Histological characteristics of macrodontic cheek teeth of the guinea pig

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Research Article

Keywords: Guinea pig, macrodont, odontoma, hamartoma, structural alteration, cheek teeth

Posted Date: October 6th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2082197/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at BMC Veterinary Research on January 19th, 2023. See the published version at https://doi.org/10.1186/s12917-023-03567-7.
Abstract

Macrodontia is the enlargement of tooth dimensions of different ethology. The work aims to show a histological picture of macrodontic teeth in guinea pigs. The material was obtained from animals post mortem. 90 structural changes derived from 24 guinea pigs were evaluated. All teeth used in the study showed macrodontic changes. The samples were decalcified, dehydrated and embedded in paraffin. Material was cutted in the transverse and longitudinal plane in relation to the alveolar bone. Histological evaluation included apical bud cells, pulp cavity cells, periodontium, dentin, enamel, cementum and alveolar bone tissue. Individual elements were evaluated in respect of morphology and distribution. Moreover, the arrangement of the individual hard tooth structures was assessed on the teeth. No atypia of the cells that make up the apical bud as well as pulp and periodontal cavity was found. Displacement of periodontal cells or odontoblasts towards pulp cavity as well as disorganization of the cell system in the pulp cavity were observed. Changes in the dentine ligaments and the reconstruction of the alveolar bone were also observed in areas where dentine and cement systems were affected. It was observed on dental slides that the enamel is also involved in structural remodeling of the pulp cavity. Histological assessment led to the finding that structural changes in macrodontic teeth are made up of re-arranged typical tooth tissues.

Introduction

Guinea pig (Cavia porcellus) belongs to order Rodentia, suborder Hystricomorpha. Dentition of this species consists of 20 teeth in 4 arcades, the dental formula is as follows: $I_1^1 C_0^0 P_1^1 M_3^3$. All teeth are hypsodontic - with a long crown, which can be divided into clinical and reserve crown, aradicular - the apex remains opened throughout all life and do not create any root, elodontic - growth throughout all life and in the mouth cavity they constantly worn down (1). The histological study we conducted concerned only cheek teeth of guinea pigs.

Constant growth of the cheek teeth of the guinea pig is possible thanks to the presence of the apical bud, within which stem cells capable of dividing are located. Cells of epithelial origin responsible for the production of the enamel contact with the odontoblasts responsible for production of the dentin. The space limited by the dentin is called the pulp cavity filled with connective tissue, cells of mesenchymal origin, vessels and nerves. On the longitudinal section of the cheek tooth we can see two pulp cavities, which at the bottom of the alveolus join together to form the tooth apex. The space between the alveolar bone and the tooth is called the periodontal space, which is filled with cells of mesenchymal and epithelial origin, vessels, nerves, collagen fibres forming periodontal ligaments. The periodontal ligaments provide stabilization of the tooth in the alveolus as a result of the combination of the bone and the cementum pearls on the enamel surface. In addition to cementum pearls, we can distinguish the acellular cementum on the buccal surface of the maxillary cheek teeth and on the lingual surface of the mandibular cheek teeth as well as cartilage like cementum between tooth pillars. (2, 3, 4, 5, 6) (Fig. 1).
In this study only teeth with structural alterations leading to enlargement of the tooth size which is called macrodontia were examined. This term appears comparatively rarely in the specialized literature (7, 8, 9, 10), is interchangeably used with “giant tooth” or “crippled tooth” (7). This paper aims to show histological characteristics of structural changes of macrodontic cheek teeth of the guinea pigs.

**Materials And Methods**

The material was obtained during routine necropsies performed at the Department of Epizootiology and Clinic of Birds and Exotic Animals Wroclaw University of Environmental and Life Science. Macroscopic evaluation of dental arcades was conducted. The dental arcades were collected from 24 animals, in which at least one tooth showed structural changes on the occlusal surface or had structural alterations and was larger than the rest of the teeth from this arcade. A total of 72 structurally changed teeth were found in the 44 acquired dental arcades.

Histological examination.

26 dental arcades were selected for the histological examination, within each 47 teeth with morphological changes were found. The material was fixed in 10% buffered formalin for 72h, then the fixed material was cleaned from soft tissues. Next, the material was decalcified with ethylene diamine tetra-acetic acid (EDTA) and hydrochloric acid in prep. TBD – 1 Rapid Decalcifer (Thermo Scientific). After 36h the material was rinsed in tap water, dehydrated in ascending grades of alcohol, cleared in xylol and embedded in paraffin wax. Specimens of 5 µm thickness were made in the transverse and longitudinal plane in relation to the long axis of the alveolus. The specimens were stained with Hematoxylin and Eosin (H&E). (11)

The section slides were analysed and photographed using Nikon Eclipse 80i microscope at magnification of x40, x100, x200 (Nikon, Melville, NY) provided with a video camera and NIS-Elements AR 2.30 (Nikon, Melville, NY) software. The evaluation included apical bud cells, pulp cavity cells, periodontium, dentin, cementum, alveolar bone tissue. The tissues were evaluated regarding distribution and morphology.

