico et al. (2003, Fig. 9) are unimportant for explaining the creation of Hole 3. In order to puncture a hole in a 3.9 mm thick cortex with teeth, a force up to 4000 N is required (see Turk et al. 2001, tab. 4). The opposing tooth would thus make a visible indentation or the anterior cortex would crack longitudinally. Neither occurred in this case.

Diaphysis between the remnant of Hole 3 and Hole 1

On the posterior side, the cortex at this place is slightly thinner than on the anterior side (*Fig. 4:* slices 119–122). The cortex is cracked between the two holes. The crack may be only superficial and connected with exfoliation from the distal edge of Hole 3. CT did not detect the crack.

Hole 1

The hole is irregular. It has a small notch on the edge on the distal part in the shape of a V. The largest diameter in the medial-lateral direction, determined by CT, was 8.4 mm, which is 0.2 larger than measured by calipers, and 10.5 mm in the proximal-distal direction, which is 0.8 mm larger than measured by calipers (see Turk et al. 1997, 161). The bone cortex by the hole is 4.2 mm thick, on both lateral and medial sides (*Fig. 2*).

Proximally from the hole, closer to it than away from it, the medullary cavity is longitudinally strongly weathered in 6 slices (*Fig. 5:* 127–132). It is in essence funnel-shaped crumbled cortex (Fig.6). The funnel continues in the proximal lateral rim of the hole, while there is none on the lateral rim (*Fig. 5:* slices 135–137). The major part of the crumbled zone is away from the crack that links holes 3 and 1. While the crumbled zone is situated more laterally, the crack is more medial. CT did not recognise the crack, so we do not know whether it is superficial or deep, but it is certainly very narrow.

The rim at the largest medial-lateral diameter has a perpendicular face (wall) with rounded edges. There is no funnel in this part (*Fig. 5:* slice 140; *Fig. 6*).

Both distal rims of the hole, medial and lateral, are funnelled inwards (*Fig. 5:* slices 146–149). The extreme distal is funnelled only on the medial side (*Fig. 5:* slices 150–151). There is also a slight funnel here on the outside.

The cortex is the same thickness posteriorly and anteriorly. The thickness of the cortex is not therefore a reason for the position of the hole, as some have suggested (see Nowell, Chase 2000; Albrecht et al. 2001).

Distally from the hole, the medullary cavity is longitudinally crumbled on 2 slices (*Fig. 5:* slices 152–153). The damage is similar to the damage of the remnant of Hole 3. On the posterior, pierced side, the cortex is slightly thinner at this point than on the anterior, which is the same as with the remains of Hole 3. The damage is slightly medial from the notch in the shape of a V on the edge of the hole and fairly apart from the crack linking holes 1 and 2.

A large part of the rim of Hole 1 has a perpendicular face with rounded edges. Alternating long perpendicular face on the rim of the hole with oblique face or with funnel-shaped sections is more typical of chiselling with a stone point (see Turk et al. 2001) than puncturing with teeth or a bone point (ibid; Turk et al. 2003). During puncturing with teeth, there is normally an abrupt edge opposite the funnel-shaped crumbled edge, not another funnel-shaped crumbled edge as with Hole 1.

It is similar with the irregular shape of the hole, which can only be made with stone or bone tools.

A hole made entirely with stone tools may have an only partial and unremarkable funnel on the outside. A hole pierced with a bone tool in no way differs from a hole made by teeth (see Turk et al. 2003, Fig. 3).

