Accuracy of three diagnostic tests to detect tooth resorption in unowned unsocialised cats in Denmark


Published in:
Journal of Small Animal Practice

DOI:
10.1111/jsap.13703

Publication date:
2024

Document version
Publisher's PDF, also known as Version of record

Document license:
CC BY

Citation for published version (APA):
ORIGINAL ARTICLE

Accuracy of three diagnostic tests to detect tooth resorption in unowned unsocialised cats in Denmark

J. Eriksson *,1, M. Denwood *, S. S. Nielsen *, F. McEvoy *, C. Allberg *, I. S. Thuesen † and H. Kortegaard *

*Department of Veterinary Clinical Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, Frederiksberg, Denmark
†Department of Veterinary and Animal Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, Frederiksberg, Denmark

Corresponding author email: jacob.ekirsson@sund.ku.dk

OBJECTIVES: To estimate the relative diagnostic sensitivity and specificity of oral clinical examination, full-mouth dental radiography, and cone-beam CT for the detection of tooth resorption in cats, and to estimate the prevalence of tooth resorption in unowned, unsocialised cats in Denmark.

MATERIALS AND METHODS: Cadavers of 144 adult cats underwent an oral examination, full-mouth dental radiography, and cone-beam CT. Sensitivity and specificity of the three tests, along with the true prevalence, overall and stratified by sex and tooth location, were estimated using latent class methods.

RESULTS: We found cone-beam CT to be the superior image modality, with a sensitivity of 99.5% and a specificity of 99.8%. Dental radiography had a sensitivity of 78.9% and a specificity of 100%, and oral clinical examination had a sensitivity of only 36.0% and specificity of 99.9%. We estimated the prevalence of tooth resorption among unowned unsocialised cats in Denmark to be 40% of adult individuals, and 6.1% of teeth.

CLINICAL SIGNIFICANCE: When dealing with tooth resorption, cone-beam CT can help the operator to find and treat affected teeth that could otherwise go undiagnosed. The prevalence of tooth resorption among unowned, unsocialised cats in Denmark does not appear to differ from other populations of cats.

INTRODUCTION

Tooth resorption (TR) is the most common dental disorder among domesticated cats, with reported apparent prevalences (APs) ranging from about 25% to 75%, dependent on the population studied and diagnostic method used (Girard et al., 2008; Heney et al., 2019; Ingham et al., 2001; Lommer & Verspraete, 2000; Pettersson & Mannerfelt, 2003; Reiter & Menddoza, 2002; Whyte et al., 2020, 2022).

As TR is a painful condition with no known preventive measures, early intervention and treatment is desirable to prevent unnecessary discomfort for the patients. This makes diagnostic imaging an integral part of our examination, allowing for a diagnosis at an early stage of disease (Gorrel, 2015; Verstraete & Kass, 1998). As such, full mouth intraoral dental radiography (DR) has been established as a standard of care for feline patients undergoing any kind of dental treatment (Bellows et al., 2019; Niemiec et al., 2020).

Cone-beam CT (CBCT) is becoming more available to veterinary practitioners, making it a viable alternative for diagnosis of TR in both specialised and general practice. CBCT uses an x-ray source delivering a cone-shaped beam, aimed at a detector array on the opposite side of the area of interest. The shape of the beam allows for the full field of view to be reconstructed in 3D, as well as individual slice images, using only a single rotation of the beam and array (Scarfe & Angelopoulos, 2018), providing images of all teeth in less than a minute. When comparing CBCT to DR, it is reported in the human literature to have a higher sensitivity and specificity for external and internal...
TR using CBCT (Bernardes et al., 2012; Estrela et al., 2009; Lima et al., 2016; Patel et al., 2009; Xie & Zhang, 2012). The same appears to be true for veterinary patients (Heney et al., 2019; Lang et al., 2016; Roza et al., 2011).

