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"THROUGH THE NOSE…" HORSE DOMESTICATION AND PALEOPATHOLOGY

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"It is not doubt but certitude that drives you mad."
Friedrich Nietzsche (1911, 40)

Putting domestic animals to work is known to cause deformations in their skeletons. These changes, however, tend to result from chronic, often lifelong processes whose early symptoms are hard to distinguish from manifestations of normal variability in wild populations. Moreover, variability increased with domestication making the picture even more complex. In this study, the difficulties of quantifying and interpreting one particular feature, indentations on the equine incisive bone, are analysed in a large set of calvaria (41/365 specimens) of extant equids (both wild and domestic) kept in museum collections. The results show that the indentations in question are a feature also occurring in wild equids. While they may be exacerbated by the use of bridles, they cannot be regarded as proof of domestication in themselves. This example selected for study clearly illustrates the uncertainties in the archaeological interpretation of pathological bone lesions.

Keywords: natural variability, wild equids, facial skull, harness, statistical probability

INTRODUCTION

It has long been known that domestic horses were kept in the Carpathian Basin during the Bronze Age and that Eastern cultural influences played a role in the spread of horse use (Bartosiewicz 2011). A more complex scenario emerged when phenotypic differences observed between horses from Botai, Kazakhstan (ca. 3500 BCE) and their more gracile counterparts found at sites of the Sintashta culture, Russia (ca. 2000 BCE) (Косинцев 2002) could be confirmed by aDNA research, outlining a multi-stage process of horse domestication (Orlando 2020). The question is, to what extent were the Central European horse populations descended from eastern ancestors, and to what extent did local European wild horses, still detectable in the Copper Age of the Carpathian Basin (Vörös 1981), influenced their development. This question cannot be answered using morphological research alone.

Because of the importance and popularity of horses, international literature has been rife with articles on the identification of osteological symptoms of horse domestication and use (e.g., Anthony et al. 1991; Levine 1999). Contradictions surrounding this topic are largely rooted in the fact that many 'anthropogenic' deformations may also be found on archaic, that is, wild horses, evidently unaffected by human manipulation (Olsen 2006, 101, Fig. 6). The attention of research has turned to the osteological identification of horse harnessing in later archaeological periods in Hungary as well (Takács 1985, 1994; Jerem 1998; Bárány & Vörös 2023).

Most debates have revolved around the question of whether structural anomalies on early horse skulls are *bona fide*, anthropogenic lesions or fit within the range of normal variability of wild horse populations. Some misinterpretations stem from assuming direct causality between anomalous bone formation and putative human impact, a tendency that was frequently a ruling paradigm during the emergence of modern animal paleopathology (Gandert 1966, 51).

During the analysis of a recently discovered Bronze Age horse calvarium from the environs of Tompa,

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Hungary, Róbert Bozi & Géza Szabó (2022, 114) asserted that "the remodeling observed on the *os incisivus* stands as the earliest example for a horse used for riding or transport in the Carpathian Basin", albeit no changes in the nuchal region (*squama occipitalis*) of the same calvarium – potentially attributable to horse use – could be detected (Bozi & Szabó 2022, 124).

This paper focuses on this type of incisive bone deformation. The results not only exemplify the interpretative difficulties facing animal paleopathology but, relying on the law of large numbers, also point to a methodological approach to alleviate them.

BRIEF RESEARCH HISTORY

Equine calvaria frequently display a characteristic indentation on the dorsal edge of the incisive bone (os incisivum; Fig. 1.A). Standard anatomical textbooks (e.g., Kovács 1967; Fehér 1980; Nickel et al. 1992; Barone 1995) do not refer to this anomaly. Although the usually slight deformation is not particularly striking, it is so characteristic that it even caught the keen eyes of a contemporary Hungarian artist in his naturalistic painting (Fig. 1.B).

In Hungary, this phenomenon was first described by János Matolcsi (1970, 209) in his study of the skeletons of three famous racing horses. In the case of Kincsem, a 14-year-old mare, he noted: "There are traces of mechanical [sic!] damage on the nasal processes of the intermaxillare [syn. *os incisivum*] …. The striking indentations could have been formed *in vivo* …, perhaps as a result of the use of some radical braking bridle." Matolcsi made the same observations on the calvaria of both Buccaneer (30-year-old stallion) and Skipper (26-year-old stallion).

