Discover Animals

Research

Radiographic screening of indigenous South African rodent incisor teeth for the presence of elodontomas

Quintin Norval[1,2] · Adrian Tordiffe[3,4] · Gerhard Steenkamp[1,4]

Received: 26 December 2024 / Accepted: 10 May 2025
Published online: 23 May 2025

Abstract
Elodontomas, benign growths affecting the continuously growing incisor teeth of rodents, are a significant concern in captive populations, often causing severe respiratory distress due to nasal obstruction. This study aimed to investigate the presence of elodontomas in South African rodents to propose a classification system for the anatomical location of maxillary incisor apices, which may influence susceptibility to respiratory issues. Radiographic screening of 376 dry skulls from 63 rodent species housed in the Ditsong National Museum of Natural History's small mammal archives, revealed no evidence of elodontomas. The absence of elodontomas in wild rodents supports the hypothesis that captivity-related factors such as diet, housing, and trauma may contribute to elodontoma development. Rodent species were classified based on the maxillary incisor apex location: Class I (rostral to the first cheek tooth, 80.95%), Class II (between the cheek teeth, 14.29%), and Class III (caudal to the last cheek tooth, 4.76%). The study highlights the importance of additional in-depth research into the incidence of elodontomas, particularly concerning the difference between wild and captive populations. A classification system is proposed that provides a framework for assessing anatomical susceptibility to respiratory distress linked to dental abnormalities, which could offer insights for improving rodent welfare in captive settings.

Keywords Skull radiography · Aetiology · Prognosis · Incisor · Apex

1 Introduction

Rodents are one of the most diverse and widespread groups of mammals, comprising nearly 40% of all mammalian species [1]. They are highly adaptable and inhabit almost every ecosystem worldwide, from dense forests to urban landscapes [2]. Their evolutionary success is largely attributed to their specialised dentition and high reproductive rates, which enable them to thrive in diverse environments [3, 4]. South Africa is home to many native and several introduced rodent species that have successfully adapted to local conditions [4]. An interesting aspect of South African rodent taxonomy is the diversity of indigenous species that are highly adapted to specific ecological niches. For example, the *Acomys* genus is uniquely adapted to arid environments, while the *Rhabdomys* genus is adapted to a variety of environments [5]. Anatomically, rodents are characterised by the presence of continuously developing incisor teeth [1, 6, 7]. These ever-erupting teeth are a result of the continual apposition of dentine and enamel at

✉ Quintin Norval, norvalq@cput.ac.za | [1]Department of Companion Animal Clinical Studies, Faculty of Veterinary Science, University of Pretoria, Pretoria 0110, South Africa. [2]Department of Dental Sciences, Faculty of Health and Wellness Sciences, Cape Peninsula University of Technology, Cape Town 7530, South Africa. [3]Department of Paraclinical Sciences, Faculty of Veterinary Science, University of Pretoria, Pretoria 0110, South Africa. [4]Centre for Veterinary Wildlife Research, Faculty of Veterinary Science, University of Pretoria, Pretoria 0110, South Africa.

the stem cell-rich apex of the teeth, known as the apical bud [8–10]. This type of ever-erupting tooth is classified as hypselodont, or elodont in short, as the molecular control enabling the switch to root formation is never triggered [11, 12].

Elodontomas are defined as hamartomas of continuously developing odontogenic tissue and alveolar bone at the periapical bud of elodont teeth [8]. A hamartoma is a benign malformation of disorganised cells that resemble the tissue of the location [13]. Furthermore, elodontomas are non-malignant lesions without dysplasia, characterised by the absence of cellular atypia, loss of normal maturation, and stratification [14, 15]. Uncertainty exists whether all previous complex odontomas are elodontomas [1]. Also, if there are two entities, those that display dysplasia, as in the case of pseudo-odontomas and dental dysplasia, or those that exhibit non-dysplasia, such as complex odontomas and elodontomas [1]. Some authors have proposed that pseudo-odontoma could be an intermediate condition to the formation of an elodontoma [1] Captivity, specifically factors related to husbandry, such as diet and environmental conditions, are associated with an increased incidence of elodontomas [16, 17]. More specifically, previous studies have suggested dietary factors such as fibre and Vitamin A content, and housing conditions such as barred cages could be risk factors [8, 16]. Dental trauma from falls or cage-biting due to limited stimulation and stress is common in captive rodents [17–20]. Thus, environmental enrichment is crucial, including facilitating appropriate social interactions and natural behaviours such as burrowing for semi-fossorial species or appropriate lighting for nocturnal animals, to mitigate such stress [21]. The available literature suggests that trauma is the most likely cause of elodontomas, as the maxillary teeth, which are prognathic, are more often cited with elodontomas than mandibular incisor teeth [22]. Dental trauma may also be induced iatrogenically by the improper shortening of overgrown teeth [23]. More specifically, trauma can disrupt the periodontal ligament (PDL) space maintenance by physical disruption as mentioned by Levy 1968, however, Capello 2010 rightfully noted that if acute trauma was the only cause of elodontoma formation, the cheek elodont teeth would not be affected [24, 25]. Since the cheek elodont teeth can be affected, the aetiology of elodontomas is more likely multi-factorial [25, 26].