Environmental factors may play a role in the aetiology of TR. For example, high vitamin D has been hypothesised as a potential cause (Reiter & Mendoza, 2002). Although that specific claim has failed to be supported by further research (Girard et al., 2010; Zhang et al., 2006), the question of potential environmental risk factors remains. This makes the TR prevalence among unowned unsocialised cats interesting, presuming that they have not been fed a commercial diet, in contrast to domesticated/client-owned cats which makes up a majority of the data on the subject (Girard et al., 2008; Heney et al., 2019; Ingham et al., 2001; Lommer & Verstraete, 2000; Pettersson & Mannerfelt, 2003; Whyte et al., 2020, 2022), with the exception of one study of feral cats on Marion Island (Verstraete et al., 1996).

The objectives of the present study were to estimate the diagnostic specificity and sensitivity of oral clinical examination, DR and CBCT in cats for detection of TR, and to estimate the prevalence of TR in unowned unsocialised cats in Denmark.

**MATERIALS AND METHODS**

**Animals**

The cat cadavers used were included from a larger study on the welfare of unowned and unsocialised cats in Denmark, for which 598 cats, that had been captured and euthanased by two Danish animal welfare non-governmental organisation, were collected from across the country (Thuesen et al., 2022). The cats involved in both the cited and the present study would have been euthanased regardless of their inclusion in the studies or not. Therefore, these studies had no impact, direct or indirect, on decisions about cat euthanasia.

The cited study was approved by the Animal Ethics Institutional Board (AEIRB) at the University of Copenhagen, AEIRB approval number: 2021-08-AWD-002A (Thuesen et al., 2022).

Out of the 598 cat cadavers included in that study, 187 were chosen at random to be further examined through an oral examination, DR and CBCT. As the specific age of the individuals was unknown, any cat found to have deciduous dentition, or open tooth apices as determined by CBCT, were excluded from the study. Out of the 187 cats examined, 144 were included in the results as 43 were determined as too young to be of interest.

**Data acquisition and evaluation**

**Oral examination**

All examinations were performed by the same observer (JE). All surfaces of each tooth, both crown and any exposed root, were evaluated for TR using a dental explorer (LM 23-52B, LM-Dental, Parainen, Finland) to probe for surface irregularities. Results were recorded for each individual tooth as either showing no signs of resorative lesions, having resorative lesions or missing altogether. By using only a dental explorer, it was not possible to distinguish between type 1, 2 and 3 resorative lesions (American Veterinary Dental College, 2022).

**Dental radiography**

Full-mouth dental radiographs, consisting of eight views, were acquired of all cats using a DÜRR Medical CR7 Vet imaging plate scanner with corresponding imaging plates (Dürr Dental, Bietigheim-Bissingen, Germany). The radiographs were taken by two veterinary students under supervision of a board-certified veterinary dentist (HK). Maxillary premolar and molar views were obtained using an extraoral near-parallel technique, mandibular premolar and molar views were obtained using a parallel technique, and all other views were obtained using a bisecting angle technique (Holmström et al., 2004). All radiographs were evaluated by the same observer (JE).

**Cone-beam CT**

CBCT studies of the heads of all cats were acquired using a Planmed Verity VET cone beam CT scanner (Planmed, Helsinki, Finland). Field of view was 16×13 cm, with a voxel size (slice thickness) of 200 μm. The images were evaluated on a Lenovo Thinkvision T25d-10 monitor using commercially available specialised software (Romexis Viewer 6.1.0.997, Planmeca, Helsinki, Finland). Each tooth was evaluated using multiplanar reconstruction (MPL), as this technique has previously been shown to have the highest sensitivity and specificity in regards to resorptive lesions (Heney et al., 2019). All images were evaluated by the same observer (JE).

The results of the DR and CBCT studies were recorded with each tooth assigned to one of seven groups: as either showing no signs of resorative lesions, having resorative lesions and of what type (1, 2, 3 or other – internal or external resorative lesions that do not conform to the AVDC defined types) (American Veterinary Dental College, 2022), visible root remnant (when it is present in the radiographs), or no sign of resorative lesions (Verstraete et al., 1996).