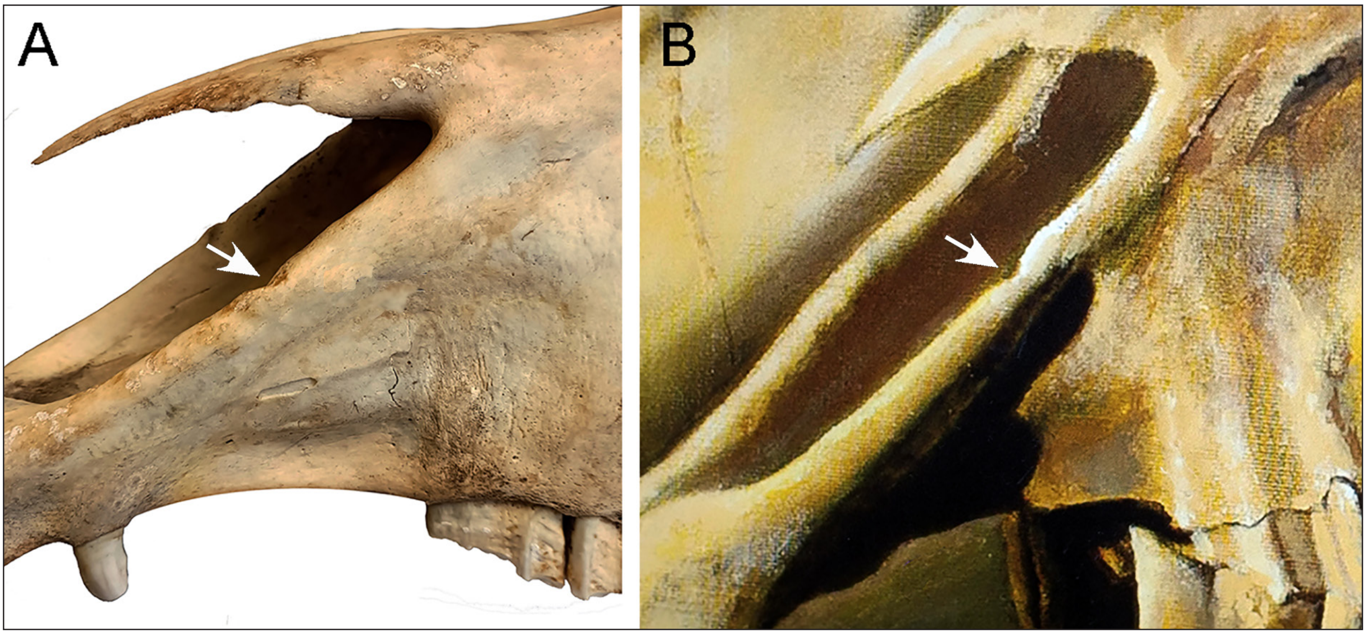

Fig. 1. A, Left lateral aspect of the viscerocranium of a 15 years old stallion (MNHN 2000-358) showing indetations on the incisive bone;. b, Similar indentation on the incisive bone in György Jovián's painting titled "Academic Study III. Still Life with a Unicorn in the Evening"

Since then, two targeted veterinary studies have been dedicated to the detailed anatomical evaluation of this phenomenon. William Pérez & Eduardo Martin (1991), dissected 13 horse heads and studied an additional 31 dry skulls, exploring the soft tissues around the indentation. However, their short article concentrates on key anatomical details, it contains no information on the age and sex of the individuals. It can only be assumed that they most likely studied adult domestic horses. Marleen Vanderwegen & Paul Simoens (2002) dissected the heads of 25 Warmblood horses and studied 55 calvaria of other domestic equids as well as five zebras. Their collection included the macerated skulls of six foals up to 3 months old. By now, indentations have also been noted on the incisive bones of archaeological specimens (Baron 2019, 238, Fig. 199; Taylor et al. 2015; Bozi & Szabó 2022).

THE STUDIED PHENOMENON

The feature under discussion is a more-or-less transversal indentation across the dorso-medial edge of the incisive bone's nasal process (*processus nasalis*). In this work, the neutral term 'indentation' is consistently used, which does not suggest preconceptions concerning origins connected to active agents (as would impression, groove, or notch, for example). Anatomical dimensions of the head are named according to Henle's somewhat simplified directional terminology (Bartosiewicz 2013, 10, Fig. 8).

