

The Study of Cave Bear Milk Teeth from Križna Jama Cave, Slovenia

by

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Zusammenfassung

Im Zuge systematischer Untersuchungen an quartären Höhlenfaunen wird gezeigt, dass diejenigen der Križna jama und Herkova jama im Hinblick auf Höhlenbärenmilchzähnen von besonderem Interesse sind. In dieser Studie werden die Milchzähne der ersten Höhle beschrieben und diskutiert. Sowohl die Analyse der Morphotypen als auch die der morphodynamischen Indices und ihrer Kauflächenmuster scheint bei den oberen und unteren Milchprämolaren – so wie auch bereits bei den P4 (RABEDER, 1983) – die Evolution des jungpleistozänen *Ursus ingressus* aus Slowenien zu quantifizieren.

Schlüsselwörter: *Ursus ingressus*, morphodynamische Analyse, Morphotypen, morphodynamische Indices

Izvleček

V teku sistematskih raziskav kvartarnega jamskega živalstva se je pokazalo, da sta Križna jama in Jama pod Herkovimi pečmi paleontološko posebno zanimivi spričo mlečnih zob jamskih medvedov. V tem sestavku smo opisali in razpravljali o mlečnih zobeh iz prve jame. Kot analiza morfotipov in morfodinamičnih indeksov bi lahko tudi vzorci žvekalne površine zgornjih in spodnjih mlečnih premolarjev dali več podatkov o razvoju mlajše pleistocenske vrste *Ursus ingressus* v Sloveniji – podobno kot pri P4 (RABEDER, 1983).

Ključne besede: *Ursus ingressus*, morfodinamična analiza, morfotipi, morfodinamični indeksi

Abstract

From systematic studies on Quaternary cave faunas in Slovenia, it is shown that two caves, Križna jama and Herkova jama are of palaeontological interest concerning the cave bear milk teeth. In this study the deciduous teeth from the former cave are described and discussed. The morphotypes that are also analyzed, as well as the morphodynamic indices and their patterns from the upper and lower fourth deciduous carnassials teeth, may quantify the cave bear evolution of the Late Pleistocene *Ursus ingressus* from Slovenia as it happened on P4 (RABEDER, 1983).

Keywords: *Ursus ingressus*, morphodynamic analysis, morphotypes, morphodynamic indices

1. Introduction & Methodology

The research and excavations in Križna jama (Ljubljana) were carried out by the Institute of Paleontology, University of Vienna in cooperation with Ljubljana University from 2000 until 2002. The material studied here is stored in the Institute of Paleontology, University of Vienna, while a few specimens are stored in the Natural History Museum of Vienna.

The chronology of deciduous teeth from Križna jama is based on dating and morphometric analyses of permanent teeth and adult post cranial material of *Ursus ingressus*, and gives an age of 34,000 to 32,000 kya. (POHAR et al., 2002; RABEDER et al., 2008).

Nordmann was the first person to study the bear milk teeth in 1858, followed by Schlosser in 1909, Kormos in 1916, Pohle in 1923, Ehrenberg in 1931, Friant & Stehlin in 1933, Mottl in 1934, 1939, Zapfe in 1946; Koby (1952), ERDBRINK (1953), RADULESCU & SAMSON (1959), EHRENBURG (1964), KURTEN (1968), TERZEA (1969), TORRES (1988), ANDREWS & TURNER (1992), DEBELJAK, (1996, 1997).

The cave bear deciduous teeth from Križna jama are described, measured, occlusally figured, discussed and compared with other materials such as the very rich

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milk teeth material from the Almopia Speleopark Bear Cave (Macedonia, Greece), as well as from Herkova jama (Slovenia), from Gamssulzen Höhle (RABEDER, 1999) and from Ochsenhalt Höhle (Austria). In addition, they have been attributed into categories according to KURTEN (1976), PAPPÀ et al. (2005), TSOUKALA et al. (2006) and PAPPÀ (2010). The four categories of development can be described as follows: A) enamel cap of tooth still concealed in the jaw, root beginning to form, B) unworn tooth with fully formed root, C) tooth with root showing resorption marks and D) shed milk tooth with resorbed root.

The aim of this study is also to apply the morphodynamic analysis and find the morphotypes of the fourth deciduous carnassials. Therefore morphodynamic indices results suggest that some cusps of the occlusal surface on deciduous carnassials are significantly important for understanding the progress of D4 teeth, which may show the evolutionary relationships between the Pleistocene bear species *Ursus ingressus*, *Ursus eremus*, *Ursus ladinicus* and *Ursus deningeri* (PAPPÀ, 2010). Morphological terms follow RABEDER (1999) and measurements have been made according to TSOUKALA & GRANDAL D'ANGLADE (2002). Morphotype drawings were made with a Karl Zeiss/Jena binocular microscope with camera Lucida in the Palaeontological Institute of Vienna and measurements were taken with dial calipers to mm.