**Statistical analysis**

Descriptive statistics were done through two-way cross-tabulations of the three diagnostic tests, and by calculation of the apparent prevalences (APs) based on each of the three tests. For these calculations, all teeth showing resorption, regardless of type, were grouped together into one group of resorption.

Latent class estimation of diagnostic sensitivity and specificity was done using the Hui-Walter paradigm (Hui & Walter, 1980). Bayesian latent class models (BLCM) were fitted to the data with a two-test, 16 population combination with MCMC (Markov chain Monte Carlo) simulation to estimate posteriors using JAGS version 4.3.0 (Plummer, 2003) using
the runjags package (Denwood, 2016) in R version 4.3.1 (R Core Team, 2022). We assumed (1) with two tests and 16 populations our models were identifiable, (2) we had similar sensitivities and specificities in all populations. The 16 populations were based on eight groups of teeth and two levels of sex (males and females), which served to simultaneously estimate the true prevalences (TPs) for each of the groups, while combining all quadrants into one group, but otherwise keeping the eight teeth locations separate. Uncertainty for the estimates was presented with 95% posterior credibility intervals (PCI).

Because the CBCT test had almost 100% sensitivity and specificity (see later, Results section), CBCT was used as a reference test for estimation of diagnostic sensitivity and specificity, and using all available data, considering empty sockets as resorbed. Uncertainty for the estimates was presented with 95% confidence intervals (CI).

RESULTS

Population

A total of 144 cats were included in the study, 67 (47%) females and 77 (53%) males, of which 18 (27%) and 12 (16%), respectively, were neutered. This resulted in a total of 4320 teeth to observe, of which 260 were determined to be fully missing, according to CBCT.

Observer reliability

CBCT analyses of 25 cats (750 teeth) were evaluated independently by both the observer (JE), a board-certified veterinary dentist (HK) and two board-certified veterinary radiologists working in tandem (FM-CA). Interobserver variation results are shown in Table 1.

Descriptive statistics

The distribution of the two-way combinations of test results from the three diagnostic tests including and excluding data from missing teeth are shown in Table 2, stratified by sex. These data were used for the estimation of diagnostic sensitivity, diagnostic specificity and true prevalences (TPs). The APs based on each of the three diagnostic tests are shown in Tables 3 and 4 including and excluding teeth that were missing from their dental alveoli.

Estimates of sensitivity and specificity

The estimated diagnostic sensitivities and specificities from the latent class estimation are given in Table 5, both including and excluding information on sockets with missing teeth. The diagnostic sensitivity was highest for CBCT (99.5%; 95% PCI: 98.1% to 100%) with a corresponding specificity of 99.8% (95% PCI: 99.4% to 100%), while DR had a sensitivity of 78.9% (95% PCI: 71.9% to 86.1%) with a specificity of 100% (95% PCI: 99.9% to 100%). These estimates were based on the inclusion of data from missing teeth presumed resorbed, but the results are also similar when not including these data (Table 4).

The estimates of diagnostic sensitivity and specificity of oral clinical examination using CBCT as reference were 36.0% (95% CI: 29.0% to 43.6%) and 99.9% (95% CI: 99.7% to 100.0%), respectively.

Prevalences

Using CBCT we found TR lesions in 265 (6.1%) teeth belonging to 57 (40%) of the sampled cats. DR found only 159 (3.7%) teeth with TR lesions, belonging to 48 (33%) different cats. The amount of TR-affected teeth found was significantly higher (P<0.0001) when using CBCT, as opposed to DR. There was, however, no significant difference in the number of cats diag-