Clinical signs of maxillary elodontomas and complex odontomas include weight loss, lethargy, and difficulty breathing or swallowing [25, 27, 28]. The surrounding anatomy of the apex of the incisor teeth is correlated to the signs the animal would experience if a expanding mass was present. Therefore, mandibular incisor masses rarely present with clinically significant signs, whilst maxillary incisor masses present with degrees of respiratory distress [29, 30]. Rodents are obligate nasal breathers, since the normal positioning of the epiglottis covers the caudal rim of the soft palate, effectively sealing the oropharynx from the trachea [31]. However, researchers have noted that Southern red-backed voles (*Myodes gapperi*) with maxillary incisor elodontomas presented with limited respiratory signs as the apex of the maxillary incisors in this species is, intranasally, in the diastema area of the maxilla [32]. Elodontomas, odontomas and pseudo-odontomas are visible on skull radiographs as well-demarcated radiopaque masses associated with the apex of elodont teeth [1, 29, 33]. The radiopacity may obstruct the pulp cavity and these masses could have one of two appearances: either an expansive lesion into surrounding structures or irregular margins along the PDL space [7, 8, 29, 32, 33]. On dorsoventral radiographs, bilateral masses affecting both maxillary incisor teeth may appear to be growing towards each other, while on lateral radiographs, larger masses affecting the maxillary incisor teeth could be observed obstructing the nasal cavity [27, 33, 34]. Importantly, these lesions should be differentiated from cementoblastomas, osteoid osteomas, cemento-ossifying fibromas, and ameloblastic fibro-odontomas [35]. A final diagnosis can only be made after microscopy, especially to observe dysplastic changes within these mixed epithelial/mesenchymal odontogenic lesions and diagnosis based on radiography is considered tentative [1].

Treatment options for peri-apical masses affecting maxillary elodont teeth include either rhinostomy or surgical extraction (trans-oral, trans-palatal, or maxillary lateral approaches) [7, 27, 28, 34, 36]. However, conservative rhinostomy treatment requires extensive postoperative care to maintain stoma patency due to the increased risk of foreign body inhalation [36]. Despite treatment, the prognosis of advanced growths are poor [33, 37].

Elodontomas have been diagnosed in captive tree squirrels in South Africa [38], while a single case in a captive Cape ground squirrel was also presented with dyspnoea (Steenkamp, pers. comm.). Therefore, this study had two primary objectives. First, to determine the presence and prevalence of elodontomas in a large skull collection of wild South African rodents. Secondly, to determine if there is a correlation between the position of the apex of the maxillary incisor teeth and the severity of clinical signs published in the literature by deriving and applying a classification system describing the extent to which the apex of the maxillary incisor teeth terminate in the nasal cavity. This work will serve to aid clinicians in diagnosing and treating elodontomas in captive rodents.

2 Materials and methods

This study was approved by the University of Pretoria—Animal Ethics Committee, REC089-21, and the research was carried out following the University of Pretoria's guidelines and regulations. Permission was obtained from the Ditsong National Museum of Natural History (City Hall, 432 Paul Kruger Street, Central Pretoria, 0001) to examine specimens from the small animal collection.

Historical dry skull specimens from the small mammal archives at the Ditsong National Museum of Natural History were radiographed using dorsoventral skull radiography to screen for elodontoma lesions. The rodent specimens were historically collected and the collection methodology is thus unrelated to this study. The only metadata available for each specimen was the museum collection number, species, location, date of collection, and sex. Species identification for this project was based on the museum classifications, without further genetic testing or morphological validation.

Data for each skull was recorded on a data collection sheet that included fields for the museum collection number, species, collection date, GPS data of collection source, and additional notes on any unique features or conditions of the skull. This approach allowed us to maintain a standardized record of each specimen, facilitating clear documentation and analysis. An x-ray generator (Port X-II, Genoray, Republic of Korea) operating at 2.3 mA and 60 kV mounted on a custom rig with a fixed 5 cm tube-to-object distance was used. Reusable phosphor imaging plates (CR sizes: four (5.7 cm × 7.5 cm) and five (5.7 cm × 9.4 cm), iM3, Ireland, UK) were developed on a laser scanner (CR7 Vet image plate x-ray scanner, iM3, Ireland, UK) and images were optimised and stored using the Vet Exam software (iM3, Ireland, UK) on a laptop in Digital Imaging and Communications in Medicine (DICOM) format. Specimens such as the Cape porcupine (*Hysrix africae-australis*), Greater cane rat (*Thryonomys swinderianus*) and South African springhare (*Pedetes capensis*), which were too large to fit on a size five image plate, were radiographed at the Diagnostic Imaging section at Onderstepoort Veterinary Academic Hospital (OVAH, Soutpan Road, Onderstepoort, South Africa, 0110) on larger phosphor cassettes (Fujifilm Pb IP cassette type CC, 24 cm × 30 cm FCR, Tokyo, Japan). These specimens were radiographed using an x-ray generator (SG Healthcare Jumong CMP200, SG Healthcare, Republic of Korea) and cassettes were developed on a Fujifilm FCR Profect CS reader (Tokyo, Japan). The radiographic DICOM images were converted to 8-bit.JPEG (Joint Photographic Experts Group) images and stored on Google Drive (California, USA). Disarticulated mandibles and crania were radiographed in the dorsoventral projection with the mandibular bodies facing the radiographic plate and the crania with the maxillary cheek teeth closest to the radiographic plate.

