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Anomalies and pathological changes of skulls and dentition of wild small mammal species from Germany

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Abstract. Skulls, jaws and teeth of wild terrestrial small mammals (Sciuridae, Soricidae, Erinaceidae, Talpidae, Gliridae, Arvicolidae, Muridae) are occasionally affected by anomalies and pathologies. The present study documents a total of 362 anomalies and 122 pathological changes across 20 different species. These are all based on data published in Germany, supplemented by our own records. Cases were classified into 14 different categories, according to bone and dental anomalies, fractures and inclusions, bone proliferation, dental disease and extreme wear of teeth. An additional category to specifically account for bone proliferation of the skull was not needed, but such findings are to be expected. The most frequent finding was abnormal tooth growth, particularly the elongation of the upper incisors. In individual cases, there was evidence that small mammals are able to recover even from serious injuries to the skull.

Key words: anomaly, pathology, skull, teeth

Introduction

Intra-specific morphological diversity comprises a normal range of phenotypic variability, but also includes marked deviations from this norm. These deviations can be attributed to pathological changes, anomalies, and the effects of disease and are a feature of all species. Despite their ubiquity, there are no uniform scientific rules for the concepts of abnormality and malformation of phenotypic traits; on the one hand, these constitute flexible transitions, and on the other, represent characteristics that are part of normal variation in one population but potentially constituting an anomaly in another (Miles & Grigson 1990). From this perspective, it is important to give recognition to such pathological anomalies and disease, and also to understand them as part of natural phenotypic variation.

Pathologies and abnormal structures are common in the animal kingdom and, in wild and domestic animals, may also affect different parts of the body, including the skulls, jaws and teeth (Hamar 1970,

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Gräfner 1986, Miles & Grigson 1990, Baumgärtner & Gruber 2015, Böhmer 2015, Stephens et al. 2018). A comprehensive work on the variation and disease of mammalian teeth does exist (Miles & Grigson 1990), though small mammals are comparatively underrepresented. Altogether, there has been relatively little research on this subject, and publications generally discuss only single cases or small samples and do not always specify observations (e.g. Johnson 1952, Mohr 1954, Buchalczyk 1961, Miyao & Mori 1969, Steinborn & Vierhaus 1984, Gräfner 1986, special section of this paper).

Here, we compiled all data published on this subject in Germany, supplemented with our own findings. The results were categorized to provide an overview of the variation in anomalies and pathologies in small mammals. Variability, such as those observed in the molar roots of Muridae (e.g. Robel 1971) and in molar patterns of Arvicolidae (e.g. Wolf et al. 2003, Kapischke et al. 2009), were not included.

1 Anomalies (362)	2 Pathologies (122)
1.1 Bone anomaly (31)	2.1 Fractures/inclusions (27)
1.2 Dental anomaly (330)	2.1.1 Skull except jaws (3)
1.2.1 Tooth position (30)	2.1.2 Jaw (5)
1.2.2 Tooth growth (146)	2.1.3 Teeth (19)
1.2.3 Absent or supplementary teeth (144)	2.2 Bone proliferation (28)
1.2.4 Fusion of teeth (1)	2.2.1 Skull except jaws (0)
1.2.5 Other maldevelopments (10)	2.2.2 Jaws (28)
	2.3 Dental diseases (50)
	2.3.1. Enamel abrasion (9)
	2.3.2. Atrophied teeth (36)
	2.3.3 Caries (5)
	2.4 Extreme wear of teeth (Abrasio dentium) (17)

Fig. 1. Anomalies and pathologies of skulls and teeth of small mammals from Germany: classification and total number of phenomena independent of the number of animals investigated (literature and own observations).

Material and Methods

We limited our research to corresponding structures on the skulls, jaws and teeth of wild terrestrial small mammals, obtained mostly from owl pellets. The material was analysed for the presence of anomalies and pathological changes, and the phenomena identified were photographically documented. The material primarily came from the collections of Jentzsch, Kapischke, Kraft and Wolf, supplemented by additional records from publications and unpublished data from other authors. Classification, based on the location of the changes (skull, jaws, teeth) and the type of variation (Fig. 1) was based on Miles & Grigson (1990). For the classification of extreme tooth wear, we referred to Renaud (2005) and Steiner (1967). Extreme tooth wear was recognised when all molars have been worn down to the roots or showed a minimum residual of tooth crowns.

In many cases, if multiple anomalies and/or pathological changes were found in a single animal, items could be assigned to more than one classification. All of these features were individually documented, regardless of any mutual dependency, and the associated categories were additionally marked with "+ #", where # represents the corresponding ordinal number from Fig. 1. Faunistic clues appear only once, each under the first mention of a specimen, and similar findings were summarized to the greatest extent possible. The order and nomenclature of the species is based on Angermann & Hackethal (1995). A detailed specification of the genera *Mus* and *Arvicola* has not been conducted.

The following abbreviations have been used: LJ – lower jaw, UJ – upper jaw, Proc. – processes, spc. – specimen/s, BB – Brandenburg, BW – Baden-Wuerttemberg, BY – Bavaria, MV – Mecklenburg-Western Pomerania, NRW – North Rhine-Westphalia, SH – Schleswig-Holstein, SN – Saxony, ST – Saxony-Anhalt. Unless otherwise stated, the phenomena described are single specimens, and the skulls are stored in the collections of Jentzsch, Kapischke, Kraft or Wolf. Photographs were taken by R. Kraft (photo print from diapositive, Figs. 2-6) and M. Kunath (Figs. 7-15).

Results

Based on data from the literature and own observations of individual specimens from 20 small mammal species in Germany, a total of 362 anomalies and 122 pathological changes were documented. These phenomena can be assigned to 15 different categories; of these, 14 have been recorded (Fig. 1).

Table 1. Small mammal species and type of anomalies and diseases of skulls in Germany (explanation of numbers see Fig. 1).

Species	1.1	1.2.1	1.2.2	1.2.3	1.2.4	2.1.1	2.1.2	2.1.3	2.2.2	2.3.1	2.3.2	2.3.3	2.4
Erinaceus europaeus						•							
Talpa europaea				•									
Sorex araneus	•			•			•	•	•				•
Neomys fodiens	•						•						•
Crocidura russula	•	•		•			•	•		•			
Crocidura leucodon				•									
Sciurus vulgaris			•						•				
Muscardinus avellanarius		•	•										
Rattus rattus	•												
Rattus norvegicus	•												
Apodemus sylvaticus	•		•										•
Apodemus flavicollis	•	•	•		•								•
Apodemus agrarius			•						•				
Apodemus spec.	•												
Mus spec.			•	•									
Cricetus cricetus			•										
Ondatra zibethicus	•		•	•		•	•		•				
Myodes glareolus	•					•							
Arvicola spec.			•	•					•		•		
Microtus agrestis		•	•	•				•	•				•
Microtus arvalis	•	•	•	•			•	•	•	•	•	•	•
Total number of species	11	5	11	9	1	3	5	4	7	2	2	1	6

Table 1 provides an overview of the assignment of occurrences in individual small mammal species. No. 115, the common shrew, exhibited five different phenomena, the maximum number found in a single specimen. The most frequently observed phenomena were excessive tooth growth and deviations from the normal number of teeth.

Special section

Order Eulipotyphla

Family Erinaceidae

European hedgehog *Erinaceus europaeus* Linnaeus, 1758

2.1.1 Fractures/inclusions (skull excluding jaws)

Wolf (2017): Healed fracture in the central area of the cranium in the contact area of crista sagittalis and crista orbitalis (1♂, 13.7.2013, Leipzig-Plagwitz, SN).

Family Talpidae

European mole *Talpa europaea* Linnaeus, 1758

1.2.3 Dental anomaly (absent or supplementary teeth)

Stein (1963): 32 ♂♂, 9 ♀♀ with one or two supplementary premolars, 3 ♂♂, 1 ♀ with missing premolar in the LJ, 3 ♂♂ with supplementary premolars, 13 ♂♂, 3 ♀♀ with missing premolars in the UJ (1949-1962, Fürstenwalde, BB).

Family Soricidae

Common shrew *Sorex araneus* Linnaeus 1758 (Figs. 2, 3)

1.1 Bone anomaly, morphology

Maternowski (2015): Proc. coronoideus (right LJ) proximally turned (11.03.2013, Rheinau-Hohbühn, BW).