Table 1. Cohen’s kappa analysis of interobserver variation

<table>
<thead>
<tr>
<th>Observers</th>
<th>Kappa</th>
<th>P-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>JE – HK</td>
<td>0.84</td>
<td>&lt;0.001</td>
<td>0.79 to 0.89</td>
</tr>
<tr>
<td>JE – FM-CA</td>
<td>0.75</td>
<td>&lt;0.001</td>
<td>0.69 to 0.81</td>
</tr>
<tr>
<td>HK – FM-CA</td>
<td>0.75</td>
<td>&lt;0.001</td>
<td>0.69 to 0.81</td>
</tr>
</tbody>
</table>

JE Main observer in this study, HK Board-certified veterinary dentist, FM-CA Board-certified veterinary radiologists

Table 2. Distributions of combined test results from three diagnostic tests (oral examination (OE), cone beam computer tomography (CBCT) and dental radiography (DR) on dental resorption from teeth of 144 unowned unsocialised cats in Denmark

<table>
<thead>
<tr>
<th>Missing teeth</th>
<th>Tests</th>
<th>Sex</th>
<th>n</th>
<th>ResRes†</th>
<th>NoResRes†</th>
<th>ResNoRes†</th>
<th>NoResNoRes†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not included</td>
<td>OE and CBCT</td>
<td>Female</td>
<td>1878</td>
<td>14 (0.7)</td>
<td>32 (1.7)</td>
<td>3 (0.2)</td>
<td>1829 (97.4)</td>
</tr>
<tr>
<td></td>
<td>OE and CBCT</td>
<td>Male</td>
<td>1987</td>
<td>45 (2.3)</td>
<td>73 (3.7)</td>
<td>1 (0.1)</td>
<td>1868 (94)</td>
</tr>
<tr>
<td></td>
<td>OE and DR</td>
<td>Female</td>
<td>1873</td>
<td>10 (0.5)</td>
<td>24 (1.3)</td>
<td>7 (0.4)</td>
<td>1832 (97.8)</td>
</tr>
<tr>
<td></td>
<td>OE and DR</td>
<td>Male</td>
<td>1984</td>
<td>39 (2)</td>
<td>40 (2)</td>
<td>6 (0.3)</td>
<td>1899 (95.7)</td>
</tr>
<tr>
<td></td>
<td>DR and CBCT</td>
<td>Female</td>
<td>1886</td>
<td>46 (2.4)</td>
<td>9 (0.5)</td>
<td>1 (0.1)</td>
<td>1830 (97)</td>
</tr>
<tr>
<td></td>
<td>DR and CBCT</td>
<td>Male</td>
<td>2017</td>
<td>110 (5.5)</td>
<td>38 (1.9)</td>
<td>0 (0)</td>
<td>1889 (92.7)</td>
</tr>
<tr>
<td></td>
<td>OE and CBCT</td>
<td>Female</td>
<td>1981</td>
<td>45 (0.5)</td>
<td>34 (1.8)</td>
<td>3 (0.2)</td>
<td>1829 (97.2)</td>
</tr>
<tr>
<td></td>
<td>OE and CBCT</td>
<td>Male</td>
<td>1987</td>
<td>45 (2.3)</td>
<td>73 (3.7)</td>
<td>1 (0.1)</td>
<td>1868 (94)</td>
</tr>
<tr>
<td></td>
<td>OE and DR</td>
<td>Female</td>
<td>1881</td>
<td>11 (0.6)</td>
<td>31 (1.6)</td>
<td>7 (0.4)</td>
<td>1832 (97.4)</td>
</tr>
<tr>
<td></td>
<td>OE and DR</td>
<td>Male</td>
<td>1987</td>
<td>40 (2)</td>
<td>42 (2.1)</td>
<td>6 (0.3)</td>
<td>1899 (95.6)</td>
</tr>
<tr>
<td></td>
<td>DR and CBCT</td>
<td>Female</td>
<td>1929</td>
<td>87 (4.5)</td>
<td>30 (0.5)</td>
<td>2 (0.1)</td>
<td>1830 (94.9)</td>
</tr>
<tr>
<td></td>
<td>DR and CBCT</td>
<td>Male</td>
<td>2066</td>
<td>158 (7.6)</td>
<td>38 (1.8)</td>
<td>1 (0)</td>
<td>1869 (90.5)</td>
</tr>
</tbody>
</table>