The location of the maxillary incisor tooth apices as seen on the radiographs (Fig. 1) was used to classify rodents into three classes: in Class I, the apex is located rostral to the first maxillary cheek tooth in the diastema area; in Class II, the

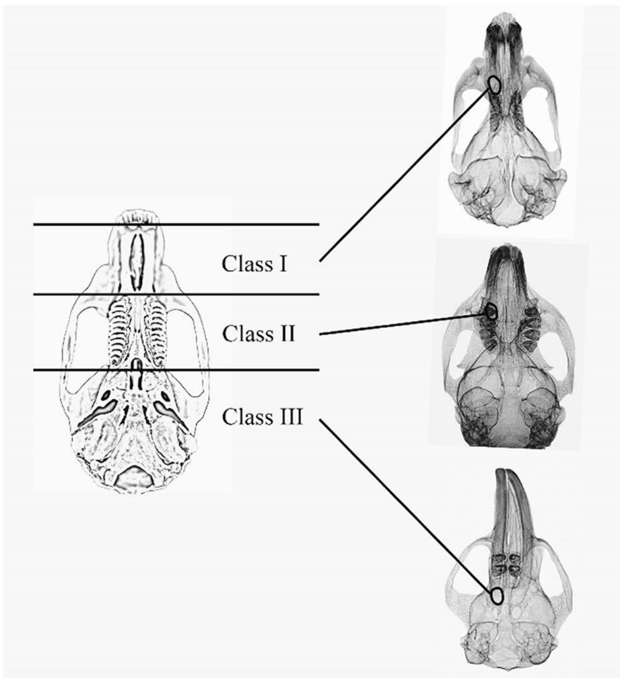

Fig.1 A maxillary incisor tooth apex location classification system was developed in this study. Apex presence was classified into three classes based on where it is positioned in the nasal cavity relative to the maxillary cheek teeth

apex is positioned between the first cheek tooth and the last cheek tooth and in Class III, the apex is located caudal to the last cheek tooth.

Data is provided within the manuscript or supplementary information files. Microsoft Excel (Microsoft Corporation, version 2024, Redmond, WA) was used for descriptive statistical analysis.

3 Results

A total of 376 dry rodent skulls, collected over 81 years (1916–1997), were examined and radiographed. Of these, 62.8% were collected in the 1970 s–1980 s. The skulls represented nine rodent families, 35 genera, and 63 species indigenous to South Africa (Table 1). The species with the most specimens evaluated was the South African vlei rat (*Otomys irriratus,* 12 skulls), while the Stone dormouse (*Graphiuris rupicola)* had only a single specimen available. The median number of skulls examined per species was five. The sex distribution was nearly even, with 47.3% (178) identified as male, 48.9% (184) as female, and 3.7% (14) of unknown sex. All South African provinces were represented, with the Limpopo province being the most diverse (27.0% of species), followed by the Northern Cape (23.8%). The KwaZulu-Natal, Mpumalanga, North West, Western Cape, Eastern Cape, and Gauteng provinces had a fairly even distribution (15.9%–19.0%), while the Free State was the least diverse (6.3%). In all examined skulls, no elodontomas or observable bony growths were detected at the apices of any maxillary or mandibular incisor teeth and none were associated with any other teeth (Table 1).

Applying the classification system to describe the radiographs: the maxillary incisor tooth apex was most commonly classified as Class I (80.95%) (51/63 rodent species). Class II was only present in 14.29% of rodents (9/63) and Class III had the least number of species 4.76% (3/63) (Table 1). In general, all the examined rodent species in a family had similar apex locations within the maxillary bone, except for outliers within the Muridae (All were Class I, except for Grant's rock mice (*Micaelamys granti)* in Class II), Gliridae (All were Class II, except for Spectacled dormice (*Graphiurus ocularis)* and Stone dormice (*Graphiurus rupicola)* in Class I), Sciuridae (All were Class II except for Bush squirrels (*Paraxerus cepapi)* and Red bush squirrels (*Paraxerus palliates)* in Class I) and Bathyergidae families (All were Class III except for Namaqya dune rats (*Bathyergus janetta*)and Cape dune mole-rats (*Bathyergus suillus)* in Class II) (Table 1).

4 Discussion

The total number of indigenous rodent species in South Africa is estimated at 80, with the molecular expansion of the *Cryptomys* and *Rhabdomys* species and including the introduced Eastern grey squirrel (*Sciurus carolinensis*) [4, 39]. The *Cryptomys* and *Rhabdomys* species are grouped in the museum and have not been separated and are regarded as *senso lato* (s.l.), that is in the broader sense. Most of the species endemic to South Africa were included in the radiographic examination, except for ten species that were not available, namely the Red rock rats (*Aethomys chrysophilus*), Neave's mice (*Mus neavei*), Fynbos vlei rats (*Otomys karoensis*), Laminate vlei rats (*Otomys laminatus*), Tanezumi rats (*Rattus tanezumi*), Cape marsh rats (*Dasymys capensis*), Robert's shaggy rats (*Dasymys robertsii*), Shortridge's rats (*Thallomys shortridgei*), Black-tailed tree rats (*Thallomys nigricauda*), and Brukkaros pygmy rock mice (*Petromyscus monticularis*) [4, 39].