Own observations:

No. 55: Right Proc. condylaris significantly abbreviated + # 2.4 (03.08.2008, Ossig, ST) (Fig. 3A).

No. 59: Proc. coronoideus of left LJ proximally turned, right LJ and skull not available (25.03.2003, Saalkreis, ST, leg. Jentzsch) (Fig. 3B).

No. 115: Alveoli partially fused + # 1.2.3 + # 2.1.2 + # 2.1.3. + # 2.2.2 (Wallerfing, BY, col. Bavarian State Collection of Zoology Munic).

1.2.3 Dental anomaly (absent or supplementary teeth)
Own observation:
No. 115: M_1 and M_2 missing + # 1.1 + # 2.1.2 + # 2.1.3 + # 2.2.2 (Fig. 2).

2.1.2 Fractures/inclusions jaw
Own observations:
No. 115: Completely healed fracture of corpus of right LJ (Fig. 2).

2.1.3 Fractures/inclusions (teeth)
Own observation:
No. 115: I_1 broken at base # 1.1 + # 1.2.3 + # 2.1.2 + # 2.2.2.

2.2.2 Bone proliferation (jaws)
Own observation:
No. 115: Right LJ, ventral bulge and porous surface, several openings along a recessed vertical cavity + # 1.1 + # 1.2.3 + # 2.1.2 + 2.1.3.

2.4 Extreme abrasion of the teeth (Abrasio dentium)
Own observation:
No. 55: I_1 of the right and left LJ worn-out near alveolus + # 1.1 (Fig. 3A).

Eurasian water shrew *Neomys fodiens* (Pennant 1771) (Fig. 4)
1.1 Bone anomaly, morphology
Own observations:
No. 60: Right Proc. postglenoidalis not helically curled, but clearly widened (16.02.2007, Wilster/Rumfleth, SH).
No. 61: Both indentations of the spirally rolled Proc. postglenoidalis formed as continuous holes (19.01.2008, Langenklint, SH).
No. 62: Crooked rostrum, turned to the left (23.02.2008, Gaarz, BB).

2.1.2 Bone proliferation (jaws)
Own observation:
No. 118: Proc. coronoideus with exostosis + # 2.3.1 + # 2.4 (Notzing, BY, col Bavarian State Collection of Zoology Munic) (Fig. 4).

2.3.1. Enamel abrasion
Own observation:
No. 118: I_1 with enamel limited to the tip, dentin medially reduced + # 2.4 + # 2.1.2.

Fig. 2. Common shrew No. 115. Completely healed fracture of corpus of right LJ and absence of M_1 and M_2.

Fig. 4. Eurasian water shrew No. 118. Proc. coronoideus of left LJ with exostosis (below), right LJ with normal expression (above).

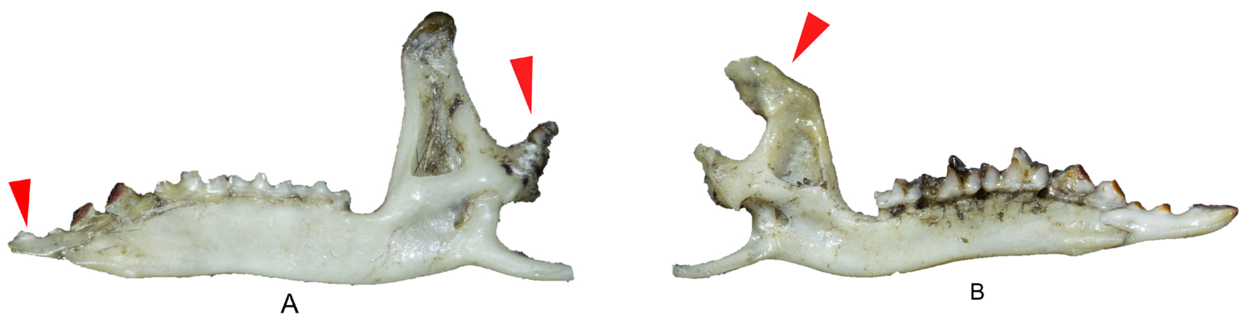

Fig. 3. Common shrew No. 55. Right LJ with shortened Proc. condylaris and worn-out I_1 (A). Common shrew No. 59. Left LJ with a Proc. coronoideus proximally deflected (B).

2.4 Extreme abrasion of the teeth (Abrasio dentium)
Own observation:
No. 118: I_2 und P_4 heavily worn+ # 2.1.2.

Greater white-toothed shrew *Crocidura russula* (Hermann, 1780) (Figs. 5, 6)
1.1 Bone anomaly, morphology
Own observations:
No. 120: Left LJ, exostosis at the upper edge of the Proc. coronoideus + # 2.3.1 (Roßstadt, BY, col. Bavarian State Collection of Zoology Munic).
No. 121: Left LJ, exostosis in anterior third of the corpus, including the alveolus of I_1 + # 1.2.3 (Sonnefeld, BY, col. Bavarian State Collection of Zoology Munic) (Fig. 5).

1.2.1 Tooth anomaly (tooth position)
Kraft (2002): As a result of the fracture both I^1 each ventrally inclined 45° + # 2.1.3 (Löffelsterz, BY).

1.2.3 Dental anomaly (absent or supplementary teeth)
Borkenhagen (2011): Missing teeth (P^2, P^3, M^3 for 51 out of 151 animals) (SH).
Kapischke & Lange (2010): Supplementary antemolar in the left UJ (19.03.2008, Mechau, ST).
Own observations:
No. 63: Left UJ, supplementary antemolar (2001-2004, Stollberg, SN, leg. K. Wetzel).
No. 64: Left UJ, missing P^4, instead there is one pin tooth or two pin teeth (2 spc., 1992, Trainau/Lichtenfels, BY, col. Bavarian State Collection of Zoology Munic).
No. 121: Missing I_2 and P_4 + # 1.1 (Fig. 5).

2.1.2 Fractures, inclusions (jaw)
Own observations:
No. 119: Left LJ with—transversal fracture, presumably caused by osteomyelitis; healed resp. body of mandible bridged by ventral callus formation, roots of M_1 and M_2 partially exposed in the area of the fracture gap, mandible body with larger visible cavities (X-ray image), from M_2 a strip-like compression extends diagonally backwards/downwards (possibly dead sequestra) (Schottenstein, BY, col. Bavarian State Collection of Zoology Munic) (Fig. 6).

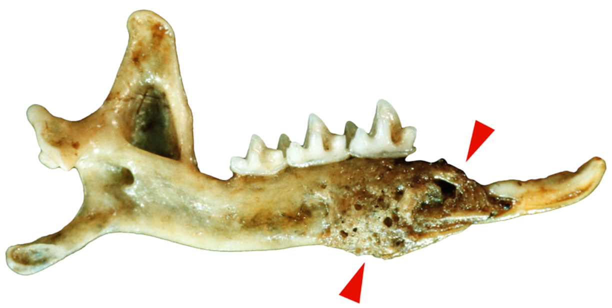

Fig. 5. Greater white-toothed shrew No. 121. Exostosis in anterior third of the corpus, including the alveolus of I_1. Missing I_2 and P_4.

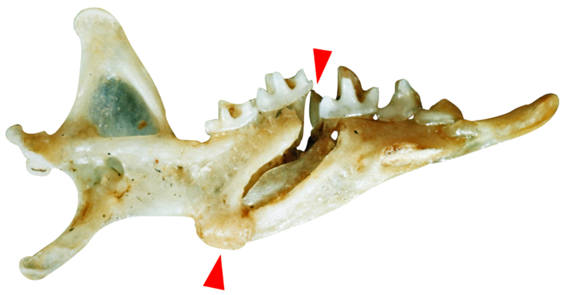

Fig. 6. Greater white-toothed shrew No. 119. Transversal fracture of the mandible, corpus of mandible ventrally bridged by callus formation.

2.1.3 Fractures/inclusions (teeth)
Kraft (2002): Loss of mandible tips of both LJ, presumably through injury, right in front of the premolars, root stumps of the I_1 are still in the mandible body, scarped ridges of the break lines show callus formation + # 1.2.1.

2.3.1 Enamel abrasion
Own observation:
No. 120: I_1 with a conspicuous notch at the upper edge + # 1.1.

Bicoloured shrew *Crocidura leucodon* (Hermann, 1780)
1.2.3 Dental anomaly (absent or supplementary teeth)
Own observation:
No. 66: Left P^2 greatly enlarged, P^3 missing, abnormal pigmentation of the coat (Taucha, SN, Kapischke 2007).