The first six rows excluded missing teeth, and the last six rows considered missing teeth as resorbed

†ResRes: both tests indicate resorption; NoResRes: test 1 indicates resorption and test 2 no resorption; ResNoRes: no resorption and test 2 resorption; NoResNoRes: both tests indicate no resorption

The first six rows excluded missing teeth, and the last six rows considered missing teeth as resorbed

© 2024 The Authors. Journal of Small Animal Practice published by John Wiley & Sons Ltd on behalf of British Small Animal Veterinary Association.

389
Table 3. Apparent prevalences of dental resorption of teeth from 144 unowned unsozialised cats in Denmark based on three diagnostic tests [oral examination (OE), cone beam computer tomography (CBCT) and dental radiography (DR)] used for detection of dental resorption

<table>
<thead>
<tr>
<th>Tooth</th>
<th>OE (n=141)</th>
<th>CBCT (n=143)</th>
<th>DR (n=143)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>0/107 (0%)</td>
<td>18/120 (15%)</td>
<td>10/115 (8.7%)</td>
</tr>
<tr>
<td>102</td>
<td>0/119 (0%)</td>
<td>22/134 (16.4%)</td>
<td>14/130 (10.8%)</td>
</tr>
<tr>
<td>103</td>
<td>2/121 (1.7%)</td>
<td>24/136 (17.6%)</td>
<td>17/130 (13.1%)</td>
</tr>
<tr>
<td>104</td>
<td>3/140 (2.1%)</td>
<td>11/141 (7.8%)</td>
<td>7/141 (5%)</td>
</tr>
<tr>
<td>106</td>
<td>4/122 (3.3%)</td>
<td>11/128 (8.6%)</td>
<td>6/125 (4.8%)</td>
</tr>
<tr>
<td>107</td>
<td>4/142 (2.8%)</td>
<td>7/143 (4.9%)</td>
<td>5/143 (3.5%)</td>
</tr>
<tr>
<td>108</td>
<td>3/141 (2.1%)</td>
<td>8/145 (5.6%)</td>
<td>6/142 (4.2%)</td>
</tr>
<tr>
<td>109</td>
<td>2/132 (1.5%)</td>
<td>8/135 (5.9%)</td>
<td>5/133 (3.8%)</td>
</tr>
<tr>
<td>101</td>
<td>0/105 (0%)</td>
<td>18/118 (15.3%)</td>
<td>13/115 (11.3%)</td>
</tr>
<tr>
<td>102</td>
<td>0/120 (0%)</td>
<td>14/131 (10.7%)</td>
<td>9/127 (7.1%)</td>
</tr>
<tr>
<td>103</td>
<td>2/116 (1.7%)</td>
<td>23/132 (17.4%)</td>
<td>14/125 (11.2%)</td>
</tr>
<tr>
<td>104</td>
<td>1/133 (0.8%)</td>
<td>7/138 (5.1%)</td>
<td>6/138 (4.3%)</td>
</tr>
<tr>
<td>106</td>
<td>3/121 (2.5%)</td>
<td>10/126 (7.9%)</td>
<td>3/121 (2.5%)</td>
</tr>
<tr>
<td>107</td>
<td>6/142 (4.2%)</td>
<td>12/143 (8.4%)</td>
<td>6/142 (4.2%)</td>
</tr>
<tr>
<td>108</td>
<td>5/142 (3.5%)</td>
<td>11/146 (7.6%)</td>
<td>7/143 (4.9%)</td>
</tr>
<tr>
<td>109</td>
<td>2/134 (1.5%)</td>
<td>8/138 (5.8%)</td>
<td>3/136 (2.2%)</td>
</tr>
<tr>
<td>301</td>
<td>0/116 (0%)</td>
<td>11/126 (8.7%)</td>
<td>9/123 (7.3%)</td>
</tr>
<tr>
<td>302</td>
<td>1/124 (0.8%)</td>
<td>11/131 (8.4%)</td>
<td>9/129 (7%)</td>
</tr>
<tr>
<td>303</td>
<td>0/123 (0%)</td>
<td>11/132 (8.3%)</td>
<td>7/128 (5.5%)</td>
</tr>
<tr>
<td>304</td>
<td>4/141 (2.8%)</td>
<td>9/143 (6.3%)</td>
<td>6/143 (4.2%)</td>
</tr>
<tr>
<td>305</td>
<td>5/139 (3.6%)</td>
<td>11/142 (7.7%)</td>
<td>10/142 (7%)</td>
</tr>
<tr>
<td>306</td>
<td>2/142 (1.4%)</td>
<td>6/143 (4.2%)</td>
<td>6/143 (4.2%)</td>
</tr>
<tr>
<td>307</td>
<td>3/139 (2.2%)</td>
<td>15/143 (10.5%)</td>
<td>15/143 (10.5%)</td>
</tr>
<tr>
<td>308</td>
<td>1/112 (0.9%)</td>
<td>15/125 (12%)</td>
<td>14/124 (11.3%)</td>
</tr>
<tr>
<td>309</td>
<td>0/124 (0%)</td>
<td>8/126 (6.2%)</td>
<td>6/126 (4.8%)</td>
</tr>
<tr>
<td>306</td>
<td>1/124 (0.8%)</td>
<td>8/127 (6.3%)</td>
<td>8/125 (6.4%)</td>
</tr>
<tr>
<td>307</td>
<td>4/138 (2.9%)</td>
<td>11/140 (7.9%)</td>
<td>8/140 (5.7%)</td>
</tr>
<tr>
<td>308</td>
<td>3/140 (2.1%)</td>
<td>8/142 (5.6%)</td>
<td>6/142 (4.2%)</td>
</tr>
<tr>
<td>309</td>
<td>2/142 (1.4%)</td>
<td>6/144 (4.2%)</td>
<td>6/144 (4.2%)</td>
</tr>
<tr>
<td>306</td>
<td>2/139 (1.4%)</td>
<td>13/144 (9%)</td>
<td>11/144 (7.6%)</td>
</tr>
</tbody>
</table>