The sometimes rather deep indentations under discussion tend not to be quite perpendicular to the sagittal plane of the head but close at an angle of 15–25° with it, pointing forward orally on their medial side. Their formation is associated with the activity of the accessory cartilage of the lateral nasal muscle (*musculus lateralis nasi*; Pérez & Martin 1991, 358). Sustained nostril dilation related to heavy breathing causes muscle hypertrophy in the area, stimulating bone remodelling causing the primary indentation. In advanced stages, new bone formation may take place on the orally located rim of this indentation, while, as a result of bone remodelling, osteoporosis may occur at its base. Incipient exostoses mobilize bone material even on the outside of the indentation's rim (*Fig. 2*). This may lead to the formation of a second, lesser indentation, located orally, more along the bone's lateral margin. This latter feature seems associated with the nasal branches (*rami nasalis interni et externi*) of the infraorbital nerve (*nervus infraorbitalis*), which run along the dorsal margin of the incisive bone (Fehér 1980, 642, Fig. 392). Accordingly, based on their longitudinal location along the incisive bone, Vanderwegen & Simoens (2002, 200) distinguished between the two

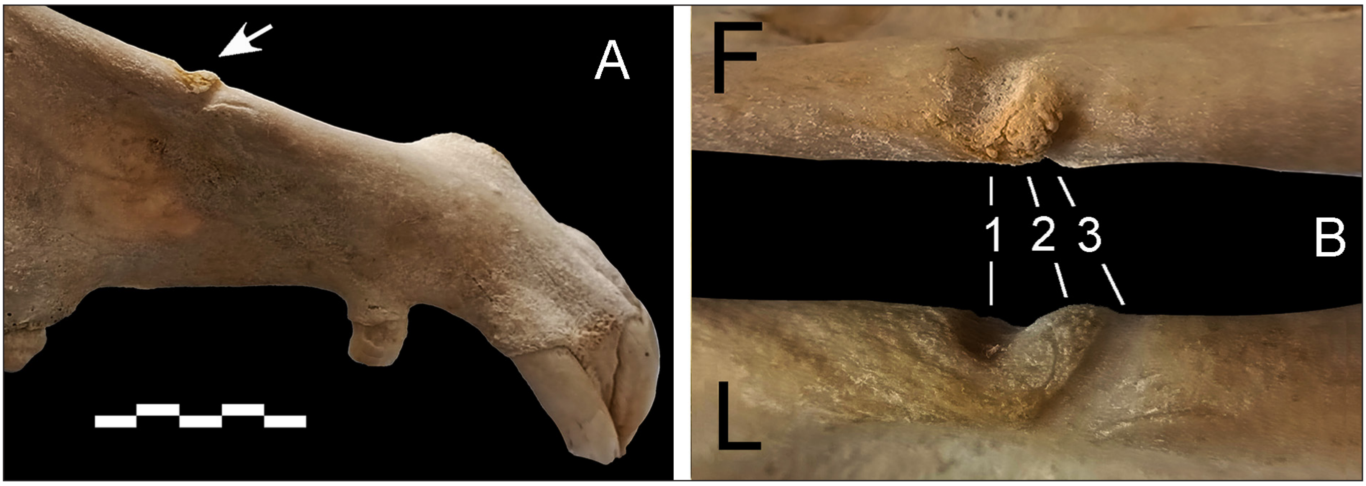

Fig. 2. A, Indentation (arrow) on the right intermaxillary bone of a 18 years old Przewalski stallion (USNM 599842); b, The same indentation in the frontal (F) and lateral (L) aspects, enlarged 3.5x. Legend: 1=aboral (primary) indentation, 2=ridge, 3=oral indentation. Scale=5cm

types as aboral (n=103) and oral (n=32) indentations. They also recorded ten intermediate cases. The latter indicate that the exact relationship between the hypertrophy of the lateral nasal muscle and the position of the infraorbital nerve is unclear. Elucidating the possible causality between the two would require further clinical veterinary research, far beyond the scope of the current study.