The pronounced indentation on the outside lateral proximal edge (*Fig. 7*) may indicate the use of a stone tool. The crack in the bone may have been created in piercing with a bone point or puncturing with teeth. Puncturing with teeth is unlikely, because there is no visible indentation or impression of the opposing tooth in slices 125–170 (see *Figs. 5* and *8* for parts of the slices and Fig. 21a in Turk et al. 2001), because the shape of the hole and morphology of the edges corresponds badly to the shape of holes made with canine teeth (see Turk et al. 2001, Fig. 16), and because the cracked bone did not split. The microscopic damage found by d'Errico et al. (2003, Fig. 9) and the presumed explanation as carnivore are not relevant to an explanation of the creation of the hole. As with Hole 3, for confirmation of such an explanation more persuasive traces of the opposing tooth would be needed here. The claim by Albrecht et al. (2001) that the impression of a tooth was found opposite this tool does not correspond with the actual situation. Similarly, the claim of d'Errico et al. (2003, 37) that there is a clear impression of a tooth opposite this hole and Hole 2 does not hold up. Nowell and Chase (2000) also established that there is no such impression.

Chase and Nowell (1998, 552) in their criticism of the explanation of an artificial creation of the holes suspected that these funnel openings originally had an irregular shape (see also Nowell, Chase 2000). The edges of the openings were later damaged or weathered and changed into being perpendicular, and the openings themselves increased by 3–4 or 1.5–2 mm and obtained a circular shape.

There cannot be such a presumption on crumbling of the edges of funnel shaped holes with Hole 1, since before weathering this would have had an explicitly oval rather than round shape (see *Fig. 5*). Such a shape of opening is not created by piercing with canine teeth, while other teeth do not enter into consideration because of the position of the hole (see Turk et al. 2001, Fig. 10). Most of those who took part in the discussion on the creation of the holes in the 'Mousterian flute' (Albrecht et al. 1998; d'Errico et al. 2003) agree with the latter. In addition, the hole would have been oval in a proximal-distal direction, while carnivores could only make an oval hole in a medial-lateral direction with carnassials (see Turk et al. 2001, Fig. 10). The same applies for holes 3 and 5.

The suspicion of Chase and Nowell is therefore possible only with Hole 2, which has an almost complete funnel on the inside.

Diaphysis between holes 1 and 2

Close to Hole 1, the cortex on the anterior side is 3.5 mm thick, and on the posterior side 4.2 mm. Close to Hole 2 the cortex is 3.7 mm on the anterior and 4.0 mm on the posterior side. All thickness were determined by CT slices (*Fig. 2*).

The pierced posterior cortex is on average thinner proximal- and distal-medial from Hole 1 (*Fig. 4:* slices 121–122; *Fig. 8:* slices 154–158). So in the case of gnawing, one would have expected the hole firstly in the part with the thinner cortex, as Albrecht et al. (2110) mistakenly showed, when the hypothesis of an animal origin of the holes was argued on the basis of their position on the thinner part of the cortex. Nowell and Chase (2000) state the same evidence.

There is a slight crack between the two holes, which CT did not detect. It is not clear therefore whether the crack is superficial or deep, but it is certainly very narrow.

Distally from Hole 2, the surface of the cortex is damaged for a distance of slightly less than a centimetre, so the structural fibres can be seen (Turk et al. 1997, Fig. 11.1: 4). The damage was probably done by grinding in order to thin the cortex, which is thickest at the site of Hole 2 (*Fig. 11:* slice 218).

On the anterior surface of the cortex there is no indentation from an opposing tooth (*Fig. 8:* slices 170–188), which could be expected with puncturing by teeth.

D'Errico et al. (2003, Fig. 9) mentions in this segment only some microscopic damage focused distally from Hole 1. The explanation of the damage may be disputable. Certainly the link with damage to the hole is highly questionable.

Notch 5 on the distal part of the diaphysis (= remnant of Hole 5)

Notch 5 is actually the remains of the only hole on the anterior side of the diaphysis. We initially doubted its existence (Turk et al. 1997), but later, on the basis of experiments, determined it as possible (Turk et al. 2001). The results of CT have finally persuaded us that Notch 5 was formerly a hole.