Data considered missing teeth as being resorbed, and root remnants with no sure signs of resorption were excluded from the data. The teeth are numbered using the modified triadan system (Floyd, 1991).

nosed with TR between the two techniques (P=0.33). The most frequently affected teeth were the maxillary third incisors (see Tables 3 and 4). There was no tooth position in which TR was not found.

Out of the 265 teeth with TR lesions, 182 (69%) were classified as “Type 1,” 75 (28%) as “Type 2,” three (1%) as “Type 3,” and five (2%) as “Other.” Among the teeth classified as “Other,” as in not conforming to the three types defined by AVDC’s classification system (American Veterinary Dental college, 2022), three showed signs of external inflammatory root resorption, and two of internal inflammatory root resorption, as described in dogs by Peralta et al. (2010).

Overall, the TP estimates of TR in male cats was 9.4% (95% PCI: 8.0% to 10.8%) of teeth and the prevalence in females was 4.0% (95% PCI: 3.2% to 4.9%) of teeth, which was lower based on the PCI. The estimated TPs for the different tooth locations are illustrated in Fig 1.

DISCUSSION

All three diagnostic tests had a high specificity, with 99.9% (OE), 100% (DR) and 99.8% (CBCT), respectively. In contrast, CBCT had a significantly higher sensitivity (99.5%), compared to only 78.9% using DR, and 36.0% using OE.