Order Rodentia
Family Sciuridae
Eurasian red squirrel *Sciurus vulgaris* Linnaeus, 1758
1.2.2 Tooth anomaly (tooth growth)
Butzeck (1988): Left I_1 arching several centimetres to the left, tip touching on the left side, strongly inflamed eyeball. Pupil screwed into orbita and apparently without function, eyelid also inflamed + # 2.2.2 (1 ♀, wild living, 23.02.1987, zoo Cottbus, BB).

2.2.2 Bone proliferation (jaws)
Butzeck (1988): severe exostoses and callus formation in the lower jaw area after chronic periodontium suppuration. The animal also showed an indentation of the facial skull in the nasal region medially and an asymmetrical pelvic structure, for which the authors assume traumatic causes + # 1.2.2.

Family Gliridae
Hazel dormouse *Muscardinus avellanarius* (Linnaeus, 1758)
1.2.1 Tooth position
Schulze (1987): Growth of I^1 of UJ sideways to the right passing LJ, both I_1 seem to have forced away the antagonists in UJ + # 1.2.2 (1 ♀, Hand capture, 21.10.1972, Südharz, ST).

1.2.2 Tooth anomaly (tooth growth)
Schulze (1987): All I show elongated growth, which led to injuries due to the malpositioning: lower I scraped the palate down to the bone and led to ulcerated wounds, right I^1 injured the tip of the tongue and the gingiva in the area of both I_1, animal was apathetic and emaciated + # 1.2.1.

Family Muridae
Black rat *Rattus rattus* (Linnaeus 1758)
1.1 Bone anomaly, morphology
Becker (1966): Both spc. each with nose bent to the left and the right, respectively (offspring of wild catch, March 1948, Liepe, BB).

Brown rat *Rattus norvegicus* (Berkenhout, 1769)
1.1 Bone anomaly, morphology
Becker (1966): Nose bent to the right or the left ("bent nose") (2 spc., offspring of wild caught specimen, Berlin-Dahlem).

Wood mouse *Apodemus sylvaticus* (Linnaeus, 1758)
1.1 Bone anomaly, morphology
Goethe (1955): At the position of one M^2, only three alveoli (tooth not developed? Heiden, NRW, leg. Zippelius).

1.2.2 Tooth anomaly (tooth growth)
Schmidt (1991): Elongated, strongly backward curved I_1 due to heavy wear of the I^1 in the LJ (02.11.1987, Sauen near Beeskow, BB).

2.4 Extreme wear of the teeth (Abrasio dentium)
Renaud (2005): Molars worn down to the roots or showing minimal crowns (14 spc., 1957-1974, northern Germany).

Yellow-necked mouse *Apodemus flavicollis* (Melchior, 1834) (Fig. 7)
1.1 Bone anomaly, morphology
Own observation:
No. 56: Right LJ, Proc. condylaris not developed, Ramus mandibulae strongly reduced and laterally dented rostrum due to elongated I_1 + # 1.2.2 (29.09.2007, Annaburg, ST, leg. K. Nehring) (Fig. 7A).

1.2.1 Tooth position
Own observation:
No. 108: Right M_3 outside the normal tooth row and shifted in direction of I_1 + # 1.2.2 (26.12.2011, Magdeburg, ST).

1.2.2 Tooth anomaly (tooth growth)
Own observations:
No. 56: Elongated I^1 and I_1 in all jaws, with right I^1 protruding above the mandible body in the area of the diastema, I_1 laterally pressed against the

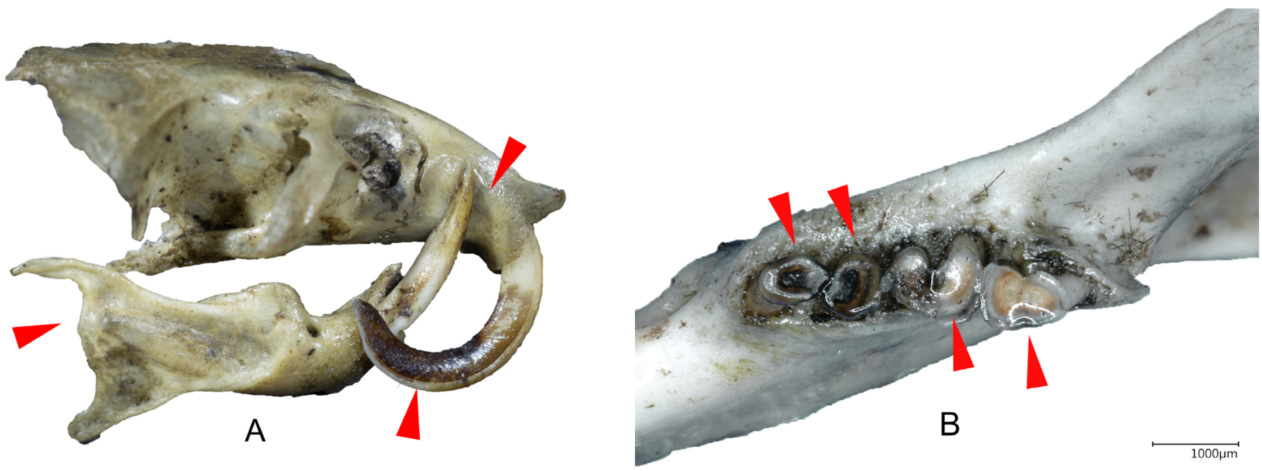

Fig. 7. Yellow-necked mouse No. 56. Skull and right LJ with dented rostrum, reduced bone leaf between Proc. coronoides and Proc. angularis and elongated I in LJ and UJ (A). Yellow-necked mouse No. 31. Left LJ with heavily worn molars (B).

rostrum, creating a recess + # 1.1 (Fig. 7A).
No. 108: Both I^1 slightly elongated + # 1.2.1.

1.2.4 Fusion of teeth
Herold (1955): Both UJ, fusion of two roots and symmetric fusion of the crowns of M^1 and M^2 (01.07.1954, Ersdorf, NRW).

2.4 Extreme wear of the teeth (Abrasio dentium)
Own observation:
No. 31: Crowns of all teeth in UJ and LJ worn to near the root area, in case of right M_1 mesial and distal root already separated + (16.01.2008, Purzien, ST, leg. K. Nehring) (Fig. 7B).

Striped field mouse *Apodemus agrarius* (Pallas, 1771)
1.2.2 Tooth anomaly (tooth growth)
Own observation:
No. 104: Left I^1 circularly elongated + # 2.2.2 (20.12.2012, Kloschwitz in Vogtland, SN).

2.2.2 Bone proliferation (jaws)
Own observation:
No. 104: Left LJ with proliferation in the area of the I_1 + # 1.2.2.

***Apodemus* spec. Kaup, 1829 (*Apodemus flavicollis sylvaticus*)**
1.1 Bone anomaly, morphology
Wilhelm et al. (2014): both LJ with "mushroom-shaped" articular process (Dresden, Leubnitz-Neuostra, SN).

House mouse *Mus* spec.
1.2.2 Tooth anomaly (tooth growth)
Krauss (1991): Elongated I^1 in the UJ almost achieving ring closure with normal growth of the I_1 in the LJ, wear in the contact area with the two I_1 (Harthau, SN).

1.2.3 Dental anomaly (absent or supplementary teeth)
Goethe (1955): M^3 associated alveoli missing, tooth not formed (Holter casle, NRW).

Family Cricetidae
European hamster *Cricetus cricetus* (Linnaeus, 1758)
1.2.2 Tooth anomaly (tooth growth)
Mohr (1954): Elongated I^1 (photo page 83).

Voles (Arvicolidae)
Muskrat *Ondatra zibethicus* (Linnaeus, 1766)
1.1 Bone anomaly, morphology
Akkermann (1974): Shortened diastema in LJ + # 1.2.2 + # 2.3.2 (Dümmer, NS).
Freye (1964): Asymmetrical, wedge-shaped expansion of the normal, almost circular shape of the Foramen magnum, resulting in embryonically incomplete assimilation of the last occipital vertebra into the occipital region (Manifestatio proatlantis) and fusion of the atlas to the occipital region (Assimiltaio atlantis).
Becker (1966): Nose bent to the left (1959-1965, Berlin-West).