Hole 5 is without cracks. The largest preserved diameter, determined by CT, is 6.2 mm, and the thickness of the cortex at the site of the hole by the lateral edge is 4.6 mm (*Fig. 2*). The edges of the hole are rounded over the entire rim.

Proximally from the hole, the medullary cavity is longitudinally greatly crumbled in 4–5 slices (*Fig. 9:* 191–195; *Fig. 12*), closer to the hole than away from it. Such damage, in the shape of a funnel, is created when punching or piercing a hole. We no longer therefore doubt that the notch is the remains of a hole.

On the outside of the cortex there is a shallow indentation at this point (*Fig. 9:* slices 193–195), which becomes deeper the closer it gets to the hole. On the last two slices (*Fig. 9:* slices 194–195) before the extreme proximal part of the hole there is a shallow indentation also medullarly on the posterior part of the cortex opposite Hole 5. This indentation also continues in the following two slices (*Fig. 9:* 196–197), so that it is partially covered by the extreme proximal edge of Hole 5, and then disappears. At the same time, an indentation appears on the outside (*Fig. 9:* slices 196–197), which is linked to grinding the posterior surface. The indentation gets deeper and deeper until it finally it ends in Hole 2 (*Fig. 9:* slices 198–202).

The extreme proximal part of Hole 5 has a funnel on the outside surface on the lateral edge and a funnel on the inner (medullary) surface (*Fig. 9:* slices 196–197). Part of the external funnel is connected to the aforementioned indentation, which would suggest that the hole was chiselled. However, the indentation could also have been made by a tooth before sliding to the place where Hole 5 is. The inner funnel could similarly have been created by chiselling or by puncturing with a tooth.

Distally, the two funnels cease. The rim of the hole in this segment has all edges strongly rounded (*Fig. 9:* slices 198–200), which gives the impression of a chiselled hole. The absence of a crack typical of puncturing with a tooth or piercing with a bone point merely strengthens this impression.

The remnant of Hole 5 has been explained by some people as the work of the tooth opposing that which made Hole 2 (Chase, Nowell 1998, 551; d'Errico et al. 1998, 77; Nowell, Chase 2000). Holes 2 and 5, namely, are approximately one on top of the other (*Fig. 10*). We have already established that such an explanation is impossible, referring mainly to the occlusion of the canine teeth (Turk et al., 2001). We would add this time that it is impossible for the fracture that damaged Hole 5 to have been made at the same time as Holes 2 and 5.

It is true that the bone cortex can fracture beside a hole in the form of the letter U or V. Such fractures are known from other sites, too (see Albrecht et al. 1998, Fig. 10: 3). However, as has been said, the hole and the fracture cannot be created simultaneously. If the bone had nevertheless cracked in the shape of a V during puncturing, the crack would have also been created on the opposite edge of the hole, which did not happen. We therefore believe that the V-shaped break beside Hole 5 post-dates the hole.

Holes one above the other are extremely rare. We also found such on the diaphysis of the femur of a juvenile cave bear from layer 4–5 among the Palaeolithic finds in Divje babe I (Turk et al. 1997, Fig. 11.15). According to the laws of physics, the two holes cannot be made by teeth (but see Albrecht et al. 2001), because they have clearly been punched or pierced in such a way that the force always operated in the same direction. We are therefore sure that they were punched at one time with a bone point (see Turk et al. 2003). We are of the firm opinion that the holes are artificial despite the undeniable traces of teeth in their vicinity, because in this case, too, they are two distinct matters. So the traces of the action of teeth cannot be the cause and the holes the result.

In connection with Hole 5, of most interest is the above mentioned damage in the vicinity of Hole 2, documented precisely for the first time: the indentation on the outside and indentation on the medullary surface of the cortex (Fig. 9: cuts 194–197). The indentations could have been created together with Hole 5, if Hole 5 had been made by one tooth and the indentation by another, as d'Errico et al. (2003) suggest. However, it is hard then to explain the creation of Hole 2 in the same way. If a tooth had once made Hole 5, a fresh bite above it could not additionally make Hole 2, nor could it at the same time fracture the bone at Hole 5 and make a new Hole 2. It is even more odd that the indentation made by the opposing tooth at the moment that it made Hole 5 did not puncture with fresh gnawing because of the previous deformation of the cortex before or together with the undeformed cortex where it made a new Hole 2 (see below).