2. Palaeontology & Taxonomy

Order: Carnivora BOWDICH, 1821

Suborder: Caniformia KRETZOI, 1943 /

Infraorder Arctoidea FLOWER, 1869

Family: Ursidae FISCHER VON WALDHEIM, 1817

Genus: *Ursus* LINNAEUS, 1758

Ursus ingressus RABEDER et al., 2004

Material: 4 dI³: Kj 185a, 54, 114c sin and Kj 114b dex, D³: Kj 51e sin, 6 D⁴: Kj 51f, 121b, 143b, 143c, 8 sin and Kj

121c dex, 4 dI₃: Kj 52e, 52g sin and Kj 168b, 52f dex, 5 D₄: Kj 185b, 51g, 54a, 62 sin and Kj 145 dex, finally 46 dC.

Description: From the cave bear material of Križna jama, 67 milk teeth were studied, drawn and measured here (Table 1), since no complete maxillas and mandibles from juveniles have been found. Most of the milk teeth are deciduous canines.

dI³: The third milk incisors are the strongest teeth of the milk incisors (Fig. 1). The dI³ is of similar morphology to the milk canine except for the shorter and more curved crown and the intense palatal cingulum. The third upper milk incisor Kj 185a is slightly worn and most of the root is preserved and shows resorption marks. The dI³ Kj 114b and Kj 54 are also slightly worn and their roots have been completely dissolved. The dI³ Kj 114c is a germ enamel cap. In table 1 shows the measurements.

D³: The third upper milk premolar Kj 51e (sin) has a pyramid-shaped crown and has slight to medium wear with well-developed talon and two roots that are widely bifurcated but broken (Fig. 2). The mesial root is thinner than the distal root. In table 1 shows the measurements.

dI₃: The third milk incisor is the largest lower milk incisor with the crown of triangular shape and a well developed root. There are two to three lingual accessory cusps, which sometimes form a crest (Fig. 3, Kj 52e; Kj 52f). Three categories of development can be distinguished: the Kj 168b is slightly worn with fully formed root but broken (category B); both the dI₃ Kj 52g and Kj 52e with root showing resorption marks (Fig. 3) (category C); and Kj 52f with completely dissolved root from osteoclasts (category D). In table 1 shows the measurements.

dC: The milk canines are the most abundant milk teeth among the Križna jama material. They are long, flattened and relatively large teeth. It is difficult to distinguish between upper and lower ones, thus both are described here together (Fig. 4). Concerning their wear stage they can be attributed to the categories shown in Table 2: (A) by few



Figure 1: *Ursus ingressus* Križna jama. Third upper milk incisor.

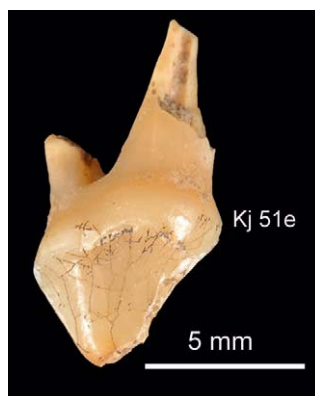


Figure 2: *Ursus ingressus* Križna jama. Third upper milk premolar (lingual side).



Figure 3: *Ursus ingressus* Križna jama. Third lower milk incisors (lingual side).

germs – milk canines consisting of an enamel cap and a root that has barely started to form, (B) by few complete milk canines with unworn occlusal surfaces and where some root development has taken place. In the wear stage (C) the root of the tooth is fully formed, but the crown has no wear, while in (D) the wear stage of the occlusal surface is slight to moderate. Finally, the last stage (E) presents heavily worn occlusal surface.

Regarding the categories of development, four were observed. The first one (A: root beginning to form) with 8 specimens (Fig. 4a) (Kj 51d), the second (B: with fully formed root) with 4 specimens (Fig. 4b) (Kj 210), the third [C: with complete canines and with root showing resumption marks, which is a preliminary stage to the tooth being shed and as the root is gradually dissolved by the osteoclasts (Koby, 1952)] with 9 specimens (Fig. 4c) (Kj 118); and finally the fourth (D: with resorbed root) with 22 specimens (Fig. 4d) (Kj 53). In table 1 shows the measurements.