Although the skeleton forms the passive basis of the locomotor system, it is also a living organ displaying remarkable plasticity. Bones have an inherited capacity to adapt to various stimuli in the natural and socio-cultural environments in subtle ways. The following questions were posed:

1. Is the hypothesis correct that indentations on the incisive bone occur exclusively in domestic equids?
2. To what extent can the phenomenon be considered pathological?

In paleopathology, single finds, such as the horse calvarium from Tompa, can only be scientifically interpreted against the backdrop of patterns observed across a broad range of observations made on verifiable reference individuals (Bartosiewicz 2013, 33). I set out to analyze the zoological background to the phenomenon using a series of calvaria from extant horses kept in museum collections.

RESEARCH MATERIALS

To test the hypothesis that this deformation is caused by the way horses put to work, I conducted a quantitative analysis of 365 wild and domestic equine calvaria in two large museum collections: the Muséum National d'Histoire Naturelle (MNHM) in Paris and the Smithsonian National Museum of Natural History (USNM) in Washington DC.

In order to answer the research questions, an important distinction needs to be made between wild and domesticated equids (*Table 1*). The complexity and uncertainties regarding the taxonomy of past and present equids (Groves & Bell 2004; Geigl & Grange 2012; Pedersen et al. 2018) is also reflected by the ever-changing scientific nomenclature. However, I adhered to the Latin names used in the museum records to enhance the transparency of the current work.

The level of detail in these records varied both between institutions and throughout their histories. The exact origin of the calvaria of taxonomically wild equids could therefore not always be identified. This information would have been of interest in drafting the animals' individual life histories, potentially shedding light on their health status. Some calvaria were documented to have originated from zoo specimens, although the vast majority of zebras were acquired on location in Africa through hunting. Przewalski horses represent a special case:[2] although they are considered genuine Mongolian wild horses, the key to their preservation was the registration and breeding of zoo specimens. However, neither of the two major collec-

Taxon		**P**	**W**	**Összes**
Háziló	*E. caballus* Linnaeus, 1758	48	42	90
Háziszamár	*E. asinus* Linnaeus, 1758	25	8	33
Öszvér	*E. caballus x asinus*		7	7
Grévy-zebra x Háziló	*E. asinus x grevy*		6	6
Háziszamár x Grévy-zebra	*E. grevy x caballus*		1	1
Lóféle	*E. sp.* Linnaeus, 1758	6		6
Házi összesen	Domestic total	**79**	**64**	**143**
Przewalski ló	*E. caballus przewalskii* Poliakov, 1881	17	8	25
Alföldi zebra	*E. burchellii* Gray, 1824	14	12	26
Burchell-zebra	*E. burchellii antiquorum* Smith C. H., 1841	5	3	8
Böhm-zebra	*E. burchellii boehmi* Matschie, 1892	12	64	76
Chapman-zebra	*E. burchellii chapmanni* Layard, 1865		6	6
Grévy-zebra	*E. grevyi* Oustalet, 1882	12	21	33
Hegyi zebra	*E. zebra* Linnaeus, 1758	4	4	8
Hartmann hegyi zebra	*E. zebra hartmannae* Matschie, 1898	8	1	9
Onager	*E. hemionus* Pallas, 1775	15	6	21
Kiang	*E. kiang* Moorcroft, 1841	2	6	8
Kvagga	*E. quagga* Boddaert, 1785		2	2
Vad összesen		**89**	**133**	**222**
Összes		**168**	**197**	**365**

Table 1. Materials studied in the MNHN (Paris: P) and USNM (Washington: W) collections

[2] The mare MNHN 1932-46 was also included in this group based on the note '*sauvage*' found on its label.

tions had the source of their Przewalski calvaria specified. Nevertheless, one may assume that only exceptional individuals among these wild equids were put to work by humans, one of the putative factors in the development of incisive bone indentations. Forty-one of the 365 equine calvaria examined showed varying degrees of change on the incisive bones. They formed the basis of these detailed examinations.

METHODS

Due to the historical inconsistency of sometimes incomplete museum records, I estimated the ages of the 41 affected individuals based on their dentition (Silver 1969, 293–294; Ócsag 1976, 375–377; Jones et al. 2014), whenever information on age was undocumented. Likewise, I identified sex as female or male/castrate based on the absence (mare) or presence (stallion/gelding) of canine teeth.

