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Outcomes of cats treated with maxillectomy: 60 cases. A Veterinary Society of Surgical Oncology retrospective study

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Abstract

Maxillectomy is poorly described for the management of oral tumours in cats and is occasionally not recommended because of the high complication rate and sub-optimal outcome reported in cats treated with mandibulectomy. The purpose of this study was to retrospectively evaluate the complications and oncologic outcome in cats treated with maxillectomy. Sixty cats were included in the study. Maxillectomy procedures included unilateral rostral (20.0%), bilateral rostral (23.3%), segmental (10.0%), caudal (20.0%) and total unilateral maxillectomy (26.7%). Intra-operative and post-operative complications were reported in 10 (16.7%) and 34 (56.7%) cats, respectively. The most common post-operative complications were hyporexia (20.0%) and incisional dehiscence (20.0%). The median duration of hyporexia was 7 days. Benign tumours were diagnosed in 19 cats (31.7%) and malignant tumours in 41 cats (68.3%). Local recurrence and metastatic rates were 18.3% and 4.9%, respectively; the median progression-free interval (PFI) was not reached. The disease-related median survival time was not reached overall or for either benign or malignant tumours. The 1- and 2-year survival rates were, respectively, 100% and 79% for cats with benign tumours, 89% and 89% for cats with malignant tumours, 94% and 94% for cats with fibrosarcomas, 83% and 83% for cats with squamous cell carcinomas, and 80% and 80% for cats with osteosarcomas. Poor prognostic factors included mitotic index for PFI, adjuvant chemotherapy for both PFI and survival time, and local recurrence for survival time. Maxillectomy is a viable treatment option for cats resulting in good local tumour control and long survival times.

KEYWORDS

complications, fibrosarcoma, oral tumour, osteosarcoma, squamous cell carcinoma

1 | INTRODUCTION

The most common oral tumours in cats are squamous cell carcinoma (SCC), fibrosarcoma (FSA) and osteosarcoma (OSA).[1-3] While the post-operative and oncologic outcomes are well recognized in cats following mandibulectomy, the published outcome of cats following maxillectomy is sparse with only seven published case reports.[4-8] In the experience of the authors, maxillectomy is frequently not offered as a treatment option for cats with maxillary tumours because of the reported complication rate and outcome following mandibulectomy.

In one retrospective study of 42 cats treated with various mandibulectomy procedures,[9] 72% of cats were dysphagic or hyporexic post-operatively and 12% were never able to eat again voluntarily; moreover, short- and long-term morbidities were reported in 98% and 72% of cats, respectively. Despite these findings, the collated results of the published feline maxillectomy case reports suggest that cats treated with maxillectomy may not have the same degree of morbidity as those treated with mandibulectomy. All cats treated with maxillectomy were eating voluntarily within 2-11 days of surgery. Furthermore, six of seven cats had good function with no evidence of local recurrence at the last follow-up, ranging from 7-66 months.[4-8]

The purpose of this study was to retrospectively evaluate the intra- and post-operative complications, and functional and oncologic outcome of cats treated with various maxillectomy procedures.

2 | MATERIALS AND METHODS

This multi-institutional retrospective study was approved by the Veterinary Society of Surgical Oncology (VSSO) research committee. The medical records of all cats treated with maxillectomy procedures at 14 participating veterinary referral hospitals between 1 January 1992 and 13 April 2016 were reviewed. Inclusion criteria for this study were cats with histopathologically confirmed maxillary tumours treated by maxillectomy with a minimum follow-up time of 3 months.

Information collected from the medical records included age, sex, neuter status and breed. The results of pre-operative diagnostics and clinical staging tests were recorded, including complete blood count (CBC) and blood chemistry abnormalities, fine-needle aspirate or biopsy of the maxillary mass, fine-needle aspirate and imaging of the regional lymph nodes and thoracic imaging. The tumour location and maximum tumour dimension were recorded. The rostral maxilla was defined as the incisive bone distal to the second premolar tooth, the mid-maxilla was defined as the second and third premolar teeth and the caudal maxilla was defined as caudal to and including the fourth premolar tooth.[10] Tumours spanning more than one of these categories were defined as having involvement of the unilateral maxilla. Surgical data included date of surgery, type of maxillectomy (unilateral rostral, bilateral rostral, segmental, caudal, total unilateral), closure method, additional resections performed en bloc with the maxillectomy, regional lymph node excision, and description and management of intra- and post-operative complications. Histopathology data included tumour type, histologic grade, mitotic index, presence of lymphatic and/or vascular invasion, completeness of excision and the presence or absence of lymph node metastasis. Additional treatments, including chemotherapy (type of chemotherapy, dose, number of doses, and complications) and radiation therapy (intended protocol, fraction size, number of fractions, total dose, and complications), were recorded. Outcome data included local recurrence, regional lymph node metastasis and distant metastasis. Progression-free interval (PFI) was defined as the time in days from surgery to the diagnosis of local recurrence or metastasis. Survival time was defined as the time in days from surgery to death, lost to follow-up or the end of the study if still alive. The cause of death and whether or not death was tumour-related was recorded. Tumour-related deaths included cats who died or were euthanized because of treatment-related complications, local recurrence or metastasis. Cats with an unknown cause of death were not considered to have died of tumour-related reasons.