Histological examination using ground sections

25 morphologically changed teeth within 18 dental arcades were selected for the study. The material fixed in 10% buffered formalin, fixed material was cleaned from soft tissues. 12 morphologically changed teeth isolated from dental arcades and cut into 3 equal parts perpendicularly to the long axis of the alveolus using a sectioning machine having diamond disc under water spray. The remaining 13 teeth with morphological changes were cut within the arcade preserving the alveolar bone structure. The cutting of the material was performed in the same way as for the isolated teeth. The obtained fragments of the dental crowns and dental arcades were subject to abrasion with papers with gradually reduced granularity (500, 700) until transparent preparations were obtained. The thickness of the specimens was performed. The material with a thickness approximately 100 µm was placed on clean glass slides. The section slides were analysed and photographed using Nikon Eclipse 80i microscope at magnifications of
x40, x100, x200 (Nikon, Melville, NY) provided with a video camera and NIS-Elements AR 2.30 (Nikon, Melville, NY) software. The evaluation included distribution of the individual hard elements of the tooth and the alveolar bone. (11)

Results

Distribution of the alterations

A total of 72 altered teeth (PM4: 1, M1: 11, M2: 28, M3: 32) within 44 dental arcades were examined. Firstly the distribution of the alterations within the crown was evaluated. On the transverse section of the crown we can determine the mesial (anterior) part in an “I” shape and distal (posterior) part in a “V” shape. In 54/72 (75,0%) cases the structural change was found in only one part of the tooth crown (37 (68,52%) in the mesial part, 18 (31,48%) in the distal part). In 18/72 (25,0%) cases the structural change was found in both the mesial and distal part. In such situation each alteration was evaluated individually in terms of morphology in further stages of work. A total of 90 structural changes were found within 72 macrodontic cheek teeth. (Fig. 2)

When evaluating the distribution of changes it was observed that the structural remodelling occurred within the pulp cavity or at the edge of the tooth crown. Firstly it was observed that the changes of cells and tissue distribution occur in the central part of the pulp cavity whereas the dentin forming the walls of the pulp cavity is not subject to deformation (Fig. 3). Such changes were found in 45/90 (50%) cases. In 43/90 (47,77%) cases various degrees of the dentin deformation and dentin indentations (concavities) from the periodontal space towards tooth pulp were observed (Fig. 4). In such cases no cells and tissue distribution changes within the pulp cavity were observed. In 2/90 (0,02%) cases the entire crown of the tooth underwent structural remodelling and it was not possible to access whether the changes derived from the pulp cavity or the periodontal space.

Morphology of the alterations

No atypia of tooth building cells was found, only the rearrangement of cells and tissue physiologically occurring within the tooth crown. The following tissues were observed to be involved in the construction of changes: osteodentin, tubular dentin, dental pulp cells, cartilage - like cementum or the cells which are precursors of cartilage like cementum. The data on the contribution of individual tissues in the formation of changes are placed in Table 1
Table 1
Participation of individual tissues in the construction of structural changes.

<table>
<thead>
<tr>
<th>Location of the change</th>
<th>Tissue that build a change</th>
<th>Osteodentin, tubular dentin, dental pulp cells, cartilage-like cementum (CC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes with dentin deformation</td>
<td>Osteodentin</td>
<td>Tubular dentin, dental pulp cells, cartilage – like cementum (CC)</td>
</tr>
<tr>
<td>Changes within the pulp cavity</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>Changes within the whole tooth</td>
<td>2</td>
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</table>