In line with the scientific protocols of quantitative evaluation, conclusions can be drawn by considering at least two characteristics of the results: the probability of occurrence (significance level: p□0.05) and the strength of the relationship between phenomena (correlation coefficient: between -1 and +1). For the sake of simplicity, I have carried out non-parametric calculations (Welkovitz et al. 1971, 239–240; Williams 1979; Hammer 2020) for testing the research hypothesis stated in this study.

RESULTS

The museum assemblages are not only taxonomically heterogeneous but also represent over a century-long collection and acquisition work in four continents. Therefore, they are unsuitable for assessing prevalence in a clinical sense: such a mixed material does not reflect the proportion of affected individuals in a population at a given time (Bartosiewicz 2013, 9). Nevertheless, it is still worthwhile to see the relative frequency of the indentations of the incisive bone in wild and domesticated equids in the pooled comparative material.

Among the individuals examined, indentations of varying degrees were found on 41 specimens. That is, the anomaly was observed in less than one eighth (11.2%) of the pooled museum materials (*Table 2*). In the combined equine assemblages from the two museums, the female:male/gelding ratio among wild equids was 8:7 and among the domestic forms 15:11, indicative of a homogeneous distribution (χ^2=0.073, p=0.787, df=1). A study of over a million mammals in six major natural history museums (Cooper et al. 2019, 6) showed a slight predominance of males, as larger or more ornate males (e.g., maned lions, antlered stags) were likely to have been collected preferentially over time. This tendency is not evident in equids because sexual dimorphism is not expressed in size, shape, or coloration. The observed proportions suggest that the predominance of either sex influences the representation of wild and domestic variants in the study material.

Taxon	n
Háziló	17
Háziszamár	4
Öszvér	4
Háziló x Grévy-zebra	1
Házi összesen	26
Przewalski ló	5
Zebra	7
Kiang	1
Kvagga	2
Vad összesen	15
Összes	**41**

Table 2. Specimens displaying indentations in the MNHN+USNM collections

A previous study on 85 equid calvaria suggested that this type of remodelling may be absent in wild equids (Vanderwegen & Simoens 2002, 201, Table 2). However, the latter group was represented by a mere five zebras in that comparative assemblage. Therefore, it is particularly important from the viewpoint of this study that both domestic and wild equids occur among the 41 individuals that developed indentations on the incisive bone. This suggests that the phenomenon cannot be attributed exclusively and unambiguously to domestication

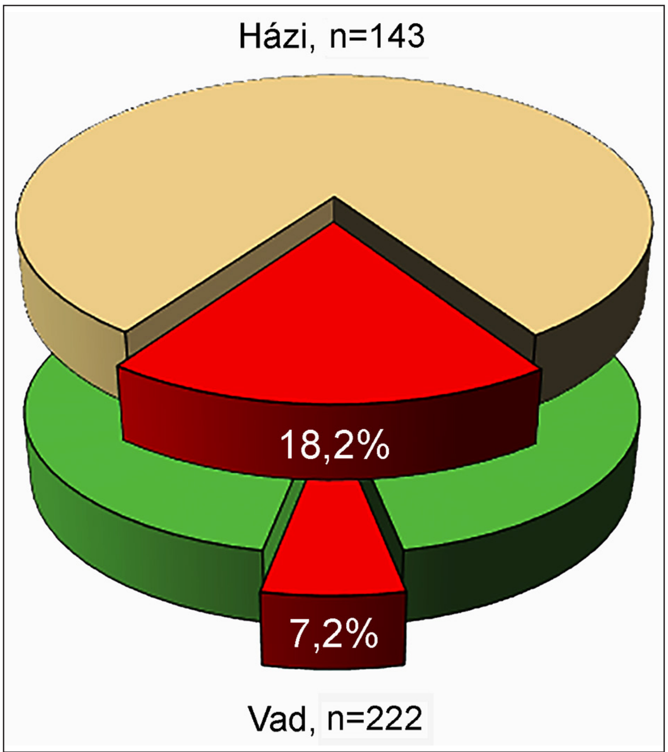

Fig. 3. The proportion of specimens displaying indentations in the pooled MNHN and USNM collections

or the human activities that accompanied it. At the same time, indentations on the equine incisive bone (regardless of their degree) tend to be more common among the domestic varieties (*Fig. 3*). The probability and strength of the difference in percentages shown in the pie charts can be statistically verified. The fewer indentations identified among the wild varieties can be easily detected by the naked eye (*Table 3*). The result of the χ^2 test confirms that the difference is significant; its probability is very high. However, the φ value, which can be interpreted according to the degrees of Pearson's correlation, is very low: below 0.200, the correlation between the