Median survival times (MSTs) and PFIs were calculated using the Kaplan-Meier method. Cats alive at the time of last follow-up, dead of unrelated disease or lost to follow-up were censored. Univariable Cox regression models were used to evaluate the relationship of variables to PFI and MST. Statistical analysis was performed using the commercially available software (SAS version 9.4, SAS Institute Inc., Cary, NC). A P-value <.05 was considered statistically significant.

2.1 | Cell line validation statement

Cell line validation was not conducted because cell lines were not used in this retrospective study.

3 | RESULTS

Sixty cats treated with maxillectomy at 14 participating institutions met the inclusion criteria.

The median age was 10.5 years (range, 0.8-17.2 years). Thirty-six cats were castrated males (60.0%) and 24 were spayed females (40.0%). There were 41 domestic short hair cats (68.3%), five domestic long hair cats (8.3%), four domestic medium hair cats (6.7%), two European short hair cats (3.3%), two Persians (3.3%), and one each (1.7%) of a Devon Rex, Himalayan, Maine Coon, Norwegian Forest Cat, Siamese and Sphynx.

CBC and serum chemistry were reported in 49 and 51 cats, respectively. CBC abnormalities were reported in 16 cats including lymphopenia (n = 6), anaemia (5), neutrophilia (3), thrombocytopenia (2), eosinophilia (2) and thrombocytosis (1). Blood chemistry abnormalities included increased blood urea nitrogen (4), increased creatinine (2) and increased amylase (3). Pre-operative tumour diagnostics included fine-needle aspirate cytology (10) and incisional biopsy (49). Cytologic diagnoses included SCC (2), sarcoma (2), OSA (1), round cell tumour (1), suppurative septic inflammation and necrosis (1), and bacterial neutrophilic inflammation (1); cytology was non-diagnostic in two cats. Incisional biopsy results included FSA (12), SCC (10), OSA (5), acanthomatous ameloblastoma (2), amyloid-producing odontogenic tumour (2), feline inductive odontogenic tumour (FIOT, 4), SCC in situ (2), and one each of ameloblastic fibroma, calcifying epithelial odontogenic tumour, calcifying epitheliodontogenic tumour, giant cell epulis, lymphoplasmacytic neutrophilic rhinitis, myxosarcoma, odontogenic tumour with squamous differentiation, odontoma, osteoma, osteoma or OSA, sarcoid and sarcoma. Fine-needle aspirates of the mandibular lymph nodes were performed in 15 cats (25.0%) and there were no cytologic evidence of lymph node metastasis in any cat. The regional lymph nodes were imaged in 43 cats with the following modalities: computed tomography

TABLE 1 A summary of tumour size, location, and treatment for 60 cats with maxillary tumours

		Location				Type of maxillectomy				
Tumour type	Size (range)	Rostral (%)	Mid (%)	Caudal (%)	Hemi (%)	Unilateral rostral (%)	Bilateral rostral (%)	Segmental (%)	Caudal (%)	Total unilateral maxillectomy (%)
Overall	1.6 cm (0.5-3.8 cm)	25 (41.7)	3 (5.0)	10 (16.7)	22 (36.7)	12 (20.0)	14 (23.3)	6 (10.0)	12 (20.0)	16 (26.7)
Benign	1.6 cm (0.5-3.0 cm)	8 (42.1)	1 (5.3)	2 (10.5)	8 (42.1)	5 (26.3)	5 (26.3)	2 (10.5)	5 (26.3)	2 (10.5)
Malignant	2.0 cm (0.5-3.8 cm)	17 (41.5)	2 (4.9)	8 (19.5)	14 (34.1)	7 (17.1)	9 (22.0)	4 (9.8)	7 (17.1)	14 (34.1)
SCC	2.0 cm (0.7-3.8 cm)	3 (23.1)	2 (15.4)	2 (15.4)	6 (46.2)	1 (7.7)	1 (7.7)	1 (7.7)	3 (23.1)	6 (46.2)
FSA	2.0 cm (0.5-3.5 cm)	10 (55.6)	0 (0.0)	1 (5.6)	7 (38.9)	5 (27.8)	6 (33.3)	1 (5.6)	1 (5.6)	5 (27.8)
OSA	2.2 cm (0.5-3.0 cm)	3 (60.0)	0 (0.0)	1 20.0)	1 (20.0)	1 (20.0)	1 (20.0)	1 (20.0)	0 (0.0)	2 (0.0)