1.2.2 Tooth anomaly (tooth growth)
Akkermann (1974): Excessive growth of both I^1 + # 2.1.1 + # 2.1.2 + # 2.2.2 (Trapping, 18.09.1971, Dümmer, NS); excessive growth of both I^1 + # 1.1 + # 2.3.2.
Hoffmann (1958): Excessive growth of both I^1, the right I^1 already goes beyond a complete revolution.
Uttendörfer (1939): Strongly elongated I^1.

2.1.1 Fractures/inclusions (skull excluding jaws)
Akkermann (1974): On the right, bone tissue of squamosum, jugals and tympanicum irregular and spongy, shattered bone fragments of the squamosum lying below the zygomatic bone only partially grown together again with the skull capsule, probably a consequence of a healed skull fracture after trapping + # 1.2.2 + # 2.1.2.

2.1.2 Fractures/inclusions jaw
Akkermann (1974): Dislocation of LJ + # 2.1.1 + # 2.2.2

2.2.2 Bone proliferation (jaws)
Akkermann (1974): Probably the result of a healed skull fracture after trapping: dislocation of the LJ due to skull injury, rostrally displaced to the left with the result that the articular head of the LJ jumped out of the socket and came to rest at the rear edge of the orbita + # 1.2.2 + # 2.1.1. + # 2.1.2.

2.3.2 Dental diseases (atrophied teeth)
Akkermann (1974): Atrophied I_1+ # 1.1 + # 1.2.2.

Bank vole *Myodes glareolus* (Schreber, 1780) (Fig. 8A)
1.1 Bone anomaly, morphology
Own observation:
No. 54: Proc. condylaris shortened and rostrally turned, opening of the alveolus shifted towards the base of the missing Proc. coronoides, Proc. angularis clearly reduced and caudally extended

(Brücken, ST, leg. Jentzsch) (Fig. 8A, normal expression Fig. 8B).

2.1.1 Fractures/inclusions (skull excluding jaws)
Wolf (2003): Healed, almost circular fracture in the area of the skull, bone medially lowered towards the brain, bone plate consisting of remains of the original skull roof (24.03.2001, Brandis, SN).

Water voles *Arvicola* spec. Lacépède, 1799 (Fig. 8B)
1.2.2 Tooth anomaly (tooth growth)
Altner (1961): Elongated I^1, tooth tips drift apart.
Kapischke & Lange (2015): Elongated I^1 with blunt tips (Collection Kulicke). Due to the malfunction of the antagonists, the cranially descending chewing surface of the right toothrow in the UJ, I^1 is elongated and irregularly worn+ # 1.2.5 + # 2.2.2 (19.05.2007, Dammwolde, MV).

1.2.3 Dental anomaly (absent or supplementary teeth)
Lerp & Sametschek (2009): Loss of M_1 in the right LJ, tooth socket was originally existing and in the further course of life completely ossified, thereby lengthening the antagonist in the UJ (2008, Leipzig county, SN).

2.2.2 Bone proliferation (jaws)
Nitsche (1996): Right LJ at the level of M_1 to M_3 with porous bone growth, probably osteosarcoma (Ziebigk near Köthen, ST).
Kapischke & Lange (2015): Exostosis of the left LJ branch in the form of a blister-like bony thickening + # 1.2.2 + # 1.2.5 (Dammwolde) and in the early stage (1959-1961, Collection Kulicke).

1.2.5 Dental abnormalities (other maldevelopments)
Altner (1961): Obliquely worn-out M in both UJ and both LJ, surfaces in same direction.
Kapischke & Lange (2015): All molars deep-seated, M_1 completely sunken + # 1.2.2 + # 2.2.2.
Own observation:
No. 57: Alveolus of the left I_1 labially exposed (03.08.2008, Ossig, ST) (Fig. 8C).

Field vole *Microtus agrestis* (Linnaeus, 1761)
1.2.1 Tooth position
Nitsche (1996): LJ molars labially displaced + # 2.2.2 (Pösigk, ST).

1.2.2 Tooth anomaly (tooth growth)
Kapischke & Dankhoff (2007): Right LJ with abnormal growth of M_1, corresponding hole in antagonistic M^1 (Grünewalde, BB).
Kulicke & Kapischke (1997): Almost circular I^1, irregular molar wear on one of the LJ (2 spc., Kulicke Collection at the Forest Research Institute).
Own observation:
No. 47: Anterior lobe of the left M_1 strongly extended + # 2.1.3 + # 2.4 (03.03.2008, Fiener Bruch, ST, leg. Birth) (Fig. 9).

1.2.3 Dental anomaly (absent or supplementary teeth)
Kraft (2000): Roundish, pin-shaped front lobe of right M_1, separated as an autonomous tooth (1998, Vierkirchen, BY).

2.1.3 Fractures/inclusions (teeth)
Jentzsch (2006): M^3 with diagonal fracture in the crown area reaching from the lingual side behind the front lobe to the back lobe, stone stuck in the crater, inner side of the tooth lingually displaced (04.03.2005, Drömling Nature Park, ST).
Lange & Kapischke (2009): Diagonal fracture of the right M_1 (12.07.2008, Minzow, MV).

Fig. 8. Bank vole No. 54. LJ with shortened and distally oriented Proc. condylaris, shifted opening of tooth canal (A). Reference with normal expression (B). Water vole No. 57, left LJ with exposed tooth socket of I_1 (C).

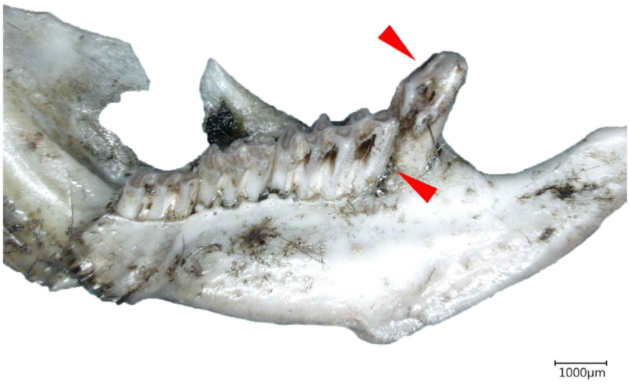

Fig. 9. Field vole No. 47. Left LJ with fracture of M_1 behind anterior lobe and extension of this lobe.

Own observation:
No. 47: Fracture behind anterior lobe of the left M_1 + # 1.2.2 + # 2.4 (Fig. 9).

2.2.2 Bone proliferation (jaws)
Kulicke & Kapischke (1997): LJ branches mostly on one side, sometimes also on both sides with blister-like, bony thickenings, probably actinomycoses (9 spc., 1954-1956, Eberswalde, BB).
Nitsche (1996): Both LJ with large exostoses on the outside below the molars and opening on the left in the rostral masseter fossa and on the right at the level of the diastema + # 1.2.1.

2.4 Extreme wear of the teeth (Abrasio dentium)
Own observation:
No. 47: Anterior lobe of the left M^1 as antagonist of the extended left M_1 mesially sloping + # 1.2.2 + # 2.1.3.

Common vole *Microtus arvalis* (Pallas, 1778) (Figs. 10-15)
1.1 Bone anomaly, morphology
Kapischke et al. (2012): Ossification of the symphysis of the LJs (Winter 2010/2011, Dresden, SN).
Kapischke (2014): Deformed Proc. articularis (Goltzscha, SN).
Manegold (2000): Left LJ with strongly deformed Ramus mandibulae (1997/1998, Kamern, ST).
Maternowski (2017): Right LJ with hole in the Ramus mandibulae (Sandweiher, Baden-Baden, Baden-Württemberg).
Own observations:
No. 7: Proc. condylaris distally, Proc. angularis proximally deflected, thus tip of LJ with I_1 and anterior half of M_1 lingually curved, anterior lobe with abnormal tooth pattern (2015, Schullwitz, SN, leg. Kapischke).
No. 15: Proc. angularis of the left LJ club-like shape (07.09.2011, Dresden-Leubnitz, SN).
No. 37: Proc. coronoides extension extended, basal with hole + # 2.1.3 + # 2.3.1 + 2.3.3 (1995, Berga, ST, leg. Jentzsch) (Fig. 10A).
No. 50: Proc. angularis extended and club-shaped (25.08.2004, Mösthinsdorf, ST, leg. G. Klammer).
No. 51: Left Proc. angularis basally dented (08.03.2008, Drobitz, ST, leg. Jentzsch).
No. 80: Deformation of Proc. articularis (06.06.2014, Rohrbach, SN, leg. Wolff) + # 1.2.2 + # 2.3.1 + # 2.3.2.
No. 116: Left LJ, Proc. condylaria with mushroom-shaped exostosis (January 2020, Dresden, Leubnitz-Neuostra, SN, leg. Wilhelm).