Elodontomas or complex odontomas appear to be more common in captive rodents than in wild populations, according to most reports [16–18, 20]. Potential hypothesised risk factors associated with captivity, such as trauma and dietary irregularities, could contribute to the formation of daughter islands of germ cells, which subsequently produce odontogenic growths [16, 40]. Therefore, not surprisingly, the radiographic screening of rodents collected as wild specimens for a museum collection did not reveal any cases of elodontomas (Table 1), with findings aligning with the predominance of elodontomas being reported in captive rodents, further suggesting a link between captivity and this condition [16]. An exception to this was odontoma-like growths present at the incisor apices of free-living Red squirrels (*Sciurus vulgaris*), presumably from trauma [41].

The position of the maxillary incisor tooth apex can be a risk factor for elodontoma-induced respiratory distress, rendering certain rodent families more susceptible to airway obstruction from expanding elodontomas due to anatomical variations. This statement was based on a study by Rodriguez-Ramos Fernandezet al. (2010), where respiratory signs were not observed in voles as opposed to Black-tailed prairie dogs, degus, or squirrels [32]. Expanding on this, we developed a classification system to determine the position of the maxillary incisor tooth apex relative to the oronasal opening as this would explain why certain species experience respiratory distress and others do not. In the literature, Black-tailed prairie dogs (Class II) are often diagnosed with dyspnoea related to maxillary incisor tooth elodontomas or complex odontomas

Table 1 The 376 specimens of indigenous South African rodent skulls examined radiographically for the anatomical location of the maxillary incisor tooth apex and the presence of elodontomas

Family and Subfamily	Genus	Species	No. specimens examined	Elodontoma presence	Mx. Incisor apex location
Pedetidae	Family of rodents that include springhares				
1	*Pedetes*	*capensis*	5	ND	Class I
Muridae	Large family of rodents with diverse subfamilies which include gerbils, rats and mice				
Gerbillinae	Subfamily that includes gerbils				
2	*Gerbilliscus*	*afra*	5	ND	Class I
3	*Gerbilliscus*	*brantsii*	5	ND	Class I
4	*Gerbilliscus*	*leucogaster*	9	ND	Class I
5	*Gerbillurus*	*paeba*	11	ND	Class I
6	*Gerbillurus*	*vallinus*	5	ND	Class I
7	*Desmodillus*	*auricularis*	5	ND	Class I
Murinae	Subfamily that includes Old World rats and mice				
8	*Aethomys*	*ineptus*	8	ND	Class I
9	*Dasymys*	*incomtus*	10	ND	Class I
10	*Grammomys*	*cometes*	6	ND	Class I
11	*Grammomys*	*dolichurus*	7	ND	Class I
12	*Lemniscomys*	*rosalia*	6	ND	Class I
13	*Mastomys*	*coucha*	5	ND	Class I
14	*Mastomys*	*natalensis*	6	ND	Class I
15	*Micaelamys*	*granti*	5	ND	Class II
16	*Micaelamys*	*namaquensis*	6	ND	Class I
17	*Mus*	*indutus*	5	ND	Class I
18	*Mus*	*minutoides*	5	ND	Class I
19	*Mus*	*musculus*	5	ND	Class I
20	*Myomyscus*	*verreauxii*	5	ND	Class I
21	*Otomys*	*angoniensis*	6	ND	Class I
22	*Otomys*	*auratus*	6	ND	Class I
23	*Otomys*	*irroratus*	12	ND	Class I
24	*Otomys*	*sloggetti*	6	ND	Class I
25	*Otomys*	*unisulcatus*	6	ND	Class I
26	*Parotomys*	*brantsii*	5	ND	Class I
27	*Parotomys*	*littledalei*	8	ND	Class I
28	*Rattus*	*norvegicus*	4	ND	Class I
29	*Rattus*	*rattus*	5	ND	Class I
30	*Rhabdomys*	*s.l*	6	ND	Class I
31	*Thallomys*	*paedulcus*	6	ND	Class I
32	*Zelotomys*	*woosnami*	5	ND	Class I
Deomyinae	Subfamily that contains mouse-like rodents				
33	*Acomys*	*selousi*	6	ND	Class I
34	*Acomys*	*subspinosus*	6	ND	Class I
Nesomyidae	Superfamily of rodents that include climbing mice, African rock mice, swamp mice, pouched rats, and the white-tailed rat				
Mystromyinae	The white-tailed mouse is the only member of this subfamily				
35	*Mystromys*	*albicaudatus*	5	ND	Class I
Cricetomyinae	Subfamily that contains the pouched rats				
36	*Saccostomus*	*campestris*	5	ND	Class I
37	*Cricetomys*	*ansorgei*	8	ND	Class I
Dendromurinae	Subfamily that contains the African climbing mice				
38	*Dendromus*	*melanotis*	8	ND	Class I
39	*Dendromus*	*mesomelas*	5	ND	Class I

Table 1 (continued)