D4: The upper and lower milk carnassials are molar-like and the most important of the milk teeth because they contribute to the morphodynamic analysis (RABEDER, 1983, 1991, 1999).

The D⁴ has one palatal and two labial roots. The occlusal shape is trapezoid and sometimes there is a lingual cuspid-like cingulum (Fig. 5, upper row). The labial margin is almost straight and longer than the lingual margin, which is very convex. The two main labial cusps are elongated mesiodistally and both are much larger than the lingual cusps. The mesial cusp (paracone) is larger than the distal cusp (metacone). A small but well differentiated cusp, the parastyle is well preserved in all specimens from Križna jama (Kj) and arises in front of the paracone. Three out of six specimens (Fig. 6, left; Kj 43; Kj 51; Kj 121c) have, on the lingual side of the metacone, an enamel crest descending toward the centre of the crown. In specimen Kj 51 it merges with another crest that originates from the lingual cusps. In

Figure 4: *Ursus ingressus* (Križna jama). Milk canines. Three categories can be distinguished:

A: Germs (Kj 51d),

B: Full teeth (Kj 210),

C: Showing resumption marks (Kj 118) and

D: shed canines (Kj 53).



	n	x	min – max	s _{n-1}	v
LdI ³ (Kj185a)		–	6.28	–	–
BdI ³ (Kj185a)		–	4.71	–	–
LdI ³ (Kj114b)		–	6.68	–	–
BdI ³ (Kj114b)		–	5.77	–	–
LdI ³ (Kj114c)		–	6.54	–	–
BdI ³ (Kj114c)		–	5.44	–	–
LdI ³ (Kj54)		–	6.59	–	–
BdI ³ (Kj54)		–	5.35	–	–
L dC	43	7.42	6.52–8.49	0.43	5.75
B dC	43	5.31	4.43–6.25	0.38	7.14
L D ³ (Kj :51e)	1	6.18	–	–	–
B D ³ (Kj :51e)	1	3.92	–	–	–
L D ⁴	6	11.19	10.11–11.94	0.64	5.72
B D ⁴	6	7.31	6.81–7.74	0.39	5.18
LdI ₃ (Kj52e)		–	5.37	–	–
BdI ₃ (Kj52e)			3.57	–	–
LdI ₃ (Kj168b)		–	4.6	–	–
BdI ₃ (Kj168b)		–	3.33	–	–
LdI ₃ (Kj52f)		–	5.97	–	–
BdI ₃ (Kj52f)		–	4.16	–	–
LdI ₃ (Kj52g)		–	5.34	–	–
BdI ₃ (Kj52g)		–	3.86	–	–
L D ₄	5	12.46	11.13–13.86	1.22	9.86
B D ₄	5	6.39	5.59–7.02	0.51	8.09

Table 1: *Ursus ingressus* Križna jama: Measurements of the milk teeth (in mm). L – length, B – breadth