1.2.1 Tooth position
Kapischke et al. (2015): Upper I crossing each other (2014, Dresden, SN).
Kapischke (2014): Diagonally ground M_1 and extended M_1 with surface buccally sloping down, respectively (2 spc., Chemnitz-Rabenstein); M_1 surface lingually sloping down (Dresden-Kleinzschachwitz).
Lange & Kapischke (2007): All molars worn in the same sloping direction (see Manegold 2000) (21.02.2007, Wetterndorf, SH).
Manegold (2000): Tooth surfaces of the molars worn into likely or opposite direction and molars worn diagonally to lingual, respectively + # 1.2.2 + # 2.1.3 (5 spc., 1997/1998, Kamern, ST).
Maternowski (2001): I^1 drift apart apically + # 1.2.2 (18.10.1994, Wendefeld, BB).
Own observations:
No. 22: Right I^1 with labially deflected thin tip, left I^1 very thin + # 1.2.2 (02.07.1995, Nellschütz, ST, leg. M. Schlüter).
No. 24: Molars of left LJ and left UJ worn-out into opposite direction + # 1.2.2 + # 2.1.2 + # 2.2.2 (25.12.2015, Trafo Nellschütz, ST) (Fig. 10C, D).
No. 30: Both M^2 labially displaced + # 2.2.2 (September 2007, Wittgendorf, ST, leg. F. Köhler).
No. 53: Right I_1 buccally deflected (15.02.2011, Dresden-Gohlis, SN).
No. 76: Left I_1 buccally deflected (18.02.2016, Altmügeln, SN).

1.2.2 Tooth anomaly (tooth growth)
Altner (1961): Extension of all cheek teeth of right LJ and of right M_1 from mesial to apical ("Pan flute"), respectively (2 spc.).
Bischoff (2005): Strongly elongated I^1, grown into the oral cavity + # 1.2.3 (22.08.2005, Gülpe, ST).
Dolch (2016): Strongly elongated I_1 (8 spc., 20.09.2014, Manker, BB).

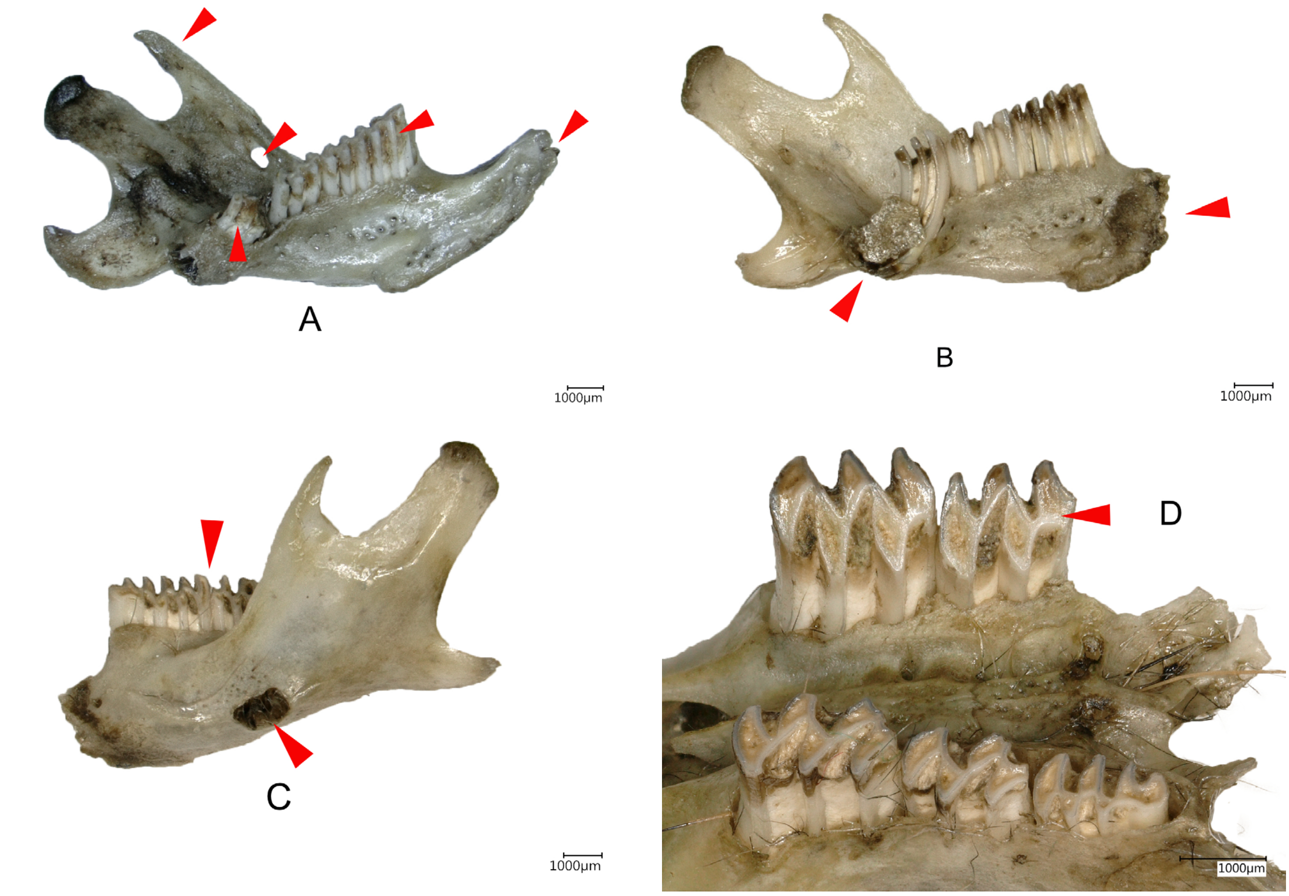

Fig. 10. Common vole No. 37. Left LJ with extended process, hole in the Proc. coronoides, enamel hypoplasia in the molar region, broken I_1 and progressive caries at M_3 (A). Common vole No. 24. Left LJ lingually with embedded stone, widened dental bed and exostosis in the area of I_1 (B), labially with exostosis and obliquely ground molars (C), obliquely ground molars in the left UJ (D).

Goethe (1955): Left LJ arched outwards, anterior tip of M_1 protrudes 6.5 mm from the inner alveolar rim (1945, Heiden, NRW; 2 spc., 1945, Reelkirchen, NRW).
Jaschke (2017): Strongly elongated I^1 (26 spc., 10./11.10.2005, NSG Havelländisches Luch; 5 spc., 08.02.2008, 3 spc., 14.12.2008, Garlitz; 4 spc., 09.12.2008, Barnewitz; 5 spc., 18.12.2008, Damme, BB).
Kapischke (2014): Circular I^1 (Goltzscha, SN; Torgau-Köllitzsch, SN).
Lange (2020): Both I^1 circularly grown + # 1.2.3 + # 2.3.1 (26.22.208, Volzendorf, NS); left LJ “Pan flute” (2019, Steinburg, SH).
Lange & Kapischke (2007): Lengthened right M_1, molars of LJ obliquely worn-out from frontal to caudal (21.02.2007, Wetterndorf, SH).
Manegold (2000): Circular I^1 + # 1.2.1 + # 2.1.3; elongated right I_1 (1997/1998, Kamern, ST); elongated M_1 of left LJ in the area of the anterior lobe and separated from the remaining tooth by a gap (1997/1998, Kamern, ST); right M^1 30 % extended compared to left M^1, with strong cement inclusions (1997/1998, Kamern, ST) + # 2.1.3.
Maternowski (2001): Strongly elongated I^1, in one case circular right I^1 and half circular left I^1 (18.10.1994, Wendefeld, BB); strongly elongated I_1 + # 1.2.1.
Nitsche (1996): Extended left M_1 atrophied with antagonist in UJ (Fraßdorf, ST); elongated paired I^1 (3 spc., Fraßdorf, Libbesdorf, ST, 6 spc., Hinsdorf, ST); elongated, circular I^1, in one case left I^1 broken off + # 2.3.2 (2 spc., Hinsdorf, 4 spc., Pösigk, ST).
Schmidt (1991): M_1 growth malformation (3 spc., Harthau, SN).
Uttendörfer (1939): Strongly elongated I_1 (1898) + # 1.2.3; extension of M_1 from mesial to apical (“Pan flute”) (1936).