Alterations with dentin deformation are those in which the concavities observed above the apical bud towards the pulp cavity without breaking the dentin continuity or prominence (protrusions) resembling dentin fractures towards the periodontal space and alveolar bone. The space formed by the dentin indentation is filled with tissue of epithelial origin from which cementoblasts are formed and attached to periodontium. In some cases the presence of odontoblasts forming additional dentin bundles in the periodontal space has been found (Fig. 5). It has been noticed that enamel participates in the formation of the alterations with dentin deformation. However in areas where the dentin protrudes toward the periodontal space the enamel thins or disappears which also affects the arrangements of periodontal ligaments (Fig. 6). The periodontal ligaments accumulate and concentrate on the dentin fragment lacking enamel (Fig. 6). No enamel presence was noted in the structural changes in the pulp cavity. In 23 of those changes the presence of variously shaped formation composed of osteodentin was observed which occurred individually to form a column extending vertically within the crown from the apex to the occlusal surface or in clusters of several smaller changes. In the structure a remaining 20 alterations variously shaped formations composed of tubular dentin were observed. In this case the arrangement of tubules was often disorganized (Fig. 7a). Dental pulp cells, cementoblasts and cementum and in 6 cases also the osteodentin were trapped between dentin bunds or in rings made of tubular dentin (Fig. 7b). Regardless of the location of structural remodelling the shape of the tooth and its size were changed and the alveolar bone was remodelled adjusting to the new shape of the tooth. In 29 cases it was possible to evaluate the occlusal surface of the tooth crown and in 8 of these cases loss of the enamel, dentin and cementum were found on the edge of the altered part of the tooth. In such cases the presence of plant remains and bacteria was observed in the interdental space and within the tooth tissues on the occlusal surface (Fig. 8).

Discussion

Macrodont is by definition the tooth that is larger than normal (12). This statement is also found in specialized literature, both veterinary and dental (7, 8, 10, 12, 13, 14). In the conducted study the presence
of characteristic structural changes within the macrodontic cheek teeth of the guinea pig was found. Similarly one author observed structural deformities and splitting of the teeth with enlarged outlines (7). The same author used the terms “giant tooth” and “crippled teeth” to describe this pathology. It is difficult to compare the observed structural alterations to possible changes found in human macrodontic teeth, as there are few papers in the available literature describing the histopathology of these teeth. However, according to Komatsu et al., the development of macrodontic tooth in humans occurs in the bell stage. The constantly growing cheek tooth of the guinea pig remains in the bell stage throughout the animal's life. In the work of Komatsu et al., in the histological examination of the human macrodontic tooth showed enamel hypoplasia, dentin abnormalities, hypertrophy of the cementum and immature enamel. Similar changes were observed in the examined cheek teeth of the guinea pig in areas where there was thinning or complete loss of the enamel on the dentin surface. In such situations the cementum filled the areas where dentin had been driven into the pulp cavity. Köestlinger et al. (8, 9) twice found that 90% of macrodontic cheek teeth are M2 and M3. We obtained similar results during histological evaluation as 87% of lesions in our study are located within M2 and M3 teeth.

Due to the presence of structural alterations in the examined teeth the possibility of odontogenic tumours was suspected. Structural changes in macrodontic teeth of guinea pig are composed of physiologically occurring hard and soft tissue of the tooth with disordered arrangement, whereas the cells do not show any signs of atypia. The possibility of the odontogenic cysts was rejected first. The changes of epithelial origin not containing ectomesenchymal components were also eliminated (ameloblastoma). Alterations containing both epithelial and ectomesenchymal components in the structure (ameloblastic fibroma, ameloblastic odontoma, dentinoma, odontoma) were carefully analysed (15). Among many odontogenic tumours the posted description is most compatible with an odontoma. Odontomas are benign tumorlike malformation of the hard tissue of the tooth and arise from disorders of the division of the dental lamina. They are built of epithelial and ectomesenchymal components hence in the structure we can see tissues such as: enamel, dentin, cementum, dental pulp, their arrangement can be normal or disrupted but the cells do not show changes. Due to their structure odontomas are more likely to be classified as hamartomas (non-neoplastic tumours). There are 2 types of odontomas: compound odontoma (odontoma compositum), altered tissues form structures that anatomically resemble teeth (odontoids), a small remnants of epithelial tissue are found within the changes. The second type is called complex odontoma (odontoma completum), which is a chaotic mass of hard and soft tissue of the tooth that shows no morphological resemblance to a properly formed tooth (13, 16, 17). Variations of this type have so far been described for many animal species including: dogs, cats, voles, (18) squirrels (19), prairie dogs (20, 21, 22), mouse (23, 24), rats (25), degus (26), guinea pigs (27). However due to different structure of brachydontic and elodontic rodent teeth a different name has been proposed in the literature for the change histologically resembling the odontoma of anelodontic teeth. Boy and Steenkamp proposed the term “elodontoma” for a change diagnosed in a squirrel. In contrast Pelizzone et al. suggested the term “pseudo - odontoma” to describe a change within the incisor of a prairie dog.

From the work of Capello et al. We only know that the changes diagnosed in 2 guinea pigs showed features of elodontoma and were composed of hard and soft tissues of the tooth haphazardly. We found
similar structure of changes in histologically examined guinea pigs teeth, however in our case the alterations localized within the pulp cavity or at the periphery of the tooth crown, and in the 2 cases described by Capello et al. the changes were localized outside the apex and showing local expansion.

