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A retrospective analysis of oral tumors in dogs in Switzerland identifies peripheral odontogenic fibroma and melanoma as the predominant tumor types

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OBJECTIVE
Determine the prevalence, types, and geographical distribution of oral tumors in dogs in Switzerland to provide insights into demographics, tumor characteristics, and trends.

METHODS
The medical and pathology records of dogs diagnosed with oral tumors from 2012 to 2022 were sourced from diagnostic laboratories in Switzerland. The focus was on histopathologically confirmed oral neoplasms. Inflammatory, viral, and cystic lesions were excluded. Geographic trends were analyzed by use of postal addresses, revealing local distributions.

RESULTS
Of the 948 reports, 773 cases fulfilled the study's criteria. Benign tumors constituted 63% (487 of 773), with peripheral odontogenic fibroma being the most common (77.8% [379 of 487]). Among the malignant tumors, malignant melanoma was the most frequent (38.1% [109 of 286]), followed by squamous cell carcinoma (21% [60 of 286]) and fibrosarcoma (8% [23 of 286]). The locations of tumors varied, with a higher prevalence of malignant melanoma on the lips. Histopathologic findings indicated ulceration and necrosis were more common in malignant tumors. Significant differences were noted in the mitotic index between benign and malignant groups. No tumor predisposition was noted for any breed. Oral tumors were prevalent in older dogs (median age, 9.4 years).

CONCLUSIONS
The findings highlighted the predominance of benign tumors in dogs in Switzerland, with specific histopathologic features distinguishing benign from malignant cases.

CLINICAL RELEVANCE
Understanding the prevalence, types, and geographic distribution of oral tumors based on the representation in dogs in Switzerland may aid in early detection, appropriate diagnostic workup, and informed treatment planning for oral tumors in dogs.

Keywords: oral, tumor, neoplasia, canine, histopathology

Oral tumors represent 1.24% of all reported canine cancer cases in Switzerland.[1] Broader studies[2,3] from the US reveal a variable prevalence ranging from 0.5% to 7%. In the past decade, the dog population in Switzerland has substantially increased.[4] Parallel to this growth, canine lifespan has increased, attributable to advancements in veterinary care and improved living conditions.[4] This demographic shift poses new challenges for veterinary medicine and requires a reassessment of epidemiologic parameters of complex conditions like oral tumors.

Oral tumors are a significant concern due to their potential to rapidly progress before being diagnosed, potentially leading to severe health complications.[5] Specifically, oral tumors may affect a dog's ability to eat and result in severe discomfort, negatively impacting quality of life. Additionally, at advanced stages, treatment of oral tumors often requires complex interventions, including surgery and radiation treatment, which may be costly and challenging to owners and veterinarians alike.[6–10]

The wide spectrum of oral tumors in dogs encompasses a range of conditions, from benign to highly

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aggressive malignancies, each with unique histologic features and clinical implications.[11–14] Primarily histopathologic studies[2,11,15] from the US have reported a higher prevalence of malignant tumors compared to benign tumors. Among malignant tumors, malignant melanoma (MM) is the most common.[8,13,16–21] When considering benign tumors, acanthomatous ameloblastoma (AA) is the most reported.[22] Furthermore, 1 study[23] found a higher prevalence of MM in the gingiva and labial mucosa (lip) compared to other locations, suggesting a location predilection for MM in dogs in the US. Recognizing the vast array of tumors, their prevalence, and their clinical challenges is crucial for developing a treatment plan and providing an accurate prognosis. Our study aimed to elucidate the spectrum of oral tumors affecting dogs in Switzerland through a comprehensive analysis of medical records, diagnostic reports, and histopathologic data including ulceration, necrosis, and mitotic index (MI). Additionally, we investigated the relationships between tumor types and potential clinicopathologic and environmental risk factors including tumor locations, sex, breed, and geographical distribution patterns. Up-to-date data on the prevalence and nature of oral tumors based on histopathologic samples can update our current epidemiologic knowledge and help us identify and potentially mitigate risk factors for the development of oral tumors in dogs in Switzerland. Furthermore, knowledge on the diagnostic accuracy of necrosis, ulceration, and MI to distinguish malignant from benign lesions can help in challenging oral pathologic diagnoses.

Methods

Pathology records were sourced from 2012 to 2022 from 3 veterinary diagnostic laboratories in Switzerland: Institut für Tierpathologie (Universität Bern), Pathovet, and Pathologie Kühn. Search terms such as *oral tumor*, *odontogenic tumor*, and the names of all oral tumor types were used to identify cases of interest. The individual databases of each of the laboratories were searched, and cases were identified and merged into the research database.