	Házi	Vad	Összes
ép	117	207	324
bemélyedt	26	15	41
Összes	**143**	**222**	**365**
χ^2=11,386, szabadságfok=1, ϕ=0,176, p=0,000			

Table 3. Testing the distribution of indentations in wild and domestic equids

occurrence of the indentation and the wild/domestic state of the individuals classifies as weak, almost negligible (Williams 1979). The deformation of incisive bones, thus, should not be considered an irrefutable proof of working horses.

The unexpected occurrence of indentations in several wild equids warns that the question deserves further scrutiny. Harnessing clearly cannot be considered the sole reason behind this anomaly. A Kolmogorov-Smirnov test for equal distributions carried out on the 41 affected individuals showed that their age distribution with great probability coincided with that of the indentation scores (p=0.001, D=0.980). Therefore, an additional hypothesis concerning the effect of the wild/domestic age difference also had to be tested in formal statistical terms.

However, before additional calculations can be carried out, a critical review of the age composition of the material is essential. The average age of the 26 domesticated equids studied was 12.1 years, while that of the 15 wild equids was only 9.5 years. The 2.5 years age difference between the two groups was not statistically significant (p=0.089). However, the distribution of wild individuals shows an asymmetric, *quasi* 'L'-shaped pattern (*Fig. 4*), typical of the age structures of live populations (Discamps & Costamagno 2015): in spite of originating from two different institutions, hunting seems to mimic the results of random sampling in the wild. The only difference is the notable absence of very young individuals (a usually marked vertical element of 'L'), rarely targeted by hunters. In comparison, the age

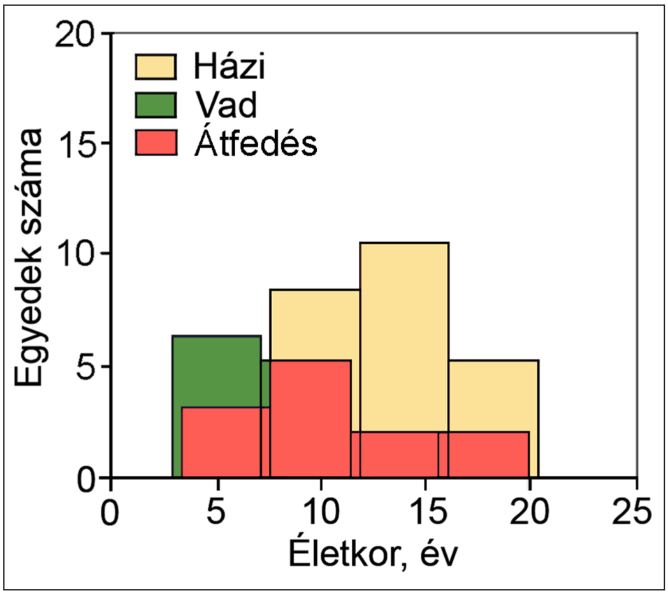

Fig. 4. Differences between the age distributions of wild and domestic equids among the 41 individuals showing indentations.

distribution of domesticated equids in *Fig. 4* suggests that most of the collected individuals reached the end of their useful life well after ten years of age, as there were many older individuals. The oldest specimens originated exclusively from domesticated forms, presumably thanks to the better care that domestic animals receive. In general, foals were extremely rare in the entire material, appearing almost only as curiosities. Some half dozen specimens included among the 365 studied skulls showed no indentation on the incisive bone. During previous research, out of six foals, shallow aboral indentations were found on the skulls of two individuals of unspecified breeds (Vanderwegen & Simoens 2002, 200).