Hole 5 is the only hole which, on the basis of the collected evidence, could be explained in two ways: either as a human artefact or the result of gnawing with teeth. Because the bone cortex is not cracked beside the holes, puncturing with a tooth or piercing with a point is less likely than chiselling with a stone point.

Hole 2

Hole 2, like Hole 1, has an irregular shape. The largest diameter in the medial-lateral direction, determined by CT, is 9.2 mm, which is 0.5 mm more than we measured with calipers, and in the proximal-distal direction 11.1 mm, which is 2.1 mm larger than we measured with calipers (see Turk et al. 1997, 161). Hole 2 is thus slightly larger than Hole 1. The bone cortex beside the hole on the medial side is 4.9 mm thick (*Fig. 2*), which is 0.9 mm more than we originally thought (ibid).

Proximally from the hole, the medullary cavity is almost intact (*Fig. 9:* slices 198–201), which means that the cortex here was not broken in a funnel shape. The remaining edge of the hole has an almost fully expressed funnel shape on the inside (*Fig. 6*) but less pronounced on the outside, which may also be a result of weathering of the edges (*Fig. 11:* slices 203, 208, 214). It is characteristic of the edges that they are strongly rounded.

The inner funnel is more pronounced in the distal part than in the proximal, in medial and lateral directions (*Fig. 11:* slices 214–219; *Fig. 6*). The bone cortex is the same thickness on the anterior and posterior sides.

Distally from the hole the medullar canal is longitudinally strongly crumbled, which indicates the existence of a funnel in this part, too. The damage extends to 4 slices (*Fig. 11:* 220–223). The posterior side of the bone cortex is here 1 mm thinner than in the part with Hole 2 (*Fig. 2*). So in the case of gnawing one would expect the hole first at this point, i.e., more distally than is actually the case. The crack which runs from Hole 2 to Notch 4 starts exactly in the centre of Hole 2. CT did not detect the crack, so it is not clear whether it is superficial or deep, but certainly very thin.

Hole 2 was undoubtedly punctured. The crack in the cortex could have been made with puncturing. The question is, how was it punctured: naturally with a tooth or artificially with a tool?

If Hole 2 was made with a tooth, Hole 5 is artificial. If Hole 5 was made with a tooth, Hole 2 is artificial. In no circumstances were both holes made with teeth, though both could be artificial.

The damage in the shape of an indentation proximally beside Hole 2, to which we already drew attention in the first exhaustive publication on the »flute« is important for explaining the creation of Holes 2 and 5 (Turk et al. 1997, 160). The indentation, which is bordered by two longitudinal cracks and one transversal one, has not to date been adequately explained. D'Errico et al. (2003) in their critique of the »flute« explain it as the impression of a tooth.

Experiments confirmed that there is a high probability with gnawing that a hole is made on the anterior side (Turk et al. 2001). So Hole 5, despite the above scruples, could have been made by a tooth. A tooth (the opposing) undoubtedly deformed the cortex immediately beside the future Hole 2. It thus created damage in the shape of a small indentation on the outside and on the medullary surface of the cortex. The main critics of the »flute« cite the external indentation as evidence that the hole was made by a carnivore (d'Errico et al. 2003). At the same time, they talk of other microscopic damage between Hole 2 and Notch 4, which a carnivore is supposed to have made together with the holes. The indentation and other damage may be connected either with the creation of Hole 5 or with the fracture of the anterior part of the distal diaphysis and metaphysis, but not also with Hole 2. In other words, the indentation and both holes cannot have been made by teeth. We therefore think that Hole 2 was pierced later, in the way that we explained in our last article (Turk et al. 2003). Before that, the very thick cortex in the area of the hole was slightly thinned; perhaps because the maker had suffered enough with Hole 1, where the cortex was also approximately the same thickness. In piercing with a bone point, the cortex cracked. In addition, a piece of the bone on the proximal rim of the hole was depressed, where the cortex had been deformed because of the pressure of a tooth. In this a force was released that elsewhere on the rim of the hole created a pronounced funnel-shaped indentation on the inside (*Fig. 11:* slices 212–221). There is, therefore, no pronounced funnel on the depressed part of the cortex and laterally in its vicinity (*Fig. 9* and *11:* slices 200–209). The irregular shape of the hole may be connected with the shape of the point.