Abbreviations: FSA, fibrosarcoma; OSA, osteosarcoma; SCC, squamous cell carcinoma.

(CT) (40), magnetic resonance imaging (2) and ultrasound (1). Imaging findings were not suggestive of nodal metastasis in any cat. Thoracic imaging was performed in 52 cats (86.7%), including three-view thoracic radiographs (26), CT (18), both three-view thoracic radiographs and CT (7), and positron emission tomography-CT (1). Pulmonary metastasis was not identified in any cat.

The median maximum tumour dimension was 1.6 cm (range, 0.5-3.8 cm) (Table 1). Tumours were located in the rostral maxilla and nasal planum (n = 25), mid-maxilla (3), caudal maxilla (10) and the entire maxilla including zygoma (22) (Table 1). The maxillectomy procedures were categorised as unilateral rostral (12), bilateral rostral (14), segmental (6), caudal (12) and total unilateral maxillectomy (16) (Table 1). The approach for caudal maxillectomy and total unilateral maxillectomy was recorded for four cats with an intra-oral approach in three cats and a combined intra-oral and dorsolateral approach in one cat. Partial or complete nasal planectomy (4), lip resection (3), zygomatic arch resection (8) and orbitectomy (3) were additional resections performed en bloc with the maxillectomy. Concurrent lymphadenectomy was performed in 12 cats, including extirpation of the ipsilateral mandibular lymph node (9), bilateral mandibular lymph nodes (2), and bilateral mandibular and medial retropharyngeal lymph nodes (1). The method of closure of the maxillectomy site included labial mucosal flap (50), mucoperiosteal flap (4), caudal auricular axial pattern flap (3), labial advancement flap (3), facial axial pattern flap (2), and one each of superficial cervical axial pattern flap and temporal myofascial flap. Six cats had their maxillectomy defect closed with a combination of a labial mucosal flap and mucoperiosteal flap (3), caudal auricular axial pattern flap (2) or superficial cervical axial pattern flap (1). The closure method was not recorded in two cats.

3.1 | Complications

Intra-operative complications were reported in 10 cats (16.7%), including blood loss (n = 4), hypotension (4) and inadvertent compromise of the tumour capsule (2) (Table 2). Post-operative complications were reported in 34 cats (56.7%), including hyporexia or difficulty eating (12, 20.0%), wound dehiscence or development of an oronasal fistula (12, 20.0%), lip trauma from contact with the ipsilateral mandibular canine tooth (9, 15.0%), epistaxis (7, 11.7%), incisional swelling (3, 5.0%), and one each (1.7%) of emphysema, ptyalism and flap necrosis (Table 2). Eleven cats had multiple post-operative complications, 10 cats with two complications and one cat with three complications. Complications were managed conservatively in 17 cats. Nine cats (15.0%) with hyporexia or eating difficulties had an esophagostomy tube placed for supplementary nutrition for a median of 9 days (range, 2-42 days). The overall median duration of hyporexia or difficulty eating, including two cats not managed with an esophagostomy tube, was 7 days (range, 2-42 days). Four cats (6.7%) with lip trauma were managed with crown height reduction or dental extraction. Two cats (3.3%) with wound dehiscence or oronasal fistula had a surgical revision. One cat with flap necrosis had undergone a closure with a caudal auricular axial pattern flap and was euthanized 23 days after surgery as a result of this complication; the degree of flap necrosis was not recorded.