Taylor et al. (2015, 863) found that, in terms of the mean depth of the indentation, wild equids were likely to show lower mean values than working individuals, even after correcting for age ($p<0.01$). However, this value is still age-dependent ($p<0.01$), although age explained only part of the variance ($r=0.424$), indicative of a substantial relationship. When I calculated the coefficient of Spearman rank correlation between the age and the scores of indentations of the 41 individuals under discussion, the value obtained was almost identical ($\rho=0.409$, $p=0.005$). The results of observations made on these two very different sets of calvaria using different methods support each other: the development of indentations is significantly influenced by age. Both coefficients are indicative of a moderate but substantial relationship.

DISCUSSION

According to Bozi & Szabó (2022, 113, Fig. 4), the incisive bone of the Bronze Age horse from Tompa showed a vital reaction, a local response to bone tissue damage. This term prejudices the anomaly as originating from trauma. In that case, subperiosteal ossification could be expected, linked to the contusion of soft tissue, causing localized irritation, and even provoking inflammation. It seems that on this point of the equine incisive bone various degrees of bone remodelling result in slight elevations paralleling the shallow indentation. These seem to shelter the nerve and associated blood vessels from compression (Pérez & Martin 2001, 358). However, the exact source of the stimulus remains uncertain.

Since its first description, the feature has been tentatively linked to the hypertrophy of nasal musculature in heavily used racing horses (Matolcsi 1970), and current investigations have also pointed to prolonged pressure by bridle equipment contributing to the condition (Taylor et al. 2015). In accordance with proper differential diagnosis, Bozi & Szabó (2022, 115) also consider possible endogenous causes for the occurrence of indentations. The most important of these is obstructed breathing, which causes hypertrophy of the lateral nasal muscle, eventually compressing the branches of the infraorbital nerve and thereby affecting the bone surface. This may be due to chronic airway obstruction (heaves: Rush & Grady 2008, 198) or inflammatory airway disease (Couëtil et al. 2016). Innervation disorders of the larynx (*hemiplegia laryngis*), most common in high-performance sport horses and English Thoroughbreds, are often manifested on the left side (Karsai & Vörös 2002). However, a recent study on the asymmetry of indentations on the equine incisive bone linked the difference to styles in bridle use/riding (Taylor & Tuvshinjargal 2018, 144–145).

CONCLUSIONS

The minute paleopathological study of excavated animal remains may reveal osteological anomalies created by processes that might have turned pathological but were inconsequential in the living animal. On the other hand, the root causes of osteological lesions may also be difficult to diagnose due to the limited range of responses by the bone tissue. Therefore, the outcome and osteological appearance of various conditions may look the same (equifinality). Based on the analysis of the 365 horse skulls in museum collections, the following answers can be given to the questions posed in this paper:

1. The indentation of the incisive bone occurs in both wild and domesticated equids; therefore, its presence alone cannot be seen as unambiguous evidence of domestication or use.
2. Indentations on the incisive bone cannot considered *ab ovo* pathological. A significant part of these anomalies remains within the boundaries of normal variation, although extreme cases may be indic-

ative of a pathological condition. In addition to age, the factors causing deformation may be respiratory diseases. Excess work performed by domestic horses may exacerbate the symptoms but remains inseparable from the natural factors.

As a tendency, overworking domestic horses may contribute to the development of indentations on the incisive bone. However, this anomaly is the outcome of a complex, multifactorial process whose components include natural variability and age. The well-known archaeological evidence of Bronze Age bridle cheek pieces made from red deer antler tines found in the Carpathian Basin (Bökönyi 1953; Mozsolics 1953) and studded antler disk bridles used further east (Генинг et al. 1992, Pl. 26) have offered a far more reliable evidence of Bronze Age horsemanship. Among the rare paleopathological finds, the disfigured diastema of a Middle Bronze Age horse mandible from Hungary (Bartosiewicz 2022, 75, Fig. 3.) was likely deformed by a rope-bridle. The extent of this lesion far exceeds the highest score used in describing this type of trauma (Bendrey 2007, 1044, Fig. 7/4).

Another issue surfaced during the analysis of the reference material that so far remains unresolved. Until recently, interpretations have focused on the environmental reasons behind this phenomenon, with a particular emphasis on domestication and horse use. In the absence of targeted genetic studies, we possess no information on the possibility of inherited predisposition (drift, hybridization) on the formation of indentations on the incisive equine bone.

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