The inclusion criterion was a histopathologic diagnosis of an oral tumor (odontogenic or nonodontogenic). An additional immunohistochemical examination was used to further classify tumors when they could not be definitively diagnosed with standard histopathologic methods. The use of immunohistochemistry was at the discretion of the overseeing pathologist. Only the tumors with definite diagnoses were included in the research scope. The exclusion criteria comprised inflammatory, viral papilloma, autoimmune, and cystic pathologies. Data collected from the pathology report included age, sex, neuter status, breed, weight, tumor type, and location within the oral cavity. Tumors were sorted into 2 broad categories, malignant and benign, based on their potential ability for distant metastasis. Tumors with a < 1% metastatic ability (eg, ameloblastoma, extramedullary, plasma cell tumor [PCT]) were classified as benign.

In cases where dogs had multiple tumors, each tumor was treated as a separate case for analysis and reporting purposes. No clinical information on locoregional or distant metastasis was available.

Tumor location was categorized into the following regions: maxilla, mandible, rostral maxilla and mandible, caudal maxilla and mandible, tongue, sublingual, lip, palate, soft palate, tonsil, gingiva, and multiple locations. The caudal aspect of the maxilla and mandible was defined as the region located behind the second premolar tooth, as previously described.[22] When available in the pathology report, histologic characteristics such as MI, presence of ulceration, and presence of necrosis were collated.

Histopathologic examinations of H&E-stained sections were conducted by board-certified pathologists at 3 different pathology centers (Institut für Tierpathologie, Pathovet, and Pathologie Kühn), and 20 random samples of different tumor types were reexamined by an independent board-certified pathologist (NV) for the purpose of validating the original diagnostic evaluation. All reviews were conducted with glass slides. The tumor types selected for this reexamination included AA (n = 2), MM (2), fibrosarcoma (FS; 2), osteosarcoma (1), peripheral odontogenic fibroma (POF; 4), PCT (1), giant cell granuloma (1), hemangiosarcoma (1), histiocytic sarcoma (1), sarcoma (1), squamous cell carcinoma (SCC; 1), lymphoma (1), compound odontoma (1), and leiomyoma (1). There was complete agreement among the pathologists in the histopathologic diagnosis of the tumors listed above, with the exception of hemangiosarcoma, for which oral location could not be validated due to limited sample size and the incisional nature of the biopsy sample.

The postal addresses of the pet owners were used to identify potential trends in the geographical distribution of oral tumors. In cases where the owner's address was unavailable, the address of the veterinarian who performed the biopsy was used. The distribution was plotted on a map, divided by administrative regions (cantons) to highlight local trends.

Statistical analysis

Relevant data points were extracted from patient medical records and subsequently transferred to a Microsoft Excel (Version 16) database for statistical analysis. Prism (Version 10; GraphPad Software Inc) was used to perform descriptive statistics and analyses. Age groups for analysis were created based on the median age of the dogs, SD of the age data, and general age of skeletal maturity of most dog breeds. The χ^2 or Fisher exact test was used to examine the associations between tumor type and the presence of ulceration, necrosis, and tumor location. Numerical data were assessed for normality by use of the Shapiro-Wilk test. Then, the numerical data were analyzed for trends by use of the Kruskal-Wallis or Mann-Whitney tests. Results were considered statistically significant at $P < .05$. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for ulceration, necrosis, and MI. A receiver operating

characteristic curve analysis was performed to determine the optimal MI cutoff point for differentiating between benign and malignant tumors and associated sensitivity, specificity, PPV, and NPV.

Results

Of the 948 reports collected over a 10-year period, 773 cases of oral tumors met the inclusion criteria **(Figure 1)**. These cases originated from Pathovet (432 cases), Institut für Tierpathologie (171 cases), and Pathologie Kühn (170 cases). A total of 175 cases were excluded: 125 cases from Pathovet, 34 from Pathologie Kühn, and 12 from Institut für Tierpathologie.