Family and Subfamily	Genus	Species	No. specimens examined	Elodontoma presence	Mx. Incisor apex location
40	*Dendromus*	*mystacalis*	5	ND	Class I
41	*Dendromus*	*nyikae*	5	ND	Class I
42	*Malacothrix*	*typica*	5	ND	Class I
43	*Steatomys*	*krebsii*	5	ND	Class I
44	*Steatomys*	*pratensis*	5	ND	Class I
Petromyscinae	Subfamily of rock mice				
45	*Petromyscus*	*barbouri*	6	ND	Class I
46	*Petromyscus*	*collinus*	5	ND	Class I
Gliridae	Family of dormice				
47	*Graphiurus*	*microtis*	5	ND	Class II
48	*Graphiurus*	*murinus*	6	ND	Class II
49	*Graphiurus*	*ocularis*	6	ND	Class I
50	*Graphiurus*	*platyops*	7	ND	Class II
51	*Graphiurus*	*rupicola*	1	ND	Class I
Sciuridae	Family of squirrels				
52	*Paraxerus*	*cepapi*	5	ND	Class I
53	*Paraxerus*	*palliatus*	5	ND	Class I
54	*Geosciurus*	*inauris*	5	ND	Class II
55	*Geosciurus*	*princeps*	5	ND	Class II
Hystricidae	Family of Old World porcupines				
56	*Hystrix*	*africaeaustralis*	5	ND	Class I
Petromuridae	Family that contains only one member, the dassie rat				
57	*Petromus*	*typicus*	10	ND	Class I
Thryonomyidae	Family of rodents that contain cane rats				
58	*Thryonomys*	*swinderianus*	5	ND	Class II
Bathyergidae	Family of rodents that contain the mole rats				
59	*Bathyergus*	*janetta*	9	ND	Class II
60	*Bathyergus*	*suillus*	6	ND	Class II
61	*Fukomys*	*damarensis*	5	ND	Class III
62	*Georychus*	*capensis*	6	ND	Class III
63	*Cryptomys*	*s.l*	7	ND	Class III

ND, not detected; Mx, maxilla; No., Number

[16, 27, 28]. Similarly, Smith's bush squirrel (*Paraxerus cepapi*) and Richardson's ground squirrels (*Urocitellus richardsonii*) with elodontomas and pseudo-odontomas have also been cited to develop dyspnoea and can be classified as Class I (almost Class II) and Class II, respectively [8, 42]. Applying this classification system to the specimens in this study (Table 1), the families of Sciuridae, Gliridae, and Thryonomyidae could thus be more vulnerable to respiratory distress due to elodontomas, as they are Class II. We postulate that Class I and Class III rodents would be less affected by respiratory signs if affected with elodontomas, unlike in Class II rodents, as their apex is not located near the nasopharyngeal constriction.

Further analysis of the abovementioned exceptions or outliers, in the results of species within a family with a different classification, has led to the following observations. Stone dormice (*Graphiurus rupicola)* is restricted to the Western parts of South Africa and Spectacled dormice (*Graphiurus ocularis)* is restricted to the Southern parts of South Africa. Rock dormice (*Graphiurus platyops)* and Small-eared dormice (*Graphiurus microtis)* prefer the Northern savannas, whilst Woodland dormice (*Graphiurus murinus)* are found in the montane areas of the Eastern parts of South Africa. The difference in incisor classification could indicate an East–West geographical difference which could also explain why *Graphiurus rupicola* and *Graphiurus ocularis* in the Greater Karoo biodiversity region fall within Class I and the other members in the Gliridae fall within Class II [43]. Grant's rock mouse (*Micaelamys granti)* is also a rodent with a limited distribution within the Karoo biome, which could explain its classification as an outlier [43]. The *Bathyergus* species are scratch-diggers, in contrast to the other mole-rats that are chisel-tooth diggers [44]. This potentially explains the difference in the location