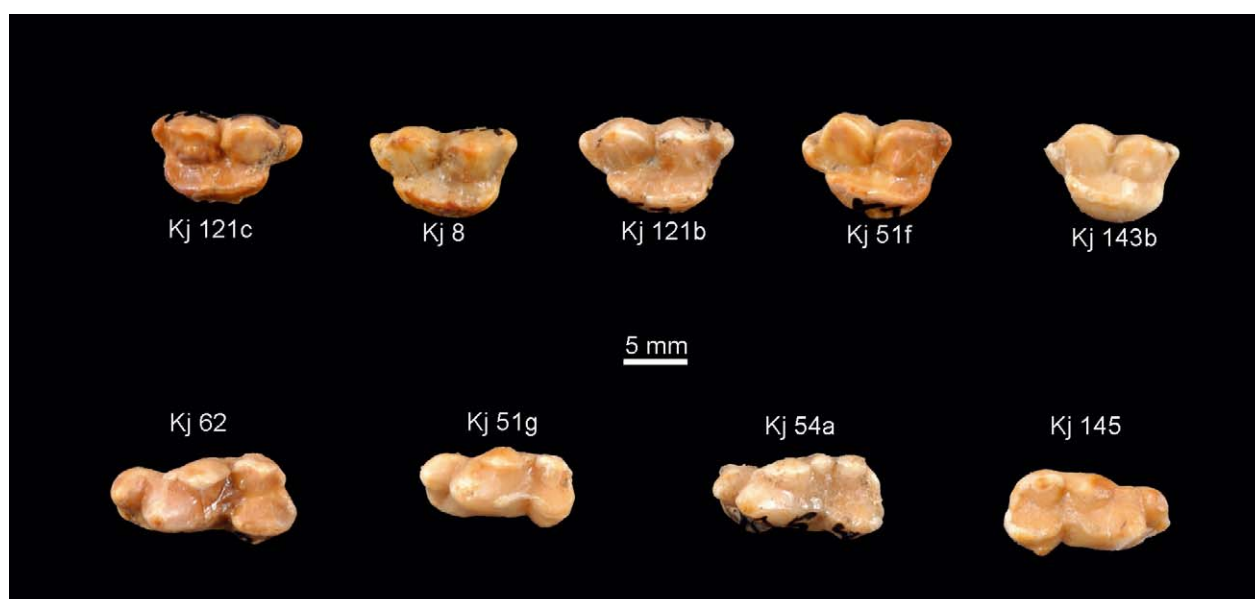


Figure 5: *Ursus ingressus* Križna jama: Material of the milk carnassials showing the variability of their morphotype. Upper row: occlusal views of the upper carnassials D⁴, Lower row: occlusal views of the lower carnassials D₄

all specimens the metastyle, which sometimes forms a continuous crest towards the hypocone, originates from next to the metacone. Hypocone is the most important cusp for the morphodynamic analysis. All the D⁴ from Križna jama have a hypocone. This cusp is distolingually located on the lingual-distal side of the crown. Additionally, on the lingual margin of the crown there are three to four relatively low cusps which are usually connected with each other by a continuous crest. In some cases the protocone has two apices (Kj 121c). In table 1 shows the measurements.

The D₄ are much more variable than the upper ones, with the crown bearing at least 5 cusps and two roots. The crown consists of two areas, the talonid and trigonid (Fig. 5, lower row). The trigonid shows three main cusps in all Križna jama specimens, paraconid, protoconid and metaconid. The protoconid is the most conspicuous cusp and separates the paraconid from metaconid as in M₁. From the protoconid, descend three ridges. The first one is on the mesial side towards the paraconid, the second on the distolabial side toward the talonid area and the third on the distolingual side toward the metaconid. In some specimens there is a small lower cusp present between paraconid and metaconid (Fig. 11, right; Kj 62; Kj 51g). Sometimes the paraconid varies in size, for example in Kj 145 (Fig. 11, right) it is small. The discontinuous line in the sample Kj 145 (Fig. 11, right) explains the broken

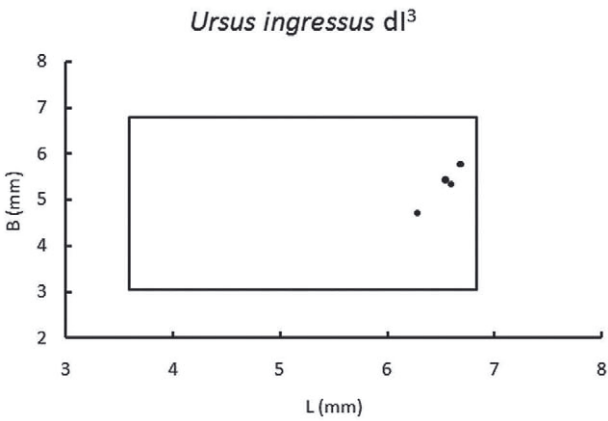


Figure 6: Scatter diagram of L = length and B = breadth of the dI³ *Ursus ingressus* from Kj and *Ursus arctos* from collections in Moscow (rectangle of a continuous line) (BARYSHNIKOV & AVERIANOV, 1991).

part of the tooth. There are two main cusps on the talonid area, the hypoconid and the entoconid cusps. Usually the hypoconid is larger than the entoconid and is placed on the labial margin. The entoconid is the most important cusp for the morphodynamic analysis of D₄. This cusp varies in number and in size which is a key factor for the final morphodynamic index. In table 1 shows the measurements.

dC Wear stage categories	Description		Križna jama	LAC PAPPA et al., 2005	Westbury ANDREWS & TURNER, 1992	Odessa KURTÉN, 1976
			Number of specimens			
A	Unerupted	Neonates	7	132	22	13
B	Erupted		5	500	10	26
C	Unworn		1	83	32	—
D	Slightly wear	Year- lings	31	130	39	165
E	Heavy wear		—	600	80	—

Table 2: *Ursus ingressus* Križna jama: Wear stages categories of the milk canines in reference with LAC (Loutra Almopias Cave, Greece), Westbury and Odessa localities. Unerupted, when the crown is formed but the root is not; erupting, when some root development has taken place; unworn, when the root is fully formed but the crown has no wear; slight to moderate wear; heavy wear.