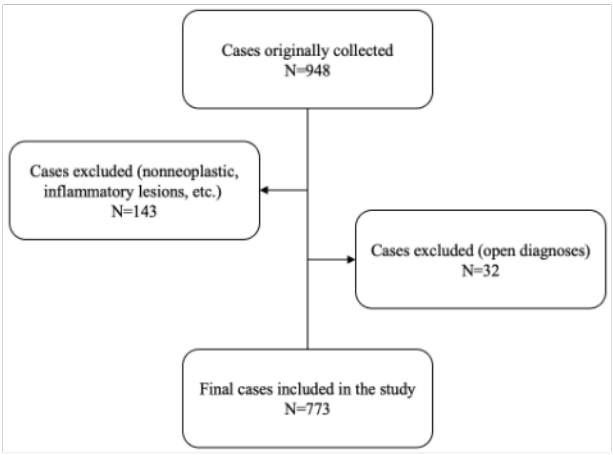

Figure 1—Inclusion and exclusion criteria from the case selection process.

Tumor histology

Most tumors were benign, accounting for 63% (487 of 773) of all cases. Peripheral odontogenic fibroma was the most common tumor, comprising 77.8% (379 of 487) of all benign tumors, followed by AA, which accounted for 11.3% (55 of 487). In contrast, the most prevalent malignant tumors were MM, accounting for 38.1% (109 of 286) of all malignant tumors, followed by SCC, comprising 21% (60 of 286), and FS, comprising 8% (23 of 286; **Table 1**).

Tumor localization

For benign tumors, location was available for 74.9% (365 of 487) of corresponding cases **(Supplementary Table S1)**. The most common location for POF tumors was the rostral maxilla, accounting for 29% (89 of 307) of POF cases ($P < .0001$; **Figure 2**). Cases of AA were primarily observed in the rostral mandible, comprising 32.7% (16 of 49) of AA cases ($P < .0001$).

For malignant tumors, location was confirmed for 94.4% (270 of 286) of corresponding cases. The

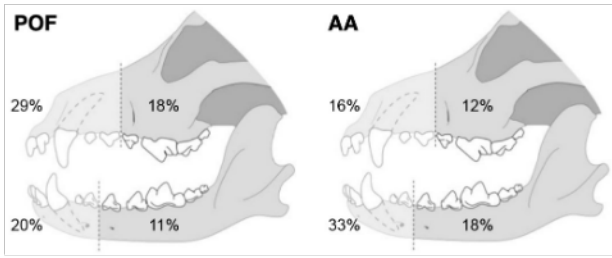

Figure 2—Distribution of peripheral odontogenic fibroma (POF) and acanthomatous ameloblastoma (AA) in the oral cavity.

Table 1—Tumor type, breed, and sex categories.

Tumor type	No. of tumors	Most common breed(s)	Female	Male	Spayed female	Castrated male
POF (fibromatous epulis of periodontal ligament origin)	379	MIX and BOXE; each 9.23% (35/379)	20.6% (78/379)	30.1% (114/379)	25.6% (97/379)	20.8% (79/379)
AA (canine AA)	55	MIX; 14.54% (8/55)	20.0% (11/55)	32.7% (18/55)	25.5% (14/55)	21.8% (12/55)
SCC	60	MIX; 16.67% (10/60)	20.0% (12/60)	26.7% (16/60)	23.3% (14/60)	30.0% (18/60)
MM (melanoma)	109	MIX and GOLD; each 12.84% (14/109)	21.1% (23/109)	25.7% (28/109)	24.8% (27/109)	26.6% (29/109)
FS	23	MIX; 26.09% (6/23)	21.7% (5/23)	34.8% (8/23)	26.1% (6/23)	13.0% (3/23)
OSA	22	MIX; 18.19% (4/22)	13.6% (3/22)	27.3% (6/22)	31.8% (7/22)	27.3% (6/22)
Chondrosarcoma	2	LABR; 50% (1/2)	0.0% (0/2)	100.0% (2/2)	0.0% (0/2)	0.0% (0/2)
Hemangiosarcoma	5	MIX; 20% (1/5)	0.0% (0/5)	20.0% (1/5)	20.0% (1/5)	40.0% (2/5)
Lymphoma	19	MIX; 31.58% (6/19)	10.5% (2/19)	31.6% (6/19)	36.8% (7/19)	15.8% (3/19)
Mast cell tumor	5	BGL; 20% (1/5)	0.0% (0/5)	20.0% (1/5)	40.0% (2/5)	40.0% (2/5)
Lipoma	2	—	0.0% (0/2)	0.0% (0/2)	50.0% (1/2)	50.0% (1/2)
Osteoma	3	SHEP; 33.33% (1/3)	0.0% (0/3)	0.0% (0/3)	66.7% (2/3)	33.3% (1/3)
PCT	39	MIX and WHT; each 10.26% (4/39)	15.4% (6/39)	28.2% (11/39)	25.6% (10/39)	23.1% (9/39)
Peripheral nerve sheath tumor	1	—	100.0% (1/1)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)
Lipochondroma	1	—	100.0% (1/1)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)
GCG (peripheral GCG)	4	—	25.0% (1/4)	25.0% (1/4)	25.0% (1/4)	25.0% (1/4)
Liposarcoma	1	—	0.0% (0/1)	0.0% (0/1)	100.0% (1/1)	0.0% (0/1)
Papillary squamous cell carcinoma	3	—	0.0% (0/3)	66.7% (2/3)	33.3% (1/3)	0.0% (0/3)
Fibrolipoma	1	—	100.0% (1/1)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)
Sarcoma	12	—	16.7% (2/12)	41.7% (5/12)	16.7% (2/12)	25.0% (3/12)
Histiocytic sarcoma	2	—	0.0% (0/2)	50.0% (1/2)	0.0% (0/2)	0.0% (0/2)
Adenocarcinoma	4	—	0.0% (0/4)	75.0% (3/4)	0.0% (0/4)	25.0% (1/4)
Carcinoma	4	—	25.0% (1/4)	0.0% (0/4)	50.0% (2/4)	25.0% (1/4)
Multilobular tumor of bone (multilobular osteochondrosarcoma)	3	—	33.3% (1/3)	33.3% (1/3)	0.0% (0/3)	33.3% (1/3)
Amyloid-producing odontogenic tumor	1	—	0.0% (0/1)	0.0% (0/1)	100.0% (1/1)	0.0% (0/1)