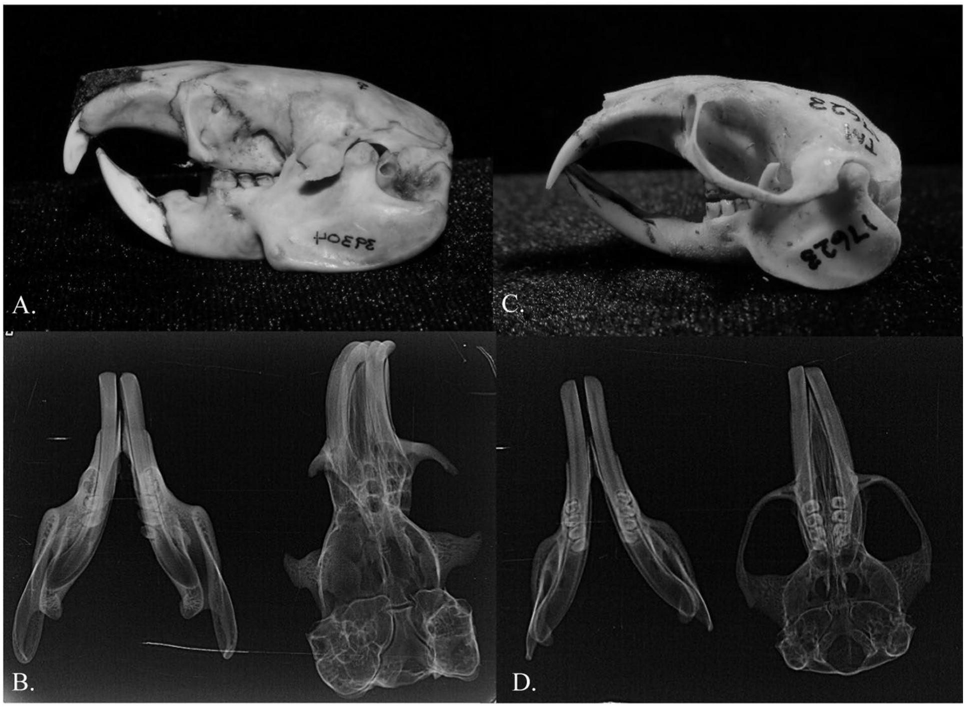

Fig. 2 **A** Photo of *Bathyergus janetta* articulated skull lateral view, **B** Radiograph of *Bathyergus janetta* skull de-articulated. **C** Photo of *Cryptomys s.l.* articulated skull lateral view, **D** Radiograph of *Cryptomys s.l.* de-articulated skull. Example of scratch-digger (**A**, **B**) and chisel-tooth digger (**C**, **D**) maxillary incisor apex locations, with chisel-tooth digger maxillary apices located more caudal

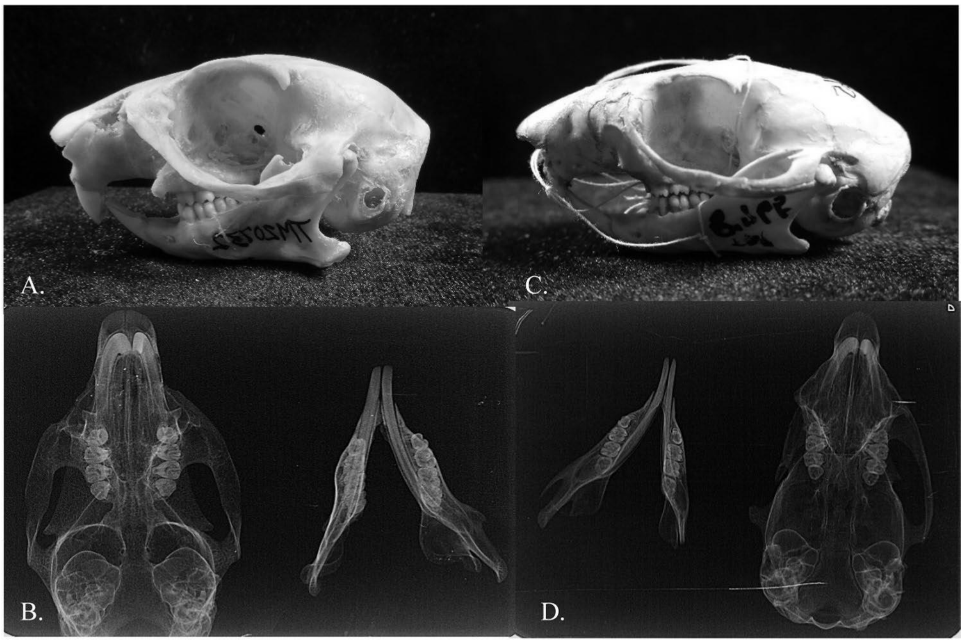

Fig. 3 **A** Photo of *Geosciurus inauris* articulated skull lateral view, **B** Radiograph of *Geosciurus inauris* skull de-articulated. **C** Photo of *Paraxerus palliatus* articulated skull lateral view, **D** Radiograph of *Paraxerus palliatus* skull de-articulated. Example of semi-fossorial (**A**, **B**) and arboreal (**C**, **D**) maxillary incisor apex locations, with semi-fossorial maxillary apices located more caudal

of the apex of the maxillary incisor teeth in chisel-tooth diggers (Fig. 2), as their tooth arc is longer to absorb the forces of digging [45].

Additionally, the distinct environmental and dietary adaptations of the *Paraxerus* and *Geosciurus* species may explain differences in their incisor classification (Fig. 3). *Paraxerus* species, as tree squirrels, have evolved for an arboreal lifestyle, favouring fruit-based diets and requiring strong, sharp incisors suited for gnawing through tough plant material. In contrast, *Geosciurus* species are semi-fossorial ground squirrels with slight cranial adaptations for subterranean activity that primarily browse on grasses [46, 47]. These differences suggest that the specific demands of climbing, grasping, and processing fruit may have influenced the incisor structure in *Paraxerus*, just as burrowing behaviours have shaped the cranial features in *Geosciurus*.

Despite the large number of specimens studied here, the small number of samples per species is a limitation and the authors suggest that future studies should include larger numbers of specimens per species.

5 Conclusion

Elodontomas or any peri-apical masses around elodont teeth were absent in the wild South African rodents evaluated in this study, supporting the opinion that captivity-related factors contribute to their development. This work also introduced a classification system for maxillary incisor apex positioning, linking Class II rodents (e.g., Sciuridae, Gliridae, Thryonomyidae) to a higher risk of respiratory distress from elodontomas, while Class I and III rodents appear to be less affected.

Variations in classification suggest that environmental, dietary, and biomechanical adaptations influence incisor positioning and in turn elodontomas formation, while geographic distribution may explain certain outliers. This study is the first large-scale radiographic screening of wild rodent skulls for elodontomas in Africa and the first to apply an incisor classification system, laying the groundwork for future research and clinical application.

Acknowledgements The authors would like to thank Teresa Kearney, curator of the Vertebrate Department, Small Mammals, DNMNH for the help with the specimens in the museum archive.