Teeth	Number of left (sin)	Number of right (dex)
Third milk incisor dI ³	3	1
Fourth milk premolar of upper jaw D ⁴	5	1
Fourth milk premolar of lower jaw D ₄	4	1

Table 3: *Ursus ingressus* Križna jama: Number of specimens from dI³, D⁴ and D₄ (dex) and (sin) showing the MNI (minimum number of individuals).

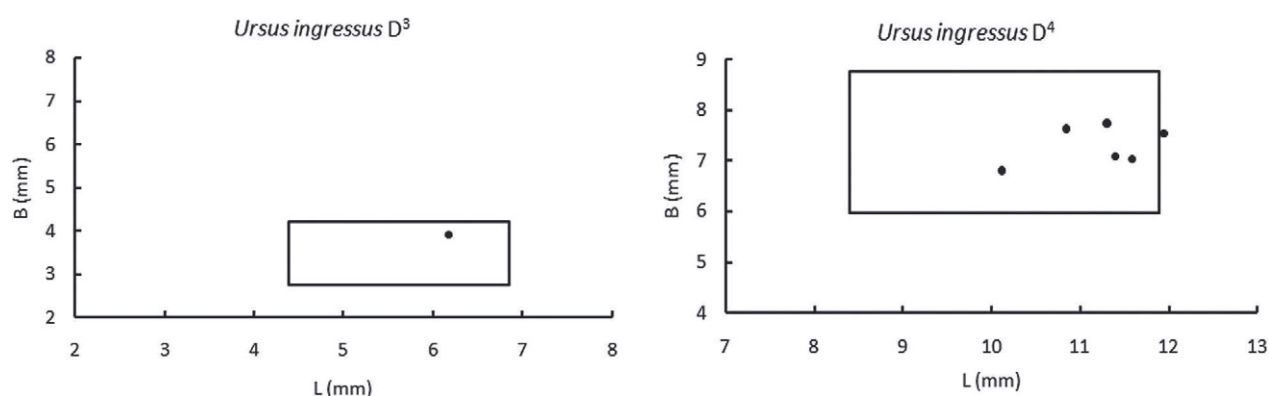


Figure 7: Scatter diagram of L = length and B = breadth of the D³ (left) and D⁴ (right) *Ursus ingressus* from Kj and *Ursus arctos* from collections in Moscow (rectangle of a continuous line) (BARYSHNIKOV & AVERIANOV, 1991).

3. Discussion

The study of the milk teeth can show the presence of unborn bears. Additionally, however, the completely worn milk teeth show that some specimens belonging to one year old individuals have also been found. In table 2, the wear stage categories of the milk canines from Križna jama are given, in reference with those from various other localities.

By differentiating the number of left and right samples of dI³, D⁴ and D₄ we can find the MNI (minimum number of individuals). Thus the MNI of juvenile individuals is approximately 4 to 5 (table 3).

From the analysis of scatter diagrams of L = length and B = breadth of the upper milk teeth from Kj in comparison with *Ursus arctos*, it is noticeable that there is not a remarkable difference between the measurements (Fig. 6, 7 right and left, 8). However, from the measurements of lower milk teeth from Kj in comparison with *Ursus arctos* it is obvious that in *Ursus ingressus* from Kj the measurements are larger than the lower milk teeth of *Ursus arctos* (Fig. 9

right and left). From the ratio diagram (Fig. 10) it can be seen that there is a similarity in the dimensions between the milk carnassials of *U. ingressus* from Križna jama and Loutra Almopias bear cave, as well as of *U. eremus* from Ochsenhalt. It is also noticeable that the D⁴ of *Ursus ingressus* and *Ursus eremus* is smaller in comparison with those of the Middle Pleistocene *U. deningeri* milk carnassials from Herkova jama, while the D₄ is larger.