Fragmentation of the diaphysis between Hole 2 and Notch 4

The thickness of the cortex on the posterior side, determined by CT slices, is 3.9 mm (*Fig. 2*). The missing anterior side could not have been essentially thinner.

The edges of the fracture in the shape of a letter V on the anterior side are more or less rounded. The bone cortex fractured when Hole 5 was already there. The fracture and Hole 5 could not have been created at the same time, as Chase and Nowell (1998, 550) envisage. Similarly, the explanation (ibid) that it was some sort of 'scooping' with teeth is also mistaken, because the medial edge is clearly fractured. The medial part of the fracture, namely, has an oblique edge almost throughout the entire length, which is turned inwards. This shows that the force operated from the outside inwards. The lateral part of the fracture has a very varied edge and for the most part more rounded, which could be connected with gnawing that followed the fracture. The suspected microscopic traces of gnawing that d'Errico et al. found (2003, Fig. 9), are covered by this explanation. They were created when a carnivore turned the bone between its teeth.

With the pressure from teeth, the cortex gave way where it was weakest, or more deformed because of the hole. That the diaphysis fractured only anteriorly, despite the anterior and posterior holes, can be explained by the greater frequency of puncturing the diaphysis of the femur precisely on that side (see Turk et al. 2001). In addition, the majority of notches in the shape of a U on the distal metaphysis (see below) of juvenile femurs of cave bear are similarly on the anterior side. This means that the likelihood of damage from teeth is greater on the distal anterior side than the distal posterior, which may be explained by the convexity or flatness of the bone cortex.

Notch 4 on the metaphysis

Notch 4 was never a hole, since there is no trace of a funnel on the rounded edges. It measures 9.4 mm at the widest part. The diameter, determined by CT, was 3.6 mm smaller than the largest diameter measured with calipers (see Turk et al. 1997, 161). The large difference is a result of where we measured. The thickness of the cortex at the widest part of the notch is 3.2 mm laterally and 3.7 medially (*Fig. 2*). Proximally, both parts of the cortex thicken by slightly over a millimetre.

The lateral and medial parts of the metaphysis end distally in a blunt tip. All edges are strongly rounded, we suspect because of greater chemical weathering or dissolving.

We agree with critics that the distal posterior edge of the metaphysis of the suspected flute, including Notch 4, may have been caused by carnivores gnawing (see 4 Chase, Nowell 1998, 550; d'Errico et al. 2003). However, we do not agree that it also rounded them (ibid). All bone fragments, from the smallest to the largest, have rounded edges. We therefore conclude that rounding is mainly connected with chemical weathering, which is also clearly visible on dolomite clasts (see Turk et al. 2002).