Author contributions QN – concept and design, acquisition of data, analysis and interpretation of data, drafting article, final approval of completed article, agreement to be accountable. GS – concept and design, analysis and interpretation of data, reviewing article, final approval of completed article, agreement to be accountable. AT – concept and design, analysis and interpretation of data, drafting article, final approval of completed article, agreement to be accountable.

Funding The research was funded by the developmental fund from the Department of Companion Animal Clinical Studies and an Agri-SETA post-graduate scholarship by the Department of Veterinary Tropical Diseases (DVTD), Faculty of Veterinary Science, University of Pretoria.

Data availability Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate Not applicable.

Competing interests The authors declare no competing interests.

References

1. Mancinelli E, Capello V. Anatomy and disorders of the oral cavity of rat-like and squirrel-like rodents. Vet Clin North Am Exot Anim Pract. 2016;19(3):871–900. https://doi.org/10.1016/j.cvex.2016.04.008.
2. Auffray J-C, Renaud S, Claude J. Rodent biodiversity in changing environments. Agric Nat Resour. 2009;43(1):83–93.
3. Wilson DE, Reeder DM. Mammal species of the world : a taxonomic and geographic reference. 3rd ed. Baltimore: Johns Hopkins University Press (in English); 2005.
4. Monadjem A, Taylor PJ, Denys C, Cotterill FP, Rodents of sub-Saharan Africa: a biogeographic and taxonomic synthesis. Walter de Gruyter GmbH & Co KG, 2015.
5. Rymer TL, Pillay N, Schradin C. Extinction or survival? Behavioral flexibility in response to environmental change in the African striped mouse Rhabdomys. Sustainability. 2013;5(1):163–86.
6. Crossley DA, Aiken S, "Small mammal dentistry," In: Ferrets, rabbits, and rodents: clinical medicine and surgery, 2nd ed. St Louis, MO, USA: Elsevier Saunders, 2004, pp. 370–379.
7. Capello V. Diagnosis and treatment of dental disease in pet rodents. J Exot Pet Med. 2008;17(2):114–23. https://doi.org/10.1053/j.jepm.2008.03.010.