Morphodynamic Analysis

The milk carnassials D⁴ and D₄ are the most important deciduous teeth in the study of morphodynamic analysis of milk teeth and provide evidence for different stages of bear evolution (RABEDER, 1983, 1999; PAPP, 2010). The evaluation of statistic relevant morphological characteristics on selected elements, first only P4, made it possible to quantify the cave bear evolution (RABEDER, 1983). In recent years through radiometric dating methods, there has been a great advance in showing the benefits

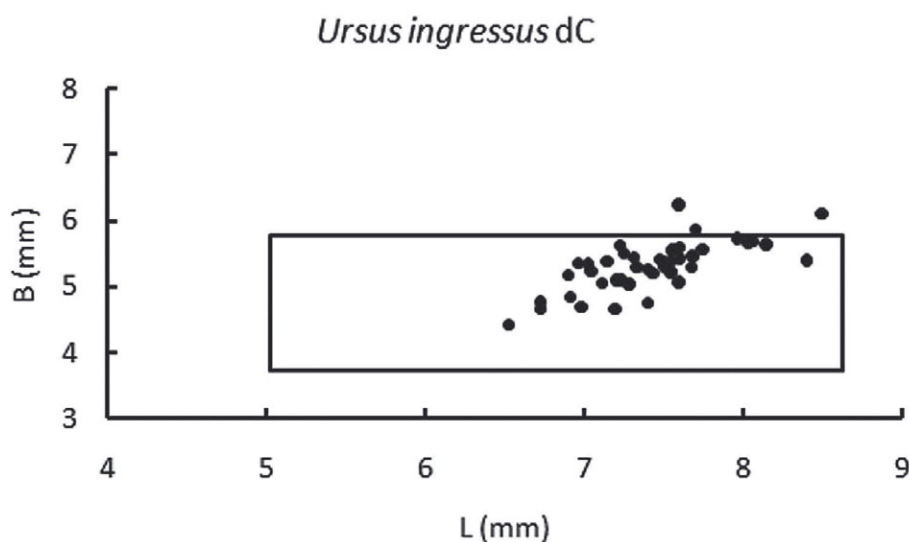


Figure 8: Scatter diagram of L = length and B = breadth of the dC *Ursus ingressus* from Kj and *Ursus arctos* from collections in Moscow (rectangle of a continuous line) (BARYSHNIKOV & AVERIANOV, 1991).

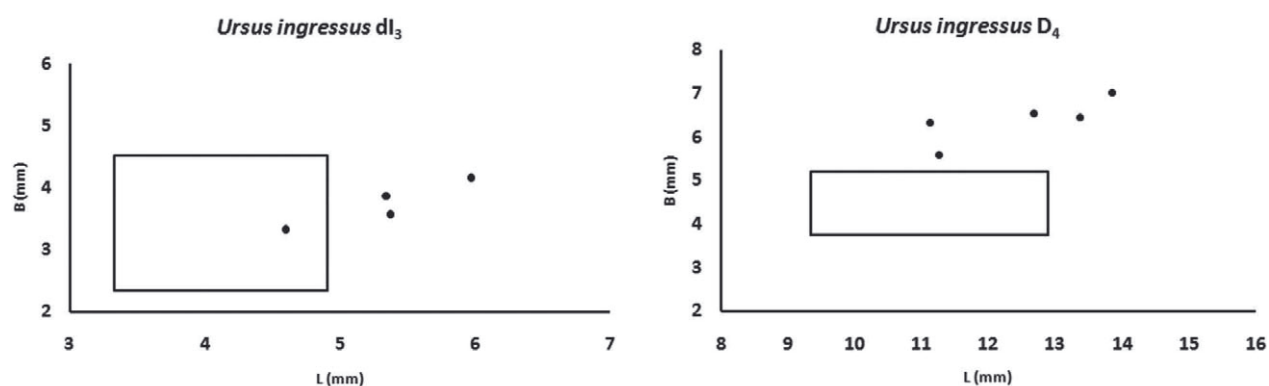


Figure 9: Scatter diagram of L = length and B = breadth of the dI₃ (left) and D₄ (right) *Ursus ingressus* from Kj and *Ursus arctos* from collections in Moscow (rectangle of a continuous line) (BARYSHNIKOV & AVERIANOV, 1991).