Own observations:
Elongation of both I^1:
No. 2: Due to atrophy of both I_1, right I^1 tip broken off + # 2.1.3. + # 2.3.1 (2015, Schullwitz, SN, leg. Kapischke) (Fig. 14A).
No. 5, 48: + # 2.1.3 (2015, Schullwitz, SN, leg. Kapischke; 12.05.2015, Dresden-Tolkewitz, SN, leg. K. Fabian).
No. 22: + # 1.2.1.

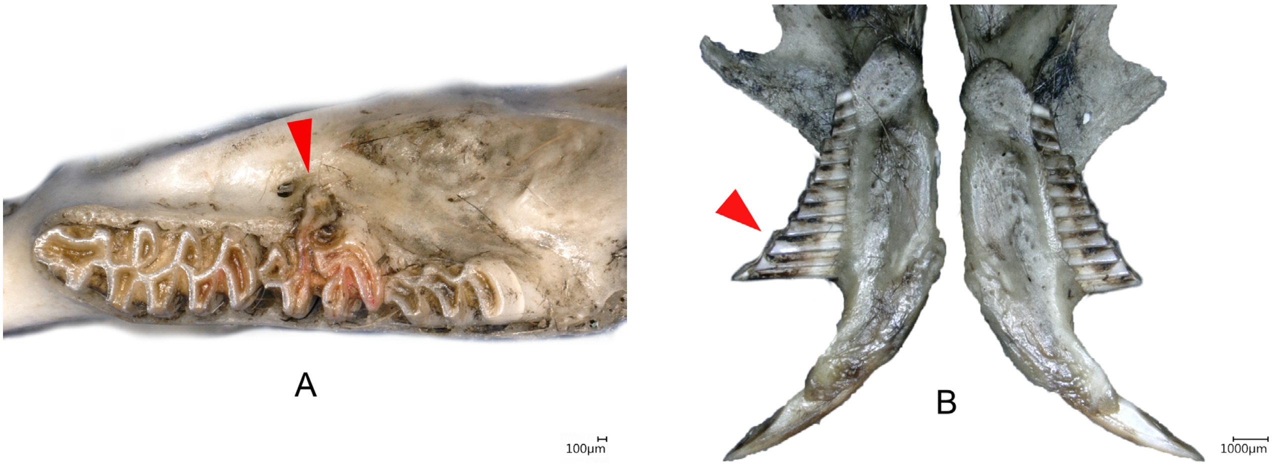

Fig. 11. Common vole No. 49. Left right LJ, M_1 buccally penetrating into the corpus mandibulae (A). Common vole No. 33. Right UJ with extension of M_1 from mesial to apical ("Pan flute"), in the opposite LJ tooth row normally developed (B).

Fig. 12. Common vole No. 40. Left skull with elongated I^1 (A). Common vole No. 39. Left LJ with elongated I_1 (B).

Fig. 13. Common vole No. 34. Right LJ with cross-braked M_1 (A). Common vole No. 23. Both LJ each with bone proliferation in the area of the diastema, in the right LJ shaping a hole (B).

No. 26, 35, 42, 44, 45: Almost circular, tooth tips partly growing apart (1995, Berga, ST, leg. Jentzsch; 08.03.2008, Drobitz, ST, leg. Jentzsch; 16.01.2008, Purzien, ST, leg. K. Nehring; 3 spc., 28.01.2003, Niemberg, ST, leg. G. Klammer).

No. 83: + # 1.2.3 (01.07.2015, Nemt, SN; 20.02.2011, Magdeburg, ST).
No. 65, 66, 109, 110: + # 2.3.2 (15.10.2011, Göbschelwitz, SN, leg. I. Kittel; 01.06.2016, Bernau, BB; 2 spc., 27.10.2010, Dresden, SN, leg. H. Kapischke).

Fig. 14. Common vole No. 2. Skull, frontal view, enamel dysplasia at the I^1 and indicated fracture edge at the left I^1 (A). Common vole No. 16. Right LJ with voluminously widened M_1 (B).

No. 84: Circular, lower jaw normal (01.07.2015, Nemt, SN).
No. 97, 112: + # 2.3.2 (31.01.2015, Altmügeln, SN; 20.12.2012, Kloschwitz/Vogtland, SN; 2008, Brandis, SN).
No. 100: + # 2.3.2 (31.01.2015, Altmügeln, SN).
No. 74, 79, 86, 95, 102, 111: Circular (19.02.2016, Lüttnitz, SN; 18.02.2016, Altmügeln, SN; 2 spc., 08.01.2015, Blankenhain, SN; 20.12.2012, Kloschwitz/Vogtland, SN; 2008, Körlitz, SN).
No. 105: + # 2.3.2 (01.07.2015, Nemt, SN; 20.02.2011, Magdeburg, ST).
No. 123: Strongly elongated I^1 (3 spc., 23.10.2019, Hackeboe (1 spc., 27.12.2019, Christinenthal, SH).
No: 124: right I^1 circularly elongated + # 1.2.3 (SH, leg. L. Lange).
No. 125: right I^1 circularly elongated + # 1.2.3 + # 2.3.1 (23.10.2019, Wilster, SH, leg. L. Lange).
No. 126: left I^1 needle like elongated + 2.4 (22.12.2019, Itzehoe, SH, leg. L. Lange).

Elongation of re I^1:
No. 1: + # 2.3.2 (2015, Schullwitz, SN, leg. Kapischke).
No. 13: Due to atrophy/break of the right I_1 + # 2.3.1 (Gombsen/Kreischa, SN, leg. Kapischke).
No. 39, 41: (2 spc., 16.01.2008, Purzien, ST, leg. K. Nehring) (Fig. 12B).
No. 73: Circular (20.12.2015, Magdeburg, ST).
No. 106: + # 2.3.2 (20.02.2011, Magdeburg, ST).
Nr. 121: + # 2.3.2 (12.01.2020, Borsfleth, SH, leg. L. Lange).

Elongation of teeth le I^1:
No. 3: Almost circular + # 2.1.3 (2015, Schullwitz, SN, leg. Kapischke).
No. 14: (Dresden-Gohlis, SN, 15.02.2011, leg. Kapischke).
No. 40: Almost circular, growing slightly outwards + # 2.1.3 (16.02.2008, Purzien, ST, leg. K. Nehring) (Fig. 12A).

"Pan flute": No. 12: Left M_1 "Pan flute" and front lobe buccally deflected, left M^3 sunk in and less worn-out than other molars + # 1.2.5 + # 2.2.2 (29.12.2015, Klienzschachwitz, Sachsen).
No. 33: Extension of right M_1 from mesial to apical ("Pan flute") + # 1.2.5 + # 2.3.3 (03.08.2008, Ossig, ST) (Fig. 11B).

Elongation, growth of other teeth:
No. 24: Right and left M_3 + # 1.2.1+ + # 2.1.2 + # 2.2.2.
No. 38: Right and left M^1, anterior lobe approximately 0.9 mm higher than distal tooth edge (16.01.2008, Purzien, ST, leg. K. Nehring).
No. 80: I_1 continual growth inside the tooth socket + # 1.1 + # 2.3.1 + # 2.3.2.
No. 96: Right M_1 obliquely (08.01.2015, Blankenhain, SN).
No. 101: Both M_1 (20.12.2012, Kloschwitz/Vogtland, SN).
No. 49: Right M_1 abnormal tooth pattern, buccally penetrating into the corpus mandibulae (07.07.1995, Förstgen, SN) (Fig. 11A).
No. 28: Teeth of the left upper toothrow + # 1.2.5 + # 2.3.3 (Mai 2008, Reußen, ST).
No. 122: Laterally extended right upper molars, chewing surface laterally sloping down (31.01.2020, Dresden, Leubnitz-Neuostra, SN).

1.2.3 Dental anomaly (absent or supplementary teeth)
Bischoff (2005): Missing I_1 + # 1.2.2.
Kapischke (1995): Additional molar, UJ, left side (1994, Piskowitz, SN, leg. Würflein).