AA = Acanthomatous ameloblastoma. BGL = Beagle. BOXE = Boxer. FS = Fibrosarcoma. GCG = Giant cell granuloma. GOLD = Golden Retriever. LABR = Labrador Retriever. MIX = Mixed-breed dog. MM = Malignant melanoma. OSA = Osteosarcoma. PCT = Plasma cell tumor. POF = Peripheral odontogenic fibroma. SCC = Squamous cell carcinoma. SHEP = German Shepherd Dog. WHT = West Highland White Terrier.

Sex was not reported in 2.6% (20 of 773) of cases.

lip was the most frequent site for MM, comprising 21.2% (18 of 85) of all submitted MM cases. Diagnosis of MM was significantly more common on the lip than any other malignant tumor type ($P < 0.0001$). Of all sites, the tonsil was most frequently affected by SCC, comprising 20.7% (11 of 53) of SCC cases. Diagnosis of SCC was significantly more common in the tonsils than other tumor types ($P = .0038$). For the remainder of the tumor types, the limited number of cases and varied distribution across locations did not allow meaningful statistical assessment.

Signalment

Of all oral tumors, 19.8% (154 of 773) were diagnosed in intact females, 29.6% (229 of 773) in intact males, 25.5% (197 of 773) in spayed females, and 22.4% (173 of 773) in castrated males (Table 1). Sex was not reported in 2.6% (20 of 773) of cases. Analysis revealed no statistically significant difference in sex predilection between the most common oral tumor types ($P = .9973$).

The study cohort comprised 132 different breeds **(Supplementary Table S2)**, with mixed-breed dogs being the most prevalent (11.9% [92 of 773]). Breed was not reported in 9% (70 of 773) of cases. Other overrepresented breeds included the Golden Retriever, comprising 6.9% (53 of 773) of cases; Labrador Retriever, representing 6.6% (51 of 773) of cases; and Boxer, representing 5.6% (43 of 773) of cases. Mixed-breed dogs and Boxers showed a notably high number of cases of POF, each representing 4.5% (35 of 773) of cases **(Supplementary Table S3)**. The median age was 9.4 years, with a range of 0.3 to 19 years. Age was not reported in 3% (23 of 773) of cases. Dogs aged 6 to 10 years were most affected by oral tumors, representing 49% (381 of 773) of cases.