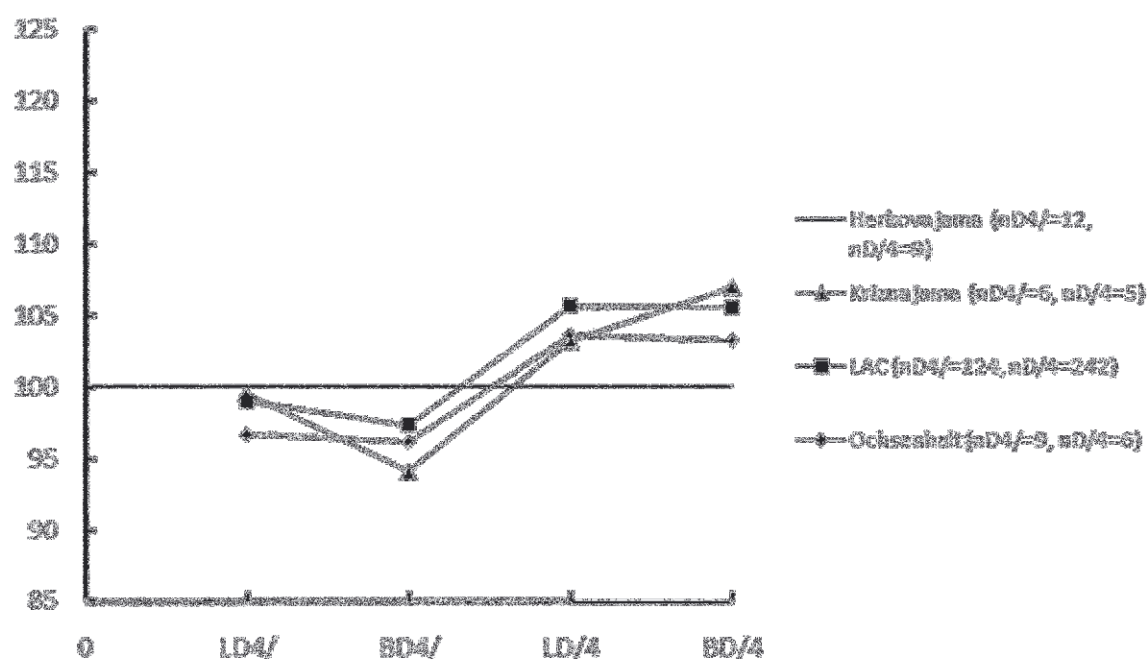


Figure 10: Ratio diagram showing the differences between the standardized Herkova jama: *U. deningeri* (Hj = 100%), comparing the dimensions of the D⁴ and D₄ from various sites. Križna jama: *Ursus ingressus*, Loutra Almopias bear cave *Ursus ingressus*, and Ochsenhalt *U. eremus*.

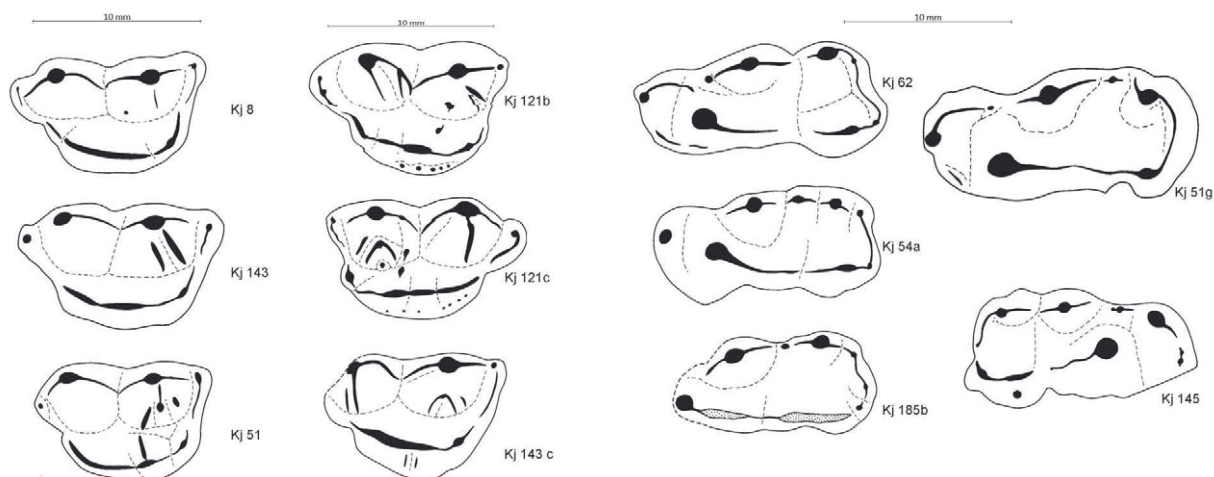


Figure 11: *Ursus ingressus*, Križna jama: morphology of milk carnassials in occlusal views. On the left D⁴ and on the right D₄.

Factor	0	1	2		
Morphotype	A	B	C	n	Morphodynamic Indices
Križna jama <i>U. ingressus</i>	1	5	—	6	83
Gamssulzenhöhle <i>U. ingressus</i>	3	17	1	21	90.5
Herkova jama <i>U. deningeri</i>	7	1	—	8	12.5

Table 4: Categories of morphotypes in milk carnassials D4 and their morphodynamic indices from Križna jama. Compared with morphotypes from Gamssulzenhöhle and Herkova jama (PAPPA, 2010).