Kapischke (2011): Left M^2 consists of two separate teeth (2010, Dresden, SN).
Kapischke (2014): Supplementary tooth in LJ (Frauendorf, SN).
Kraft (2000): Supplementary pin-like tooth adjacent to the front edge of the right M^1 (Woringen, BY); divided right M_2 (1998, Oberndorf).
Lange (2000): On both sides four molars in the UJ (26.12.1998, Bekdorf, SH).
Kapischke (2014): deformed M_1 (SN).
Own observations:
No. 36: Left M_1 between first labial and first lingual dental triangle transversely divided, tooth margins developed + # 2.2.2 (05.10.2006, Sachau, ST, leg. Jentzsch).
No. 81: Right I_1 missing, tooth socket closed (06.02.2015, Meltewitz, SN).
No. 83: Both I_1 missing + # 1.2.2.
No. 103: Right I_1 missing, tooth socket almost overgrown
No. 124: Right I_1 swaged (23.10.2019, Hackeboe, SH); right I^1 of normal length, but strongly tapered + # 1.2.2.
No. 125: Left I^1 of normal length, but strongly tapered + # 1.2.2 + 2.3.1.

1.2.5 Dental abnormalities (other maldevelopments)
Kapischke (2014): Necrotic M^1 (Röthenbach, SN)
Own observations:
No. 4: Tooth roots barely developed, only the front lobe pronounced + # 2.2.2.
No. 12: M_3 lost or not formed + # 1.2.2 + # 2.2.2.
No. 16: Right M_1 voluminously widened, associated alveolus widened (15.02.2011, Dresden-Gohlis, SN) (Fig. 14B).
No. 28: Left M_1 voluminously widened, associated alveolus widened + # 1.2.2 + # 2.3.3.
No. 33: Deviating tooth pattern of the right M^1 + # 1.2.2 + # 1.2.5.
No. 78: Left M^1 not erupted, tooth socket closed (18.02.2016, Altmügeln, SN).

2.1.2 Fractures/inclusions (jaw)
Own observation:
No. 24: Left LJ at the level of the M_3 with embedded stone and exposed periodontium + # 1.2.1 + # 1.2.2 + # 2.2.2 (Fig. 10B).

2.1.3 Fractures/inclusions (teeth)
Kapischke (2014): Broken M_1, inclined and divergently worn (Dresden-Kleinschachwitz, SN); Broken hind lobus of M_1 (Goltzscha, SN).
Kapischke & Kraft (2012): Crater in M_1 possibly due to the inclusion of a foreign body (e.g. grain of sand or small stones) (Dreschen, BY); enclosure of a foreign body in M_1 (Etting, BY); Fracture in M_1, separate anterior lobe (2 spc., Dresden, SN und Vierkirchen, BY).
Kapischke et al. (2006): Left M_1 lingual with enclosed sand grain in the second dentine triangle, this slightly rounded off.
Manegold (2000): Li LJ broken off at the top + # 1.2.1 + # 1.2.2; Right M^1 split antagonistic M_1 up to the third outer anticline + # 1.2.2.
Own observations:
No. 2: Left I_1 broken off, indicated breaking edge of left I^1 already clearly visible due to enamel hypoplasia + # 1.2.2 + # 2.1.3 + # 2.3.1 (Fig. 14A).
No. 3, 40: Right I_1 broken off + # 1.2.2.
No. 5: Both I_1 broken off + # 1.2.2.
No. 17: Crown area of the posterior lobe of right M_1 broken off (14.09.2011, Dresden-Leubnitz, SN).
No. 27: Posterior lobe of right M_1 continuously broken + # 2.3.3 (01.07.1995, Berga, ST, leg. G. Schröter) (Fig. 15).
No. 34: Right M_1 broken in the middle, tooth edges partially healed + # 2.3.3 (01.10.2007, Axien, ST, leg. K. Nehring) (Fig. 13A).
No. 37: Left I_1 aborted at the level of the alveolus, probably also fracture in the crown area of the left M_3 + # 1.1 + # 2.3.1 + # 2.3.3 (Fig. 10A).
No. 48: Both I^1 broken + # 1.2.2.
No. 75: Right M_1 partly broken (18.02.2016, Altmügeln near Oschatz, SN).
No. 120: Left M1 dental crown broken crosswise and widened by bonelike foreign object, root still connected, hind root canal in the crater visible from above (31.01.2020, Wilster, SH, leg. L. Lange).

2.2.2 Bone proliferation (jaws)
Manegold (2000): Both LJ in the area of I_1 with bone proliferation (1997/1998, Kamern, ST).

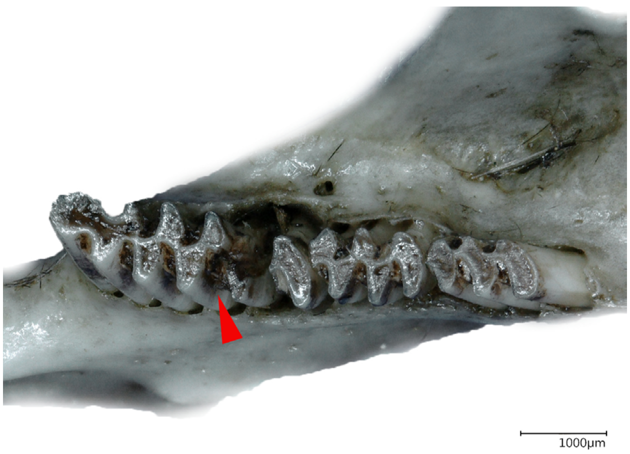

Fig. 15. Common vole No 27. Right LJ with caries and fracture of the posterior lobe of M_1.

Own observations (exostoses of diastema on or near the tooth socket of I_1, tooth necks of I often exposed):
No. 18: Right LJ (14.09.2011, Dresden-Leubnitz, SN, leg. Kapischke).
No. 6, 23, 32: both LJ, No. 23 in the right LJ shaping a hole (15.02.2011, Dresden-Gohlis, SN, leg. Kapischke; 27.02.2009, Trafo Nellschütz, ST, leg. M Schlüter; 31.12.1995, Berga, ST, leg. Schröter) (Fig. 13B).
No. 24: Instead of I_1 strong exostoses and exostosis labial in the area of the LJ corpus + # 1.2.1 + # 1.2.2 + # 2.1.2 (Fig. 10B, C).
No. 25: Left LJ (08.10.2008, Königsmark, ST).
No. 30: Right LJ + # 1.2.1.

Own observations (bone proliferations in other areas of the jaw):
No. 4: Tooth socket of the M_3 lingual + # 1.2.5.
No. 12: Loss of bone mass in the area of corpus mandibulae at the level of M_3, root area of left I_1 exposed like a window + # 1.2.2 + # 1.2.5.
No. 20: left LJ Ramus mandibulae atrophied, proliferation spreads to the tooth socket of the lower molars, Proc. angularis fin-like (30.06.2012, Dresden-Tolkewitz, SN, leg. Kapischke).
No. 36: Front lower area of both mandible bodies + # 1.2.3.
No. 82: Bubble-like Proc. angularis, especially in the area of the root of I_1 (06.02.2015, Meltewitz, SN).

2.3.1 Enamel abrasion
Lange (2020): Enamel in both I^1 limited to the tip of the tooth + # 1.2.2 + # 1.2.3.
Own observations:
No. 1, 13: Enamel restricted to the tip of the tooth in right I^1, completely missing in left I^1 + # 1.2.2 + # 1.2.5.
No. 2: Enamel in both I^1 limited to the tip of the tooth and left alveolar region, dentine severely damaged, left I^1 almost broken off + # 1.2.2 + # 2.1.3 + # 2.3.1 (Fig. 14A).
No. 37: Left lower toothrow lingual and labial in the upper crown area + # 1.1 + # 2.1.3 + # 2.3.3 (Fig. 10A).
No. 80: Left M_3 without enamel + # 1.1 + # 1.2.2 + # 2.3.2.
No. 107: Both I^1 (20.02.2011, Magdeburg, ST).
No. 125: Right I^1 with two gaps of lost enamel + # 1.2.2 + 2.3.1.