The question is when and how the notch was created. That it was made by a carnivore is very probable. However, the majority of similar notches actually to have been made by carnivores, probably wolves, on distal metaphyses of juvenile femurs, are on the convex anterior side. Irrespective of who or what made Notch 4, this was very probably made before the large fracture in the shape of a letter V on the anterior side, which ends in Hole 5. Such notched long bones are frequent at the site and also elsewhere, but the bone cortex is always preserved opposite the notch, thus giving one tooth support while the other gauged the notch (see Turk et al. 1997, Fig. 11.19). Without the anterior cortex, the teeth would only crush the posterior cortex and with a shear strength, a larger piece of cortex would be broken off, as on the proximal end of the 'flute'. We therefore conclude that notch 4 is older than the anterior fracture. Because the break is earlier than Hole 5 and because Hole 2 cannot be earlier than Hole 5, Notch 4 was probably made before the holes. It could therefore have served as the mouthpiece of the suspected flute, regardless of who made it. However, a carnivore could have damaged and transformed its lateral part, which, together with the undamaged medial parts, was normally accessible to it after the large break on the anterior side of the metaphysis.

3. DISCUSSION AND CONCLUSIONS

Critics of the suspected Mousterian flute oversimplified the question of the creation of the holes. They were sure that they had set about the problem on a higher scientific level, with more practice and with better methods than the finders of the flute (Chase, Nowell 1998; d'Errico et al. 2003). Among them, Chase and Nowell stand out for constructiveness and impartiality of point of view, since they allow the possibility that the two hypotheses are equally likely (Nowell, Chase 2000). The most partial and tendentious are d'Errico et al. (1998, 2003), since they approach the question of the origin of the 'flute' mainly from the point of view of a single hypothesis.

Research by the finders, including that presented here, shows that the question is complex and does not provide simple answers (Turk et al. 2001, 2003). We agree with Nowell and Chase on this (2000). So rejection of the hypothesis of an artificial origin of the holes was overhasty and the alternative hypothesis was quickly shown to be poorly grounded (for a summary of the discussion to date on the 'flute' see Horusitzky 2003).

The new finding of multi-slice computed tomography is that the 'flute' was created in two phases. The four holes were created first, and only subsequently the majority of the damage, which can be ascribed to carnivores. We even succeeded in establishing a more exact succession of events at the two ends of the diaphysis and the distal metaphysis, which will probably contribute to a more accurate explanation of the find.

The main findings are the following:

CT confirmed that the medullary cavity of the diaphysis is entirely without spongiosa. The interior parts of the metaphyses have spongy bone only preserved in traces (*Fig. 13*).

Similarly, the new research reconfirmed that the holes, with the possible exception of only one, were not made by teeth. The cortex is too thick in the places where there are holes for such an explanation and, as we know, at the same time too brittle. It would therefore certainly have split in two with so many bites producing holes (see Turk et al. 2001). With tooth pressure, the holes would have been made where the cortex was actually thinner, and mostly on the convex anterior side instead of on the flat posterior side (ibid). The posterior part of the cortex at the site of the holes is the same thickness as the anterior. So the original assumption of a thinner posterior cortex (Turk et al. 1997), which Chase and Nowell (1998, 551; Nowell, Chase 2000) also adopted, turns out to be false, as does the assumption of Albrecht et al. (2001), that the holes were made at the places where the cortex was thinner (see *Fig. 4, 5, 8, 11* and *13*).

Before the bone was pierced, carnivores made the "mouthpiece of the flute" or Notch 4. Only a human could have made the holes, for a particular purpose. Similarly the mouthpiece, unless carnivores had already made it. The same holds for the "hole for the thumb" on the anterior side. Its origin and significance still remain unclear. It could have been made by either man or a carnivore. When man stopped using the product, carnivores, probably wolves, damaged it at the ends. Carnivores could also have transformed the "mouthpiece of the flute", which had already been available to humans. The suspected course of events is shown in *Fig. 14*.

Almost all the damage on the pierced diaphysis typical of carnivores is at the two ends between Holes 1 and 2 and the metaphysis (Turk et al. 1997; 2001; Chase, Nowell 1998; d'Errico et al. 2003; Nowell, Chase 2000). The central part of the diaphysis is without damage (see also d'Errico et al. 2003, Fig. 9). This means that carnivores gnawed the bone from the end with molars, and for the suspected piercing could have used canine teeth. Mainly Holes 1 and 2 could have been made, if they were, exclusively with canines (but see Nowell, Chase 2000).