3.2 | Oncologic outcome

Histopathology was available for all cats following maxillectomy. Benign tumours were diagnosed in 19 cats (31.7%) and malignant tumours in 41 cats (68.3%). Benign tumours included amyloid-producing odontogenic tumour (n = 8), FIOT (4), osteoma (3), acanthomatous ameloblastoma (2), giant cell epulis (1) and odontogenic cyst (1). Malignant tumours included FSA (18), SCC (13), OSA (5), nasal adenocarcinoma (2), and one each of SCC in situ, sarcoid and myxosarcoma. Mitotic index was reported in 29 cats and histologic grade was reported in 18 cats (Table 3). Lymphatic and vascular invasion were reported in two cats, both with SCC (3.0% overall, 4.9% of malignant tumours and 15.4% of SCCs). The completeness of histologic excision was reported in 58 cats and these results are

TABLE 2 A summary of intra-operative and post-operative complications for each type of maxillectomy procedure and overall

Complications		Unilateral rostral maxillectomy	Bilateral rostral maxillectomy	Segmental maxillectomy	Caudal maxillectomy	Total unilateral maxillectomy	Overall
Intra-operative	Overall (%)	5 (41.7)	2 (14.3)	0 (0.0)	3 (25.0)	0 (0.0)	10 (16.7)
	Blood loss (%)	2 (16.7)	1 (7.1)	0 (0.0)	1 (8.3)	0 (0.0)	4 (6.7)
	Hypotension (%)	2 (16.7)	0 (0.0)	0 (0.0)	2 (16.7)	0 (0.0)	4 (6.7)
	Tumour compromise (%)	1 (8.3)	1 (7.1)	0 (0.0)	0 (0.0)	0 (0.0)	2 (3.3)
Post-operative	Overall (%)	7 (58.3)	6 (42.9)	4 (66.7)	7 (58.3)	10 (62.5)	34 (56.7)
	Eating difficulties (%)	5 (41.7)	2 (14.3)	2 (33.3)	1 (8.3)	2 (12.5)	12 (20.0)
	Eating difficulties duration (median; range),	7 days (range, 2-42 days)	14 days	14 days (range, 13-15 days)	4 days	3 days	7 days (range, 2-42 days)
	Wound dehiscence (%)	0 (0.0)	4 (28.6)	1 (16.7)	4 (33.3)	3 (18.8)	12 (20.0)
	Epistaxis (%)	0 (0.0)	0 (0.0)	1 (16.7)	2 (16.7)	4 (25.0)	7 (11.7)
	Lip trauma (%)	2 (16.7)	2 (14.3)	1 (16.7)	2 (16.7)	2 (12.5)	9 (15.0)
	Incisional swelling (%)	1 (8.3)	0 (0.0)	0 (0.0)	1 (8.3)	1 (6.3)	3 (5.0)
	Subcutaneous emphysema (%)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)
	Hypersalivation (%)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)
	Flap necrosis (%)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.3)	1 (1.7)

summarized in Table 3. For cats with complete histologic excision, the mean lateral histologic tumour-free margin was 3.2 mm (SD ±1.5 mm; range, 0.5-6.0 mm). Regional lymph nodes were assessed in 20 cats (31.7%); one cat with a SCC had histologic evidence of nodal metastasis (2.4% of cats with malignant tumours and 7.7% of cats with SCC).

Eight cats (13.3%) were treated with adjuvant chemotherapy, including two cats each with SCC, FSA and OSA, and one cat each with a nasal adenocarcinoma and amyloid-producing odontogenic tumour (Table S1). The cat with a metastatic maxillary SCC to the regional lymph node was not treated with chemotherapy. The intended chemotherapy protocol was completed in two cats (25.0%). The reasons for failure to complete the intended chemotherapy protocol was a grade 4 neutropenia in one cat; however, the reasons were not reported in the remaining five cats.

Eight cats (13.3%) were treated with adjuvant radiation therapy, including six cats with curative-intent protocols and two cats with palliative protocols (Table S2). Two of these cats, one with a nasal adenocarcinoma and another with an amyloid-producing odontogenic tumour, were also treated with chemotherapy. The cat with a metastatic maxillary SCC to the regional lymph node was not treated with radiation therapy.

Local tumour recurrence was reported in 11 (18.3%) cats, including three cats with benign tumours (15.8%) and eight cats with malignant tumours (19.5%) (Table S3). Local tumour recurrence was reported in three cats with FSA (16.7%); two cats each with SCC (15.4%), OSA (40.0%) and amyloid-producing odontogenic tumour (25.0%), and one cat each with a FIOT and myxosarcoma. Local recurrence was diagnosed in four cats with complete histologic excision (11.1%) and seven cats with incomplete histologic excision (31.2%) of their maxillary tumours.