8. Boy SC, Steenkamp G. Odontoma-like tumours of squirrel elodont incisors-elodontomas. J Comp Pathol. 2006;135(1):56–61. https://doi.org/10.1016/j.jcpa.2006.03.002.
9. Ohshima H, Nakasone N, Hashimoto E, Sakai H, Nakakura-Ohshima K, Harada H. The eternal tooth germ is formed at the apical end of continuously growing teeth. Arch Oral Biol. 2005;50(2):153–7. https://doi.org/10.1016/j.archoralbio.2004.09.008.
10. Kuang-Hsien Hu J, Mushegyan V, Klein OD. On the cutting edge of organ renewal: identification, regulation, and evolution of incisor stem cells. Genesis. 2014;52(2):79–92. https://doi.org/10.1002/dvg.22732.
11. Tummers M, Thesleff I. Root or crown: a developmental choice orchestrated by the differential regulation of the epithelial stem cell niche in the tooth of two rodent species. Development. 2003;130(6):1049–57. https://doi.org/10.1242/dev.00332.
12. Kertesz P, Colour atlas of veterinary dentistry & oral surgery. Wolfe Publishing, 1993.
13. Kumar V, Abbas AK, Aster JC, Perkins JA, Robbins basic pathology, Tenth edition. ed. (Basic pathology). Philadelphia, Pa: Elsevier, 2018.
14. Pindborg JJ, Reichart P, Smith C, Van der Waal I, Histological typing of cancer and precancer of the oral mucosa: in collaboration with LH Sobin and Pathologists in 9 Countries. Springer Science & Business Media, 2012.
15. Barnes L, Eveson J, Reichart P, Sidransky D, World Health Organization classification of tumours: pathology and genetics of head and neck tumours, 2005.
16. Thas I, Wagner RA, Thas O. Clinical diseases in pet black-tailed prairie dogs (*Cynomys ludovicianus*): a retrospective study in 206 animals. J Small Anim Pract. 2019;60(3):153–60. https://doi.org/10.1111/jsap.12974.
17. Donnelly TM, Bergin I, Ihrig M, Biology and diseases of other rodents, In: Laboratory Animal Medicine, 2015, pp. 285–349.
18. Jekl V, Hauptman K, Knotek Z. Diseases in pet degus: a retrospective study in 300 animals. J Small Anim Pract. 2011;52(2):107–12. https://doi.org/10.1111/j.1748-5827.2010.01028.x.
19. Osofsky A, Verstraete FJM. Dentistry in pet rodents. Comp Cont Educ Pract. 2006;28(1):61–73.
20. Wagner R, Johnson D. Rhinotomy for treatment of odontoma in prairie dogs. Exotic DVM. 2001;3(5):29–34.
21. Colby LA, Rush HG, Mahoney MM, Lee TM, Degu, In: The laboratory rabbit, guinea pig, hamster, and other rodents, 2012, pp. 1031–1053.
22. Thas I, Garner MM. A retrospective study of tumours in black-tailed prairie dogs (*Cynomys ludovicianus*) submitted to a zoological pathology service. J Comp Pathol. 2012;147(2–3):368–75. https://doi.org/10.1016/j.jcpa.2012.01.016.
23. Capello V. Incisor extraction to resolve clinical signs of odontoma in a prairie dog. Exotic DVM. 2002;4(1):9–9.
24. Levy BA. Effects of experimental trauma on developing first molar teeth in rats. J Dent Res. 1968;47(2):323–7. https://doi.org/10.1177/00220345680470022101.
25. Capello V, Maxillary cheek tooth elodontoma in a guinea pig, In: Association of Avian Veterinarians, 2010, pp. 93–102.
26. Ignaszak-Dziech J, Kuropka P, Piasecki T. Histological characteristics of macrodontic cheek teeth of guinea pigs. BMC Vet Res. 2023;19(1):12. https://doi.org/10.1186/s12917-023-03567-7.
27. Wagner RA, Garman R, Collins B. Diagnosing odontomas in prairie dogs. Exotic DVM. 1999;1(1):7–10.
28. Smith M, Dodd JR, Hobson HP, Hoppes S. Clinical techniques: surgical removal of elodontomas in the black-tailed prairie dog (*Cynomys ludovicianus*) and eastern fox squirrel (*Sciurus niger*). J Exot Pet Med. 2013;22(3):258–64. https://doi.org/10.1053/j.jepm.2013.08.006.
29. Pelizzone I, et al. Computed tomographic features of incisor pseudo-odontomas in prairie dogs (*Cynomys Ludovicianus*). Vet Radiol Ultrasound. 2017;58(3):273–83. https://doi.org/10.1111/vru.12475.
30. Legendre LF. Oral disorders of exotic rodents. Vet Clin North Am Exot Anim Pract. 2003;6(3):601–28. https://doi.org/10.1016/s1094-9194(03)00041-0.
31. Harkema JR, Morgan KT, Normal morphology of the nasal passages in laboratory rodents, In: Respiratory system: Springer, 1996, pp. 3–17.
32. Rodriguez-Ramos Fernandez J, et al. Elodontoma in captive southern red-backed voles (*Myodes gapperi*). J Zoo Wildl Med. 2010;41(3):555–61. https://doi.org/10.1638/2009-0244.1.
33. Phalen DN, Antinoff N, Fricke ME. Obstructive respiratory disease in prairie dogs with odontomas. Vet Clin North Am Exot Anim Pract. 2000;3(2):513–7. https://doi.org/10.1016/s1094-9194(17)30085-3.
34. Bulliot C, Mentré V. Original rhinostomy technique for the treatment of pseudo-odontoma in a prairie dog. J Exot Pet Med. 2013;22(1):76–81. https://doi.org/10.1053/j.jepm.2012.12.012. (**In English**).
35. Jang DD, et al. Spontaneous complex odontoma in a Sprague-Dawley rat. J Vet Med Sci. 2002;64(3):289–91. https://doi.org/10.1292/jvms.64.289.
36. Pelizzone I, Vitolo GD, D'Acierno M, Stefanello D, Forlani A, Broich G. Lateral approach for excision of maxillary incisor pseudo-odontoma in prairie dogs (*Cynomys ludovicianus*). In Vivo. 2016;30(1):61–7.
37. Samour J, Exotic animal medicine-review and test-E-book, 2012.
38. Boy SC, Steenkamp G. Odontoma-like tumours of squirrel elodont incisors—elodontomas. J Comp Pathol. 2006;135(1):56–61. https://doi.org/10.1016/j.jcpa.2006.03.002.
39. Linchamps P, Avery DM, Cornette R, Denys C, Matthews T, Stoetzel E. Quaternary rodents of South Africa: a companion guide for cranio-dental identification. PLoS ONE. 2023;18(11): e0289812.
40. Steenkamp G, Venter L, Crossley D, Buss P. Mandibular incisor apicoectomy in a Canadian beaver. J Vet Dent. 2009;26(3):164–7.
41. Sainsbury AW, Kountouri A, DuBoulay G, Kertesz P. Oral disease in free-living red squirrels (*Sciurus vulgaris*) in the United Kingdom. J Wildl Dis. 2004;40(2):185–96. https://doi.org/10.7589/0090-3558-40.2.185.
42. Takami Y, Une Y. Removal of pseudo-odontomas via lateral maxillotomy in three Richardson's ground squirrels (*Urocitellus Richardsonii*). J Zoo Wildl Med. 2022;53(3):600–4. https://doi.org/10.1638/2021-0099.
43. Main D, et al. Unravelling the taxonomy and distribution of two problematic small mammal genera in the Karoo biome. Afr Zool. 2019;54(3):125–35. https://doi.org/10.1080/15627020.2019.1628661. (**In English**).
44. McIntosh AF, Cox PG. Functional implications of craniomandibular morphology in African mole-rats (Rodentia: Bathyergidae). Biol J Lin Soc. 2016;117(3):447–62. https://doi.org/10.1111/bij.12691. (**In English**).
45. McIntosh AF, Cox PG. The impact of digging on craniodental morphology and integration. J Evol Biol. 2016;29(12):2383–94.
46. Menéndez I, et al. Dietary adaptations and tooth morphology in squirrels: Insights from extant and extinct species. Palaeogeogr Palaeoclimatol Palaeoecol. 2023;629: 111788.

47. GomesRodrigues H, Damette M. Incipient morphological specializations associated with fossorial life in the skull of ground squirrels (Sciuridae, Rodentia). J Morphol. 2023;284(1):e21540.