Our hypothesis that CBCT would have a significantly higher diagnostic yield for identifying TR lesions as compared to DR was shown to stand in this study. These results are in line with previous studies from both the veterinary (Heney et al., 2019; Roza et al., 2011) and the human field (Bernardes et al., 2012; Cohena et al., 2007; da Silveira et al., 2007; D’Addazio et al., 2011; Durack et al., 2011; Estrella et al., 2009; Kamburoğlu).
Three tests to detect tooth resorption in cats

et al., 2011). Our results demonstrate that CBCT has high sensitivity and specificity in the detection of TR lesions, and that CBCT performs significantly better than DR in this regard. The reason for this is that CBCT provides information in the third dimension, and allows images to be reconstructed in such a way as to eliminate overlying structures. A radiograph on the other hand, being a 2D representation of a 3D structure, sometimes makes it difficult to distinguish TR lesions, especially on the lingual or buccal side of the teeth, due to superimposition of dentoalveolar structures (Alqerban et al., 2011; da Silveira et al., 2007; Goldberg et al., 1998). CBCT has also been shown to be able to identify smaller resorptive lesions than DR in human dental studies (Bernardes et al., 2012; Lima et al., 2016), indicating that CBCT should allow us to identify TR lesions in cats at an earlier stage.

We estimate the prevalence of TR among unowned unsocialised cats in Denmark to be 40% of adult individuals, and 6.1% of teeth. Comparing prevalences between different studies and populations is made difficult by the different diagnostic modalities utilised and the population studied. Furthermore, many prevalence studies use dental patients for their data, whereas our population was collected at random.

The prevalence results reported here are similar to previous studies using randomly selected cat populations (Girard et al., 2008; Ingham et al., 2001; Pettersson & Mannerfelt, 2003), though slightly higher which may be due to the increased sensitivity of CBCT in comparison to DR which was used by the previous studies. For example, Pettersson and Mannerfelt (2003) found radiographic signs of TR in 32% of examined cats. Using that AP, we can estimate the TP using the Rogan-Gladen estimator (Rogan & Gladen, 1978) TP = (AP + Sp − 1) / (Sp + Se − 1) and our values for sensitivity and specificity of DR. This results in a TP of 40%, equal to our results. Verstraete et al. (1996), which studied a feral cat population, found an AP of 14.3% using OE as their diagnostic tool. The same calculation, using our values for sensitivity and specificity of OE, results in a TP of 39.6%. Heney et al. (2019) which also used CBCT for the diagnosis, found a similar prevalence to ours as to the percentage of cats affected (10/27, 37%), but showed a much higher number of affected teeth (12.3% versus 6.1% in our study). Again, this may be due to the population studied, as the majority of the population studied by Heney et al. (2019) was made up of “client-owned cats admitted for evaluation and treatment of dental disease”. It would be expected to see a higher prevalence of TR among cats brought to a veterinarian specifically for the treatment of dental disease.

In the present study, we found a significantly higher prevalence of TR among male cats’ teeth [9.4% (95% PCI: 8.0% to 10.8%)] as compared to female teeth [4.0% (95% PCI: 3.2% to 4.9%)]. One possible explanation for this could be that the vast majority of the male unsocialised cats in this study were sexually intact (Thuesen et al., 2022). Sexually intact male cats tend to participate in more agonistic behaviour compared to neutered male and female cats (Finkler et al., 2011), and acute and chronic mechanical trauma can be an inducing factor of apical root resorption (Reiter & Mendoza, 2002). One previous study also reported TR to be more prevalent in males (van Wessum et al., 1992); however, that part of the study used only oral examination, and no diagnostic imaging modality. Hence, given the significant value of diagnostic imaging for the diagnosis of TR (Verstraete & Kass, 1998), the conclusions we can draw from it is limited, as presumably a lot of TR lesions may have gone unnoticed which could have equalised the prevalence between genders. Another study with the same limitations showed females being more
prevalent (Lund et al., 1998). The only statistically significant observation supported by several studies is that the prevalence of TR increases with age (Girard et al., 2008, 2009; Gorrel, 2015; Ingham et al., 2001; Lund et al., 1998; Petterson & Manerfelt, 2003; Reiter & Mendoza, 2002; van Wissum et al., 1992; Whyte et al., 2020). Since our population consists of unowned unsocialised cats, though all adults, their age is unknown and we therefore cannot evaluate this factor.