The key items of evidence of critics of the view that it is a "flute" are in our opinion the damage with the remains of an indentation beside Hole 2 on the posterior side and the remnant of Hole 5 anteriorly below Hole 2. The critics believe that both holes or the indentation and Hole 5 were made with teeth, more precisely, with canines or molars. This is theoretically possible if with the two holes we take no account of the indentation (Chase, Nowell 1998, 551; d'Errico et al. 1998, 77) or with the indentation and Hole 5 we take no account of Hole 2 (d'Errico et al. 2003). In passing we mention that the sentence of d'Errico et al. (2003), which probably refers to Hole 5 and the indentation by Hole 2 (for the indentation see also Turk et al. 1997, 160, Fig. 11.2: 3; Chase, Nowell 1998, 552), is inaccurate and should read: "A large deep impression found on the anterior (= *posterior*) face near the proximal end (*of the hole*), indicating strong pressure exerted by carnivore teeth, can reasonably be interpreted as the counterbite of the anterior hole (= *semi-hole*)." The conclusion of d'Errico et al. (2003): "The presence of two or possibly three perforations on the suggested flute cannot therefore be considered as evidence of human manufacture, as this is a common feature in the studied sample" is inaccurate and tendentious. The mentioned sample is from the cave site Križna jama (and Mokriška jama?) in Slovenia and was first published by M. Brodar (1985). D'Errico et al. do not cite this publication, and how they came to the studied sample. Perhaps because there is no such example of a pierced diaphysis, let alone so many times, in Križna jama, as the femur from Divje babe I. There is also nothing similar in Mokriška jama, from which is known textbook example of a diaphysis with a chiselled or punched hole (see Turk et al. 1997, Fig. 11. 12; M. Brodar 1985, t. 5:8). Unfortunately, there are no stratigraphic data for it (M. Brodar 1985), but it is from a site with Aurignacian finds in two layers of ten and all contain the remains of cave bear (M. Brodar 1959).

If in the context of the hypothesis that the holes were made by carnivores both distal holes and the impression are taken into account, it leads to the following conclusion:

It would be possible with teeth exceptionally to make only the indentation in the broken part of the bone and Hole 5 or only Holes 2 and 5. However, whether both are possible is questionable, since the indentation and Hole 5 are exactly one below the other, and the proximal edge of Holes 2 and 5 is shifted between 3 and 4 mm (*Fig. 10*). The tips of the canines of an adult cave bear, which are the only ones that enter into consideration for piercing, are more disaligned (minimum 10 mm) with an almost closed mouth, than is required by the anterior-posterior diameter of the pierced diaphysis.

If we accept one of the two possibilities for a natural origin of Holes 2 and 5, we cannot explain in the same way either Hole 2 or the indentation beside it, because with a fresh bite both teeth or one of them slips into the already existing hole or indentation, because of which the other tooth cannot make the hole or indentation. If a carnivore were to try this, the indentation would either collapse because the cortex is weakest here because of the deformation or the bone would crack with expanding the existing hole, or it would burst. None of these things happened. The bilateral crack by Hole 2 may have been created at the same time as Hole 5, and the unilateral crack with the V-shaped fracture on the distal anterior side or with piercing Hole 1. Certainly the crack could not have been made with a fresh bite with canines.

The V-shaped fracture by Hole 5 is evidence that a carnivore only bit at that time, or when the hole was already made. This means that a causal connection between the holes and other carnivore damage (see Chase, Nowell 1998; d'Errico et al. 1998; 2003; Nowell, Chase 2000) is questionable. Even more problematic is reaching a conclusion on the origin of the holes on the "flute" on the basis of holes which have actually been made by carnivores on long bones (see mainly Albrecht et al. 1998; d'Errico et al. 1998, 2003) in Divje babe I and elsewhere (see Kos 1931; M. Brodar, S. Brodar 1983; Brodar 1985). These holes have little in common with the holes on the "flute" (see Turk et al. 2001).