Histopathologic characteristics

The histopathologic description was present in 82.7 % (640 of 773) of cases **(Supplementary Table S4; Figure 3)**. Ulceration was significantly lower in benign tumors (13.32% [63 of 473]) compared to

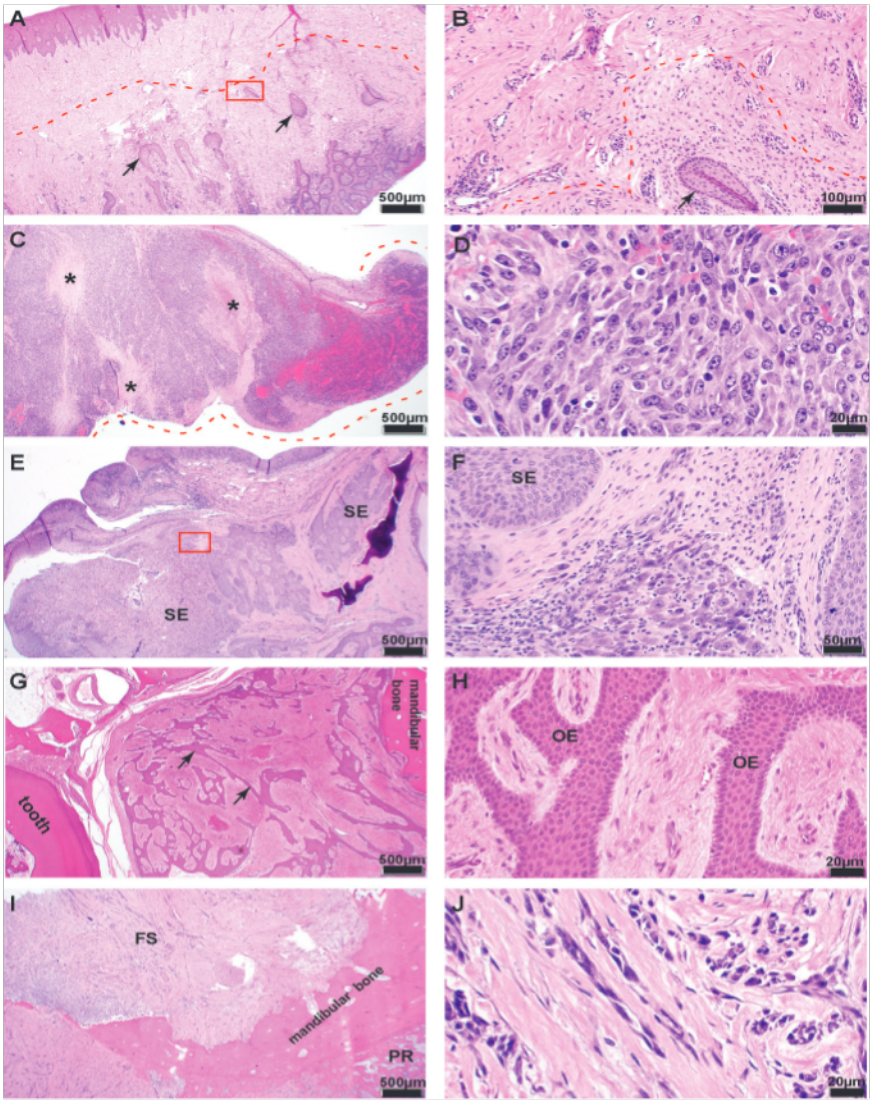

Figure 3—Histopathology of the most common oral tumor types. A—Low-magnification photomicrograph of POF or fibrous epulis of periodontal ligament origin. Note the small islands of odontogenic epithelium (arrows) entrapped in the spindle-cell–predominant mass (dashed red line). B—Same tumor depicted in panel A's red rectangle, shown at a higher magnification. Note that the stroma of the tumor is different from the normal subepithelial stroma. The POF area is more cellular, and the cells have more angular nuclei. The arrow indicates the location of the odontogenic epithelium island. C—Low magnification of malignant melanoma. Note that the majority of the mass is ulcerated (dashed red line), and there are multifocal areas of necrosis (asterisks) scattered throughout the mass. D—High magnification of the malignant melanoma depicted in panel C. Note the spindle-to-plump shape of the neoplastic cells with large nuclei and multiple nucleoli. Cellular atypia and individual dead cells (with clear halo) are prominent. E—Low magnification of squamous cell carcinoma. Note the sheets, fronds, and coalescing islands of squamous epithelium (SE). F—High magnification of the area outlined in the red rectangle in panel E. Note a small island and sheet of almost-individualized squamous epithelium (SE) cells surrounded by numerous neutrophils. G—Low magnification of canine AA invading the periodontium and mandibular bone. The mass is composed of anastomosing ribbons of odontogenic epithelium (arrows), assuming an ink-drop pattern. H—High magnification of the canine AA shown in panel G. Odontogenic epithelium (OE) features palisading epithelial cells with antibasilary-positioned nuclei and single small intracytoplasmic vacuole outlining the ribbons. Within the ribbons, the epithelial cells have prominent intercellular outlines (acanthomatous component). I—Low magnification of fibrosarcoma (FS) invading mandibular bone. Note the scalloped edge of the remaining mandibular bone and periosteal reaction on the opposite aspect of the bone. J—High magnification of the FS depicted in panel I. Note the intersecting bundles of spindle neoplastic cells. Some are running parallel to the sectional plane, while others are running perpendicular to the sectional plane.