2.3.2 Dental disease (atrophied teeth)
Nitsche (1996): Both I_1 each atrophied + # 1.2.2 (2 spc., Hinsdorf, 4 spc., Pösigk, ST).
Own observations:
No. 1: Right I_1 atrophied, only visible as a stump in the alveolus + # 1.2.2.
No. 52: Tooth root of left I_1 atrophied (15.02.2001, Dresden-Gohlis, SN).
No. 65, 66, 85, 98, 100, 109, 110: Both I_1 atrophied + # 1.2.2.
No. 113, 114: Both I_1 atrophied (2008, Brandis, SN).
No. 67, 68, 69, 70, 71, 72: Both I_1 atrophied, tooth socket almost overgrown (20.12.2015, Magdeburg, ST).
No. 77, 103: Right I_1 atrophied, tooth socket almost overgrown (1 spc., 20.12.2012, Kloschwitz/Vogtland, SN; 1 spc., 18.02.2016, Altmügeln, SN).
No. 80: Left M_3 atrophied ("shapeless clump") without enamel pattern, right I_1 not protruding + # 1.1 + # 1.2.2 + # 2.3.1.
No. 87, 99: Both I_1 and I^1 atrophied (08.01.2015, Blankenhain, SN; 31.01.2015, Altmügeln, SN).
No. 88, 89, 90, 91, 92, 93, 94: Both I_1 atrophied (08.01.2015, Blankenhain, SN).
No. 97, 105, 106, 112: Right I_1 atrophied + # 1.2.2.
No. 121: Both I_1 brittle, visible in the tooth socket, left I^1, with normal length, but very thin and brittle + # 1.2.3 (12.01.2020, Borsfleth, SH, leg. L. Lange).

2.3.3 Caries
Own observations:
No. 27: Area of the tooth fracture of M_1 + # 2.1.3 (Fig. 15).
No. 28: Hole on the surface of left M_1 + # 1.2.2 + # 1.2.5.
No. 33: At the posterior lobe of the malformed right M^1 + # 1.2.2 + # 1.2.5.
No. 34: Right LJ with caries at mesial edge of the posterior tooth section of M_1 + # 2.1.3.
No. 37: Mesially advanced at left M_3 + # 1.1 + # 2.1.3 + # 2.3.1 (Fig. 10A).

2.4 Extreme wear of the teeth (Abrasio dentium)
Kapischke (2014): Blunt, worn I in the UJ and LJ (Dresden-Kleinzschachwitz).
Own observation:
No. 126: Left I_1 with beginning of cavity at the base formed mesially by the antagonist + # 1.2.2.

Discussion

Biodiversity is a measure of the qualitative, quantitative or functional diversity of biotic objects at all organizational levels within a concrete or abstract, spatial or temporal reference space (Beierkuhnlein 2003). This definition includes biodiversity at the level of organs and, by extension, must also include abnormal and pathological phenomena found therein. While unusual deviations from the norm in the functional performance of an organism may be irrelevant, disadvantageous, or advantageous, diseases are usually associated with impairment and, directly or indirectly, may undermine fitness or compromise survival. Small mammals show a capacity to survive such anomalies and even severe pathological phenomena for surprisingly long periods of time, which is why these features should be considered a component of population biodiversity.

Our results demonstrate that even small species, such as mice and other small mammals, appear able to not only survive the course of disease and, presumably, tolerate substantial pain and discomfort over long periods of time, but even to undergo recovery. Examples include cases of healed wounds and survival of viral and bacterial infections, which may be associated with development of an immune response. Other examples include injuries or maldevelopment of various bones of the torso skeleton (Forsman & Otto 2006) as well as anomalies and pathological changes to the skull. Lerp & Sametschek (2009) documented a period of approximately six weeks between the loss of teeth in a water vole and eventual death by predation, showing that up until the time of its death, the animal was able to feed. A bank vole with a healed fracture of the skull, found by Wolf (2003), also showed evidence of recovery. Mohr (1954) observed field hamsters in which the upper incisor grew in a circular shape after breaking off the lower incisor, but as the lower incisor regrew, it ground on the upper incisor, so that the excess part eventually broke off. In most cases, the development of the observed phenomena required a period of several weeks to have developed in this way.

Anomalies and pathologies are regularly observed in the skulls of wild small mammals and have also received wider recognition in older zoological papers (e.g. Johnson 1952, Mohr 1954, Buchalczyk 1961, Miyao & Mori 1969, Steinborn & Vierhaus 1984, Gräfner 1986, Miles & Grigson 1990). The reasons for this interest are quite diverse. In the case of anomalies, they are probably often genetically determined. Included among them are undeveloped or supplementary teeth and deviant bone forms. Bone anomalies associated with the teeth and jaw are often caused by osteomyelitis resulting from abscesses. Lawson (2010) was able to detect the coagulase-positive *Staphylococcus aureus* pathogen in cultured samples of the mandibulofacial and maxillofacial abscesses of mice he examined. He found the cause of inflammation to be crushed hair in the sulci gingivalis of the upper or lower jaw molars, which was presumably ingested and then chewed during coat care. The process of abscess formation as assumed by Lawson (2010) is shown in Fig. 16. Bone or tissue tumours can lead to impaired chewing behaviour, resulting in crooked tooth surfaces. Stones are sometimes able to cause tooth fractures, resulting in caries and tooth loss, but it is also possible for fractured pieces to establish themselves as independent teeth.

The most conspicuous, and second most frequently observed phenomenon in our study, occurs predominantly in mice and rodents and relates to the excessive lengthening of the incisors and the often simultaneously present atrophy or absence of the antagonist (see Gräfner 1986, Miles & Grigson 1990). The illustrations presented by Hoffmann (1958) and Ulbrich (1930) each show a muskrat skull in which the right upper incisor has grown completely circular and has already started another revolution. The skull shown in Miles & Grigson (1990) is that of a black rat (*Rattus rattus*) in which the growth of an incisor has reached almost two complete revolutions. Brandner (1951) states that such characteristics in muskrats can also be the result of nutritional disorders, lack of tooth wear, congenital jaw anomalies, other damage to the teeth and jaws or infections, and that they particularly affect old animals. The latter certainly

Barbering

↓

Mastication/Fragmentation of hair

↓

Fragments penetrate and expand the gingival sulcus

↓

Staphylococcal organisms carried into the submucosa

↓

Abscess develops

↓

Bone dissolution

Fig. 16. Etiopathogenesis of mandibulofacial and maxillofacial abscesses in mice proposed by Lawson (2010).

also applies to extreme wear of the teeth (abrasio dentium). Absent or supplementary teeth account for 30% of all specimens described here. However, 111 of the 144 findings of that phenomenon can be traced back to the investigations of Stein (1963) on moles and of Borkenhagen (2011) on greater white-toothed shrews.

Pathologies and anomalies occur with varying frequency in different populations. Dolch (2016) found that of 80 field mice from pellet samples, one in eight was observed to have elongated upper incisors, and Jaschke (2017) reported rates between 1.6% and 11.5% in populations of the same species. From pellet analyses from the Dresden area, Kapischke (2017) reports rates of 5.1% (Leubnitz-Neuostra) and 2.7% (Kleinzschachwitz) of pathological changes in field mice. Among 114 wood mice from northern Germany, the proportion of animals with extremely worn teeth was 9.6% (Renaud 2005).

The overview presented here includes 15 different anomalies and pathological phenomena, 14 of which have been documented in a total of 20 species of terrestrial small mammals (Fig. 1). At 75%, the proportion of anomalies outnumbered strictly pathological findings. Due to their low abundance, some communal species, such as brown rats or squirrels, are underrepresented in owl pellets. To date, there are no sources from Germany for information on the field hamster (*Cricetus cricetus*). In the latter half of the 19^{th} century, the species was still common in this country (Nechay 2000), but apparently no corresponding studies have been published, while there have been findings of malformed mandibles for the species from the Netherlands (Van Bree & Jansen 1962).

Other phenomena, such as the rotation of a P_4 in a squirrel of the genus *Petaurista*, found in the USA, whose buccal surfaces were mesially oriented (Miles & Grigson 1990), or bone proliferations on the skull, can also be expected for the local faunal area presented in this paper. The latter is regularly reported in domestic animals (e.g. Negrin et al. 2006, Gold et al. 2019). The absence of bony proliferations on the skull goes against 25 findings of these phenomena in the jaws of small mammals. The reasons for this absence can only be speculated upon. Perhaps there is a higher risk of contracting an infection through an injury to the mobile lower jaw area, which then leads to a bone ulcer. However, although there have been no corresponding publications from other faunal regions, in general such a phenomenon can be expected in the cranial region of wild small mammals. We broadly assume that all the findings recorded in our study can occur in all small mammal species and that these will be revealed in further studies.

A combination of several abnormal and/or pathological phenomena has been illustrated, both in the literature studied here and our own research. In many cases, the sequence of events that has led to these phenomena is not clear. Further research in this field is necessary to be able to fully characterise their origin.

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