Metastasis was reported in two cats, both with SCC (4.9% of cats with malignant tumours and 15.4% of cats with SCC). The metastatic sites were the regional lymph nodes in one cat, and both the regional lymph nodes and lungs in the other cat. One cat diagnosed with lymph node metastasis at surgery was alive and disease free 362 days following surgery.

The median PFI was not reached. Both mitotic index and treatment with chemotherapy were prognostic for PFI overall (Table 4), but only mitotic index for cats with malignant maxillary tumours (Table 5) on univariable analysis. Maximum tumour dimension, type of maxillectomy, histologic diagnosis, histologic margins,and treatment with adjunctive radiation therapy were not significantly associated with PFI.

At the end of the study, 28 cats were alive (median, 470 days; range, 118-1994 days) and 31 cats had died (median, 683 days; range, 21-4267 days). Deaths were unrelated in 21 cats; these included chronic renal failure (10), a second unrelated tumour (4), unknown causes (4),and one cat each as a result of blindness, trauma and hypertrophic cardiomyopathy. One cat was disease-free when lost to follow-up at 452 days post-operatively. Cats alive at the time of last follow-up, dead of unrelated disease or lost to follow-up were censored; the median follow-up time for censored cats was 627 days (range, 55-4267 days). Disease-related deaths were reported in 11 cats (18.3%) and included local tumour recurrence (9), metastasis (1) and post-operative complication (flap necrosis) (1). Local tumour recurrence as a cause of death was reported in three cats with FSAs (16.7%), two cats with amyloid-producing odontogenic tumours (25.0%), and one cat each with a SCC (7.7%), OSA (20.0%), FIOT (25.0%) and nasal adenocarcinoma (50.0%). The overall and tumour-specific outcomes are summarized in Table 6. Treatment with chemotherapy and local tumour recurrence were prognostic on univariable Cox regression analysis for all cats (Table 7), but only mitotic index for cats with malignant maxillary tumours (Table 8). While not significant, cats with incomplete histologic excision approached significance (P = .05) for disease-related survival time. Maximum tumour dimension, type of maxillectomy, histologic diagnosis and treatment with adjunctive radiation therapy were not significantly associated with survival time.

4 | DISCUSSION

The outcomes following maxillectomy in cats are poorly described in the veterinary literature and much of the information is inferred from the results following mandibulectomy.[9] The results of this study show that maxillectomy is well tolerated in cats, with a lower complication rate than reported following mandibulectomy, and that maxillectomy is associated with very good tumour control and survival times, even for cats with malignant oral tumours.

4.1 | Complications

Post-operative complications are a prevailing concern following mandibulectomy in cats and, anecdotally, often cited as a reason for not recommending oral oncologic resections in cats with either mandibular or maxillary tumours. In one study of 42 cats treated with various mandibulectomy procedures,[9] 97.5% of cats had one or more complications within the first 4 weeks of surgery and 76.3% of cats had complications persisting for longer than 4 weeks. In contrast to these findings, the overall complication rate in cats treated with various maxillectomies in the present study was 56.7%. While we did not divide the post-operative complications into defined time periods, only one cat had a complication persisting for longer than 15 days. While this complication rate is still high, these complications were short term and not as high as the complication rate reported for other treatment modalities for treatment of oral tumours in cats. For instance, hyporexia was reported in 69.5% of cats treated with toceranib phosphate,[11] and complications were reported in 85.7% to 100.0% of cats treated with palliative radiation therapy,[12-14] 80.1% of cats treated with an accelerated radiation therapy protocol and carboplatin,[15] and 80.0% of cats treated with stereotactic radiation therapy (including pathologic fracture in 54.5% of cats with mandibular SCC).[16]

The most prevalent and concerning complication following mandibulectomy in cats is hyporexia.[9] Hyporexia was reported in 72.5%

TABLE 3 A summary of the histologic features of maxillary tumours in 60 cats resected with various maxillectomy procedures