malignant tumors (22.5% [55 of 245]) (P = .0017). Necrosis was observed in only 2.33% (11 of 473) of benign tumors, whereas it occurred in 20.8% (51 of 245) of malignant tumors ($P \leq 0.0001$).

The MI (mitotic figures/10 hpf) differed significantly among tumor types (H[6] = 52.61; P < .0001), as shown in **Figure 4**. Tumor types such as SCC, MM, and FS exhibited a wider range and higher maximum values. In contrast, tumor types like PCT and AA displayed a more confined distribution of MI values. As a group, malignant tumors exhibited a significantly higher median MI of 11 mitotic figures/hpf versus a median MI of 3 mitotic figures/hpf in the benign group (Mann-Whitney U statistic = 265; n_1 = 116; n_2 = 11; P = .0009).

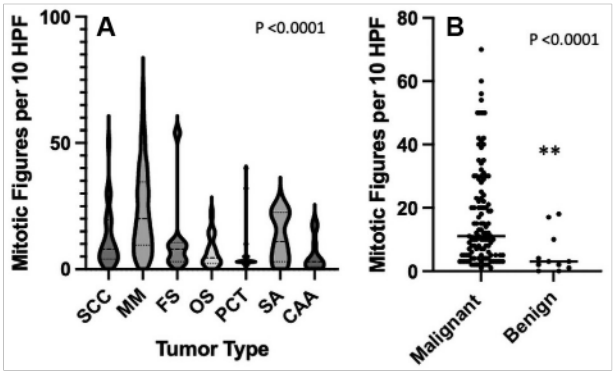

Figure 4—A—Violin plot showing the first, second, and third quartile of mitotic figures/10 hpf for samples of different benign and malignant tumor types. B—Scatterplot comparing the distribution of values for mitotic indices for benign and malignant tumor groups. CAA = Canine AA. MM = Malignant melanoma. OS = Osteosarcoma. PCT = Plasma cell tumor. SA = Sarcoma. SCC = Squamous cell carcinoma.

Ulceration and necrosis parameters exhibited low sensitivities of 22.4% (95% CI, 17.67% to 28.08%) and 20.8% (95% CI, 16.2% to 26.33%) for diagnosing malignant tumors, respectively. Conversely, ulceration and necrosis showed moderate to high specificities of 86.7% (95% CI, 83.32% to 89.45%) and 97.7% (95% CI, 95.88% to 98.70%) for diagnosing malignant tumors, respectively. The MI showed a sensitivity of 79.5% (95% CI, 71.07% to 85.91%) and specificity of 71.4% (95% CI, 57.59% to 82.15%) for malignant tumors, with an optimal cutoff of 3 used to distinguish between benign and malignant tumors (area under the curve = 0.77; 95% CI, 70% to 85%; P < .0001; **Figure 5**). Ulceration had a PPV of 46.6% (95% CI, 37.86% to 55.58%) and NPV of 68.3% (95% CI, 64.50% to 71.93%). Necrosis displayed a PPV of 82.3% (95% CI, 70.96% to 89.79%) and NPV of 70.4% (95% CI, 66.82% to 73.79%). The MI had a PPV of 86.4% (95% CI, 78.47% to 91.73%) and NPV of 60.3% (95% CI, 47.49% to 71.91%).

Geographic predisposition

Among the top 5 tumor types, POF was the most common, with 342 cases where addresses were available. The prevalence of POF was highest in the cantons of Vaud (27.5% [94 of 342]), Bern (13.2% [45 of 342]), and Zurich (2.3% [8 of 342]). Similarly, the highest concentration of MM cases was in Vaud (27.9% [24 of 86]). Acanthomatous ameloblastoma was evenly distributed, with 25.5% (12 of 47) of AA cases being in Bern and 10.6% (5 of 47) in Vaud. Squamous cell carcinoma and PCT showed regional variations, with SCC having a notable presence in Vaud (26.2% [11 of 42]) and Bern (19% [8 of 42]) and PCT being particularly prevalent in Vaud (36.1% [13 of 36]), highlighting distinct regional trends in tumor occurrences among the selected types **(Supplementary Figure S1)**.