Boy and Steenkamp also described complex odontoma type changes found in squirrels. In such a case similarly to guinea pig (27) the presence of changes composed of hard and soft tissues of the tooth with disordered arrangement located outside the apex was described. Changes on borders of the tooth crown without the formation of periapical odontogenic mass were also described. In such cases deformation of the apex and corrugated enamel were found. Similar changes were noted during histologic evaluation of guinea pigs macrodontic teeth in the work conducted (Fig. 4). Moreover Boy and Steenkamp observed that most of the changes similar to the teeth we examined spread from the apex to the occlusal plane.

Histological description of complex odontoma found in prairie dogs largely resembles changes found in guinea pigs macrodontic teeth. In both cases islands of epithelial and mesenchymal tissue forming tooth-like structures were found. Such changes in guinea pig teeth is shown in Fig. 9. The alterations were built of predentin, dentin and cementum and the arrangement of this tissues was disordered similar to macrodontia of guinea pig. (20)

Dayan et al. described a case of complex odontoma in mice. Histological examination revealed the alteration built, as in previous cases, of enamel, dentin, cementum and connective tissue. Hard tissues formed island-like structures and were mixed with surrounding connective tissue. This image resembles structural changes in guinea pigs macrodontic teeth (Fig. 7a). However for the second time (23, 26) the presence of fibrous capsule surrounding the change from the outside and beyond the apex was found. This type of change was not found in the process of evaluation of guinea pigs macrodontic teeth.

An interesting description of the complex odontoma was made by the authors of works conducted on op/op mice (24), op/op rats (25), ia rats (28) in which the development of this pathology was described as a result of osteopetrosis. Osteopetrosis is an inherited metabolic bone disease in which the process of bone resorption is disrupted. Accumulating bone trabeculae invade the enamel organ through which separate fragments of daughter tooth germs capable of further production of the tooth tissue. During the evaluation of microdontic teeth of guinea pigs no expansion of bone tissue toward the apex was observed but detached fragments of the apical bud or cracks in the dentin layer and inflow of pulp cells into the periodontal space or from the periodontal space toward the tooth pulp were observed. The structural alterations described in mice and rats also show considerable similarity to those observed in our study. In both Ida-Yonemochi et al., Philippart et al. and Schour’s et al. study and ours disorganized cells of epithelial and mesenchymal origin form various structures and rings. Trapped pulp cells were found between wavy bands and in the centre of the rings. Moreover osteodentin was found in the formation of structural changes in rats, as in macrodontic teeth of guinea pig. Osteodentin is mineralized tissue physiologically found in the incisors of rats (29, 30, 31) and the incisors and cheek teeth of the guinea pigs (32). It is a tissue of mesenchymal origin resembling bone with lacunes in which single cells are trapped. The osteodentin is surrounded by tubular dentin all around. It was observed in the top of the
pulp cavity. It is suspected that its function is to seal pulp cavity on the occlusal surface to protect the pulp cavity from the influx of pathogens from the oral cavity (30, 32). The presence of this tissue in healthy rat teeth explains its presence in the structure of complex odontoma since it is a change built of physiologically present tissues with a disordered arrangement. This observation does not yet conclusively establish that the structural changes in macrodontic teeth of the guinea pig qualify as odontomas but suggests that the osteodentin should be present in the structure of the odontoma in the guinea pig. In the papers cited in this paragraph found no connective tissue capsule surrounding the odontoma from the outside.

The presence of a ring-shaped deformity with centrally trapped pulp cells and peripherally located odontoblasts also resembles the description of complex odontoma in vole (18). In this rodent the presence of osteodentin in the odontomas structure was also found and the presence of fibrous capsule was not described. However the changes of the maxillary incisors showed expansion towards the surrounding bone. In the same work description of complex odontoma in a dog and cat was also compiled. Similar to structural alterations in macrodontic cheek teeth of a guinea pig the presence of tubular and atubular dentin of various shapes, enamel dysplasia and trapped pulp cells were shown.