Not finding any difference in TR prevalence among our group of unowned unsocialised cats, and domesticated/client-owned cats previously studied, could suggest that environmental factors such as diet are of little importance to the development of TR. However, due to not knowing how much interaction our cats have had with humans, and whether or not they have had access to commercial diets, we are unable to draw any definitive conclusion.

We found only two teeth, from two different cats (1.4%), with internal resorption. This is consistent with the low frequency found in dogs, where one study reported finding internal resorption in 4.4% of canine patients admitted for a dental procedure (Peralta et al., 2010). Recognising that we are again comparing a random population, to one specifically brought to a veterinarian for dental treatment. Only one of the internal resorptive lesions were diagnosed using DR, which may suggest that internal resorption is underdiagnosed in clinical practice today, where DR is the most prominent diagnostic tool.

It is possible that lesions were missed by the evaluator on one or more diagnostic methods, hence elevating or decreasing the reported accuracy of the other imaging method. Any diagnostic method relying on a human observer, is susceptible to human error. As seen in Table 2, there were a handful of teeth marked as having TR by OE or DR, that were not considered as having TR using CBCT. Taking this into consideration we assessed the reliability of our observations by calculating interobserver variation (see Table 1). The inter-rater agreement between the observers in the trial group was high. Although the exact interpretation of a kappa value is somewhat fluid, a value of 0.75 and above is generally considered a substantial to excellent level of inter-rater agreement (McHugh, 2012; Viera & Garrett, 2005). Our kappa values of 0.75 between the main observer and a board-certified veterinary dentist and two board-certified veterinary radiologists, provides evidence of the validity and reliability of the observations.

The lack of histopathological evidence of TR does not allow a comparison against our diagnostic method; therefore, latent class methodology was used. This approach is becoming more and more common in veterinary medicine. A key challenge is that instead of defining the target condition based on a reference method, we allow the data to decide. The resulting target condition is therefore based on the data distribution. However, in the present case, it appears that CBCT is excellent, and therefore would more or less end up being the reference method. It remains to be justified through comparison of CBCT and histopathological evidence, if this is seen as a relevant target condition.

CBCT is an excellent diagnostic test for TR lesions in cats. It has a higher sensitivity [99.5%; (95% PCI: 98.1% to 100%)] and an equally high specificity [99.8% (95% PCI: 99.4% to 100%)] as the traditional full mouth dental radiographs. Three-dimensional imaging is an important tool that is becoming increasingly available to veterinary surgeons. When dealing with TR, CBCT can help the operator to find and treat affected teeth that could otherwise go undiagnosed.

The prevalence of TR among unowned unsocialised cats in Denmark does not appear to differ from the prevalence in other random populations of domesticated/client-owned cats studied.

Acknowledgements

The cat cadavers used in this study were funded by research grants from Dyrenes Dags Komité, QATO Fonden, Dyrenes Beskyttelse, Fonden Inges Kattehjem, Foreningen Kus- toes, Kattens Værn, Kitty og Viggo Freislebens Jensens Fond and University of Copenhagen. No funds were received for this study, and the funders of the previous project had no role in designing or interpreting the results.

Author contributions

Jacob Eriksson: Conceptualization (supporting); investigation (lead); writing – original draft (lead); writing – review and editing (lead). Matt Denwood: Formal analysis (lead); writing – original draft (supporting). Soren Saxmose Nielsen: Formal analysis (supporting); writing – review and editing (equal). Fintan McEvoy: Validation (equal). Clara Allberg: Validation (equal). Ida Sofie Thuesen: Resources (equal). Hanne Kortegaard: Conceptualization (equal); supervision (lead); validation (equal); writing – review and editing (supporting).

Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Data availability statement

The data used during the current study available from the corresponding author on reasonable request.

References


Three tests to detect tooth resorption in cats