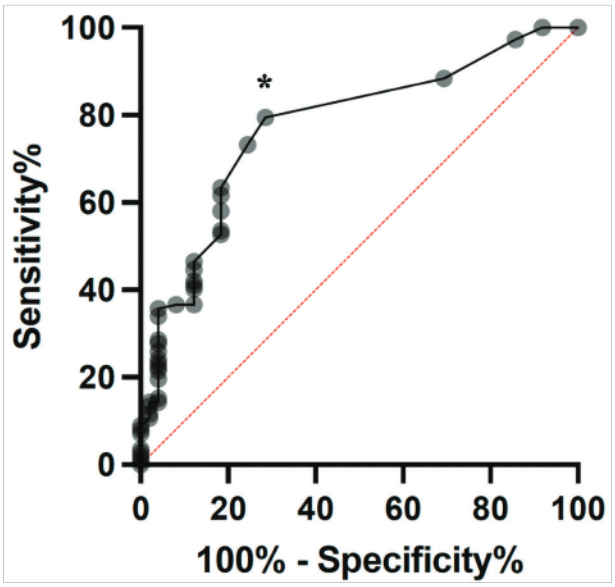

Figure 5—Receiver operating characteristic curve examines mitotic index to distinguish between malignant and benign oral tumors (area under the curve = 0.77; 95% CI, 70% to 85%; P < .0001). A mitotic index of > 3 was used as a cutoff value due to its moderately high sensitivity and specificity.

Discussion

This study investigated the anatomic location, histologic types, and geographic distribution of oral tumors in dogs in Switzerland. We found a higher frequency of benign tumors (63% [487 of 773]) than malignant ones (37% [286 of 773]), with a notably high prevalence of POF. Among malignant tumors, MM emerged as the most prevalent, followed by SCC and FS, aligning with global patterns of oral malignancies in dogs. The study also highlighted that MM occurs significantly more often on the lips, which may suggest potential environmental influences on tumor development, as the lips are more exposed to the external environment. We found no clear breed predisposition for oral tumors, but an increase in age was associated with the likelihood of having an oral tumor. Histologically, the presence of ulceration, necrosis, and a higher MI were significantly more common in malignant tumors, confirming these are valuable predictors of biological behavior.

The predominance of benign tumors, particularly the high incidence of POF among benign tumors

(77.8% [379 of 487]), contrasts with data from the US, which identified AA as the most common benign tumor.[22] A total of 152 dogs with oral tumors of possible odontogenic origin were analyzed in that study,[22] revealing that the 3 most prevalent types were AA (45% [68 of 152]), POF (31% [47 of 152]), and fibromatous hyperplasia (16% [24 of 152]). This discrepancy can be due to differences in regional diagnostic variations and genetic, environmental, or lifestyle factors affecting these populations. For example, the increased oral health awareness that has occurred since the previous study may have led to higher detection rates of benign tumors, including POF. Benign tumors such as POF generally exhibit slower growth rates and less aggressive behavior than malignant tumors. This slower progression may result in a higher likelihood of detection during routine veterinary examinations, contributing to the greater prevalence of benign tumors in the records. The current study also confirmed the common prevalence of AA and the rostral mandible as a predilection site.[12,22]

Among the malignant tumors identified in our study, MM was the most prevalent, accounting for 38.1% (109 of 286) of all malignant cases, followed by SCC (21% [60 of 286]) and FS (8% [23 of 286]). This distribution aligns closely with findings from other studies[8,13,16–21] in the field, reinforcing the global patterns observed in canine oral malignancies. The prominence of MM as the leading malignant tumor is particularly noteworthy, highlighting its high prevalence in canine oral malignancies. This emphasizes the importance of early detection and aggressive treatment strategies in managing this cancer, given its well-documented aggressive clinical behavior.[8,17,23] Interestingly, the analysis of tumor sites revealed the prominence of the lip as the most common location for MM in dogs in Switzerland. This differs from a study[23] from the US, suggesting potential variability in tumor site predilection that may be influenced by genetic or environmental factors not yet fully understood.[24]

No specific breed predisposition for oral tumors could be detected, as country-wide demographic data were unavailable for direct comparison. Nonetheless, genetic factors cannot be ruled out, especially for specific tumor types like POF that have previously documented predisposition in Boxers.[15,18,21,25] The prevalence of mixed-breed dogs and Golden Retrievers may be attributed to their overrepresentation in Switzerland in general.[1] The median age of dogs diagnosed with oral tumors in the present study was 9.4 years, with roughly half of the oral tumor samples obtained from dogs 6 to 10 years of age. The advanced age of the majority of the patients suggests that age plays a role in the development of oral cancer, aligning with the other existing studies.[2,8,15,18,21] The age-related predisposition underscores the importance of ongoing oral health monitoring, including a complete oral examination, in aging dogs.