**Conclusion**

There have already been reports in the literature about the presence of the structural alterations in the teeth with increased size (macrodonts). The collected data allow us to conclude that macrodontic tooth of a guinea pig is not only a tooth with increased outline, larger than the others but one that also has characteristic structural changes. The cells of epithelial and mesenchymal origin within the altered teeth do not show features of atypia and thus indicate that the structural changes do not show neoplasmal origin. Among many described odontogenic tumours the structural alterations of macrodontic teeth most strongly resemble those described for complex odontoma. However there are noticeable differences described by other authors, primarily the expansion of the changes beyond the apex or the presence of a connective tissue capsule at the periphery of the change. The changes described in our study localized within the pulp cavity of the tooth or at the periphery of the crown and the alveolar bone was remodelled to adapt to the new shape of the tooth. It seems that the term hamartoma is the most universal to describe the changes observed in macrodont as it refers to a malformation made of atypically arranged, physiologically present tissues. However a certain determination of what the structural changes are in macrodontic teeth of guinea pigs requires further study. From the data collected it also appears that this is the first paper describing histological structure of macrodontic teeth of the guinea pigs.

**Declarations**

Ethical Approval and relevant guidelines: not applicable

The material was obtained from the animals during routine necropsy performed at the Department of Epizootiology and Clinic of Birds and Exotic Animals Wroclaw University of Environmental and Life
Science.

Data Availability statement:

The data is not publicly available because there are the histological slides but we can share more images after the contact with corresponding author: Justyna Ignaszak – Dziech, justyna.dziech@gmail.com

Conflict of interest:

I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Funding:

University of Environmental and Life Sciences, Wroclaw, Poland

Acknowledgement: not applicable

Author contribution:

JID: conceived and designed the study, preparing and examination of histological slices, drafted the manuscript. PK: coordination the histological study and revised the manuscript. TP: participated in coordination the study and revised the manuscript. All authors read and approved the final manuscript.

Author information (optional): not applicable

References


Figures
Figure 1

Histological image of a healthy guinea pig cheek tooth. 1a. Longitudinal section of a cheek tooth (van Gieson staining, x10). 1b. Transverse section of M2 and M3 tooth (H&E, x10). 1. osteodentin, 2. dentin, 3. cartilage-like cementum, 4. periodontium, 5. enamel space, 6. alveolar bone, 7. pulp cavity. 1c. Longitudinal section of a cheek tooth apex. 1. Zone of enamel production with stellate reticulum, 2. odontoblasts and predentin, 3. germinal tissue, 4. blood vessels
Figure 2

Distribution of the structural changes within macrodontic cheek teeth.
Figure 3

Transverse section of M2 tooth of the guinea pig with structural alteration within the pulp cavity (H&E, x10). 1. alveolar bone, 2. enamel matrix, 3. dentin, 4. germinal tissue, 5. structural alteration built of tubular dentin, osteodentin and pulp cells.
Figure 4

Transverse section of M2 tooth of a guinea pig with a structural alteration within the pulp cavity and deformation of the dentin (H&E, x10). 1. alveolar bone, 2. periodontium, 3. enamel matrix, 4. dentin, 5. germinal tissue, 6. structural alteration within the pulp cavity built of tubular dentin and pulp cells, 7. structural alteration with deformation of the dentin and protrusions into the pulp cavity built of tubular dentin, periodontium cells and cementum.
Figure 5

Transverse section of a guinea pigs cheek tooth with structural alteration on the periphery of the tooth crown (H&E, x40). 1. alveolar bone, 2. periodontium, 3. enamel space, 4. protrusion of the dentin into the pulp cavity, 5. tubular dentin, 6. osteodentin, 7. cartilage-like cementum filling the indentation area.
Figure 6

Transverse section of a guinea pigs cheek tooth with structural alteration on the periphery of the tooth crown (H&E, x200). The areas of dentin prominence are not covered with the enamel matrix, which disturbs the arrangement of the periodontal ligaments. 1. germinal tissue, 2. dentin, 3. enamel matrix, 4. accumulated periodontal ligaments.
Figure 7

Transverse section of a cheek tooth with the change within the pulp cavity. 6a. structural alteration built of tubular dentin which forms various shapes, the pulp cells are trapped between the bands and rings of the dentin (H&E, x100). 6b. Two rings built of a tubular dentin in the central part of the pulp cavity. In the central part of the change the osteodentin is trapped (H&E, x10)
Figure 8

Longitudinal section of the clinical crown of a guinea pigs cheek tooth. As a result of the loss of connection between gingiva and structurally changed teeth, food debris penetrates the space between the two adjacent teeth. Bacteria present on the plant fragments penetrate deep into the tooth structure. Dentin, osteodentin and cartilage - like cementum breaks loose on the occlusal surface (H&E, x100). 1. plant material, 2. tubular dentin, 3. osteodentin, 4. bacteria.
Figure 9

Transverse section by the apex of the guinea pigs cheek tooth with structural alteration within the pulp cavity. 1. Within the pulp cavity haphazard clusters of the epithelial tissue surrounded by the pulp cells are visible. Arrows indicates the bounds of the dentin (H&E, x100).