Our objections to the suspected carnivore origin of the holes are therefore the following:

1. Both semi-preserved holes were formerly holes, which were created before the damage to the proximal and distal parts of the diaphysis, or before the indisputable intervention of a carnivore.

2. It is impossible that the cortex was simultaneously punctured and broken twice in succession by gnawing, as is clear from the two remains of holes. It is even less credible that the diaphysis would not have split if a carnivore had punctured it with teeth four successive times with teeth (see Turk et al. 2001).

3. Because carnivores bite from the end of a bone towards the centre (see Chase, Nowell 1998), there is little likelihood that it would first make at least 2–3 holes, if not four, with canines, in a straight line along the centre of the diaphysis and only then start on the ends with molars. Or that after 2–3 holes set about another 1–2 so that all the all the holes were finally in line. It is unusual that none of the holes were made where the cortex of the diaphysis is thinnest.

4. One would expect with puncturing with teeth that there would be more holes on the on the anterior than posterior side, so precisely the opposite of the case with the "flute" (Turk et al. 2001)

5. It is a mistake to conclude on the basis of other damage suspected of being made by a carnivore, how the holes were made. Carnivores chew for various purposes: to get to the nourishing marrow is only one of them. There are a fair number of bone artefacts in Palaeolithic collections, which were subsequently damaged by carnivores, but nobody imagines that carnivores also made the artefacts.

6. The different sizes, shapes and morphologies of the holes can perhaps more easily be explained by the use of simple tools than by the operation of teeth. Such tools, stone and bone, with various damage, are not unknown at the site (*Fig. 15*). While the stone ones are nicely shaped, those of bone are less processed. These are normally difficult to recognise *ad hoc* bone punchers, to which we only became attentive thanks to Z. Horusitzky (2003), who discovered a new method of making holes. It was similar with tools made from dolostone, which we long failed to recognise because we did not envisage their existence. Thus a similar problem as with the holes, where we did not expect the use of a simple technique for their production and thus imagined them to be holes punctured with teeth. We also established how Neanderthals and others used various tools for effectively piercing long bones and how such tools were damaged in this (Turk et al. 2001; 2003). Claims of critics that the holes could not be punched (Albrecht et al. 1998, 13) and that there are simpler ways of making them such as drilling etc. (Chase, Nowell 1998, 552), are unfounded. Similarly, it is not true that special effort is required for the tool to leave no trace, as Nowell and Chase (2000) thought. Punching or chiselling is the simplest and often leaves no typical tool traces. Chiselling has also been detected in the Mesolithic with holes made in antlers (Clason 1983, 85) and in finger bones of deer (Turk 2004), as well as later, e.g., in the Eneolithic on the Ljubljansko barje pile dwellings. It is of note that if the edges of the holes have been weathered, there is no longer any trace of tools.

7. With certain techniques of making holes, only exceptionally do (un)characteristic traces of tools remain on the edges, which are quickly erased by weathering. It is therefore normally difficult to distinguish holes made by stone or bone tools from those made by teeth only on the basis of morphology (see Brodar 1985). This particularly applies to holes punched with bone punchers.

On the basis of the results of in-depth research of recent years, the origin of the holes on the "flute" can no longer be in doubt.

We believe that we have demonstrated sufficiently clearly that it is actually an exceptional find, the oldest flute-like artefact, and that sooner or later it will be necessary for Palaeolithic archaeology to be reconciled with this. We can also wait for someone to excavate a similar find in a similar context. It is, of course, a question of how to continue the discussion from there. Good chronological data is certainly needed for its proper course, which, unfortunately, is lacking at many Palaeolithic sites, including those that compete with Divje babe I.

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