Detailed histopathologic descriptions were available for 82.7% (640 of 773) of cases, providing a basis for the detailed comparison of benign and malignant tumors. Ulceration presented significantly less frequently in benign tumors (13.32% [63 of 473]) than in malignant ones (22.5% [55 of 245]). The presence of ulceration may often be readily apparent on the initial oral examination and serve as a suggestive initial clinical indicator of malignancy. However, the presence or absence of ulceration cannot be utilized as a standalone determinant of diagnostics and treatment planning. Necrosis was found in only 2.33% (11 of 473) of benign tumors compared to 20.8% (51 of 245) of malignant ones, highlighting the significant distinction between benign and malignant tumor behaviors. The significantly higher occurrence of necrosis in malignant tumors may be due to rapid growth outperforming the speed of angiogenesis.[26] Additionally, tumor necrosis is likely a synergistic consequence of metabolic stress and inflammation, which lead to oxidative stress-induced cell death.[27] Ulceration and necrosis parameters were found to have poor sensitivity but moderate to good specificity for malignancy.

The MI varied significantly across tumor types, with malignant tumors like SCC, MM, and FS exhibiting a wider range and significantly higher maximum values. This significant difference in MI, with a median of 11 mitotic figures/hpf in malignant tumors versus 3 mitotic figures/hpf in benign tumors, reinforces MI as a strong indicator of biological behavior.[28,29] With that said, some proliferative conditions, such as oral papilloma, can have a high MI due to a virus-induced increase in cell replication. Thus, the MI should be assessed in conjunction with other histologic characteristics of the neoplasm. The receiver operating characteristic curve analysis suggested an MI of 3 as the best threshold for differentiating between benign and malignant tumors, although its sensitivity and specificity were only 79.5% and 71.4%, respectively, indicating room for improvement in diagnostic accuracy and precision.

The notable variation in regional tumor prevalence, particularly for POF and SCC, may be influenced by environmental factors despite their seemingly uniform distribution. Dense clusters might not necessarily indicate a rise in tumor cases, but rather reflect areas with denser dog populations or a higher concentration of veterinary facilities. It is also possible that urban dogs are more likely to be presented for investigation of oral tumors, while those in rural areas might go undiagnosed. Additionally, disparities in socioeconomic and cultural patterns can significantly influence our ability to interpret prevalence data; thus, more criteria need to be assessed to draw more solid conclusions regarding geographic distribution.

The retrospective nature of this study inherently introduced several limitations that may affect the interpretation of the findings. Notably, the reliance on pathology records led to incomplete datasets, with particular gaps in variables such as the age, sex, and breed of the subjects, in addition to the anatomical location of tumors, comprehensive histopathologic details, and owner addresses. Further, and clinically impactful, we had no information on metastatic status and tumor treatment. Such omissions may bias the understanding of tumor demographics and features. Further, the reports from several patholo-

gists and variability in individual evaluative practices introduced another layer of complexity. The lack of uniformity in assessment could lead to inconsistencies in diagnosis and classification, affecting the overall coherence of the dataset. The MI, a key parameter in assessing tumor malignancy, was in some instances subjectively described as high, moderate, or low, without quantitative values. This lack of numerical data precluded a more detailed statistical analysis of tumor behavior, potentially affecting the study's conclusions regarding the diagnostic accuracy of histopathologic features to predict malignancy.

In conclusion, oral biopsies from dogs exhibiting oral tumors in Switzerland during the past decade demonstrated that benign tumors were more common than malignant tumors. The most common benign tumor was POF, and the most common malignant tumor was MM. Histologic parameters, including the presence of ulceration, presence of necrosis, and MI, were statistically different when comparing benign and malignant oral tumors. These findings offer important information on the relative occurrence and risk factors for oral tumors in the dog population in Switzerland, setting a foundation for future studies to explore the contributing factors to the development of oral tumors. This understanding may enhance diagnostic accuracy, inform treatment approaches, and ultimately elevate the well-being of dogs suffering from oral neoplasia.

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Supplementary Materials

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