Factor	0	0.5	1		
Morphotype	A	B	C	n	Morphodynamic Indices
Križna jama <i>U. ingressus</i>	1	4	—	5	40
Gamssulzenhöhle <i>U. ingressus</i>	9	11	2	22	34.09
Herkova jama <i>U. deningeri</i>	8	1	—	9	5.55

Table 5: Categories of morphotypes in milk carnassials D4 and their morphodynamic indices from Križna jama. Compared with morphotypes from Gamssulzenhöhle and Herkova jama (PAPPA, 2010).

of morphodynamic analysis (RABEDER & NAGEL, 1997). From the morphology of D⁴ we observe that it is similar to M¹. The main difference between these teeth is that in D⁴ the distal cusps take up more surface area than the lingual cusps, so the outline of D⁴ is of a trapezoid shape in contrast to M¹ which is more quadrate. On D⁴ the hypocone is the main cusp (selected element) by which the morphotypes are differentiated. So, the presence or absence of hypocone as well as how robust it is affects the value of the factor assigned to a certain morphotype. With this hypocone reduction, the morphology of D⁴ is closer to M¹. From the different figured occlusal views of D⁴ we can observe in detail the morphology of the tooth and the size of the hypocone. Following the morphology of occlusal surface of this tooth, the next important step is to find the morphodynamic indices. The index of a population corresponds to the mean of the assessed factors multiplied by 100 (RABEDER & NAGEL, 1997; PAPPA, 2010).

The morphodynamic analysis of D⁴ from Križna jama (Fig. 11, left) shows the presence of two morphotypes, A and B. In morphotype A, the hypocone is very well preserved and is very robust (Kj 121c). While in morphotype B there is a hypocone, but it is not so intense. The morphodynamic index is 83 which is closer to morphodynamic index from Gamssulzenhöhle (Austria, *Ursus ingressus*), than to that from Herkova jama (*Ursus deningeri*), which has more specimens with (A) morphotypes (Table 4).

In lower D₄ from Križna jama (Fig. 11, right), the morphodynamic analysis shows more specimens of the (B) morphotype. In this morphotype there are two entoconids which are different in size, and the distal one is smaller than the mesial one. There is also one specimen

in the (A) morphotype category with only one robust entoconid (Fig. 11, right; Kj 62). The morphodynamic index is 40 which is closer to morphodynamic index from Gamssulzenhöhle (Austria, *Ursus ingressus*), than to that from Herkova jama (*Ursus deningeri*) which is 5.55 (Table 5; PAPPA, 2010).

4. Conclusions

- In Križna jama the study of the milk teeth shows the presence not only of unborn bears, but also of year old individuals.
- In the development stage of the deciduous canines, it is noticeable that the most abundant category is the last one (D), in which the root of the tooth has been dissolved completely by osteoclasts. Through this it is possible to estimate the approximate individual age of the animals. The ages depend on the deciduous teeth that were examined.
- The analysis of the scatter diagrams of the length and breadth of all deciduous teeth from Križna jama, in comparison with *Ursus arctos*, shows that there are no remarkable differences between the measurements of the teeth of the upper jaw, nor between deciduous canines. However, in the measurements of lower deciduous teeth it is obvious that *Ursus ingressus* from Križna jama has a larger size than the lower milk teeth of *Ursus arctos*.
- The most important deciduous teeth for applying the morphodynamic analysis are the D4 of the upper and lower jaws.
- Due to corresponding evidence of morphotypes and morphodynamic indices in Križna jama, the main cri-

terion for the identification of morphotypes in D^4 is the hypocone and in D_4 it is the entoconid. The final morphodynamic indices of the Križna jama deciduous teeth are 83% for the D^4 and 40% for the D_4 .

- The morphotype of the milk carnassials from Križna jama is more similar to that from Gamssulzenhöhle (Austria) than that from Herkova jama (PAPPA, 2010).
- The older the material is, the smaller the morphodynamic index. Thus deciduous teeth from Križna jama are almost in the same age as those from Gamssulzenhöhle and much younger than those from the Herkova jama Middle Pleistocene.
- The ratio diagram shows that there is similarity in the dimensions between the milk carnassials of *U. ingressus* from Križna jama and Loutra Almopias bear cave, as well as of *U. eremus* from Ochsenhalt, while all have smaller upper and larger lower carnassials in comparison with those of the Middle Pleistocene *U. deningeri* milk carnassials from Herkova jama.

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