	Mitotic index		Histologic grade				Histologic excision	
	Mean	Range	Overall (%)	I (%)	II (%)	III (%)	Complete (%)	Incomplete (%)
Overall	7.3	0-30	18 (30.0)	7 (11.7)	6 (10.0)	5 (8.3)	36 (62.1)	22 (37.9)
Benign	—	—	—	—	—	—	13 (68.4)	6 (31.6)
Malignant	—	—	18 (43.9)	7 (17.1)	6 (14.6)	5 (12.2)	23 (59.0)	16 (41.0)
SCC	8.2	0-22	5 (38.5)	0 (0.0)	3 (23.1)	2 (15.4)	8 (61.5)	5 (38.5)
FSA	9.3	1-30	8 (44.4)	3 (16.7)	2 (11.1)	3 (16.7)	8 (50.0)	8 (50.0)
OSA	3.3	1-5	2 (40.0)	2 (40.0)	0 (0.0)	0 (0.0)	4 (80.0)	1 (20.0)
Other	—	—	—	—	—	—	3 (60.0)	2 (40.0)

Abbreviations: FSA, fibrosarcoma; OSA, osteosarcoma; SCC, squamous cell carcinoma.

TABLE 4 Prognostic factors for overall progression-free interval for 60 cats with maxillary tumours

	Median progression-free interval (days, range)	Hazard ratio (95% confidence interval)	*P*-value	1-year survival Rate (%)	2-year survival Rate (%)
Mitotic index	—	1.11 (1.02-1.21)	.01	—	—
Chemotherapy		4.05 (1.16-14.19)	.03		
Yes	521 (249-2773)			80	40
No	Not reached			91	82

TABLE 5 Prognostic factors for progression-free interval for 41 cats with malignant maxillary tumours

	Median progression-free interval (days, range)	Hazard ratio (95% confidence interval)	*P*-value	1-year survival rate (%)	2-year survival rate (%)
Mitotic Index	—	1.11 (1.02-1.21)	.02	—	—
Chemotherapy		2.60 (0.50-13.20)	.26		
Yes	1599 (249-2773)			75	50
No	Not reached			85	80

TABLE 6 A summary of the overall outcome and tumour-specific outcome for cats with maxillary tumours treated with various maxillectomy procedures

	Surgical intent		Histologic margins						Survival rate	
Tumour type	Wide (%)	Marginal (%)	Complete (%)	Incomplete (%)	Local recurrence rate (%)	Metastatic rate (%)	Survival time	Survival time range (days)	1 y (%)	2 y (%)
Overall	45 (77.6)	13 (22.4)	36 (62.1)	22 (37.9)	18.3	3.3	Not reached	21-4267	93	84
Benign	14 (73.7)	5 (26.3)	13 (68.4)	6 (31.6)	15.8	—	Not reached	151-4267	100	79
Malignant	32 (80.0)	8 (20.0)	24 (61.5)	15 (38.5)	19.5	4.9	Not reached	21-2657	89	89
SCC	10 (83.3)	2 (16.7)	8 (61.5)	5 (38.5)	15.4	15.4	Not reached	23-2657	83	83
FSA	15 (83.3)	3 (16.7)	8 (50.0)	8 (50.0)	16.7	0.0	Not reached	21-1614	94	94
OSA	1 (20.0)	4 (80.0)	4 (80.0)	1 (20.0)	40.0	0.0	Not reached	282-1056	80	80

Abbreviations: FSA, fibrosarcoma; OSA, osteosarcoma; SCC, squamous cell carcinoma.

of cats within 4 weeks of surgery, including 83.3% of cats treated with bilateral mandibulectomy, 0.0% of cats treated with segmental mandibulectomy and 73.7% of cats treated with total mandibulectomy.[9] Hyporexia persisted for longer than 4 weeks in 41.1% of cats overall, including 8.3% of cats treated with bilateral mandibulectomy, 0.0% of cats treated with segmental mandibulectomy and 52.6% of cats treated with total mandibulectomy.[9] Feeding tubes were inserted for supplemental nutrition in 40.5% cats for a median time of 74 days (range, 2-192 days), and 11.9% of cats did not return to voluntary eating.[9] In contrast to these findings, hyporexia was reported in only

TABLE 7 Prognostic factors for survival time for 60 cats with maxillary tumours

	Median progression-free interval (days, range)	Hazard ratio (95% confidence interval)	*P*-value	1-year survival rate (%)	2-year survival rate (%)
Chemotherapy		5.50 (1.64-18.40)	.006		
Yes	791 (21-2657)			70	53
No	Not reached			96	90
Local recurrence		6.61 (1.92-22.72)	.003		
Yes	867 (282-2657)			90	56
No	Not reached			94	94

TABLE 8 Prognostic factors for survival time for 41 cats with malignant maxillary tumours

	Median progression-free interval (days, range)	Hazard ratio (95% confidence interval)	*P*-value	1-year survival rate (%)	2-year survival rate (%)
Mitotic index	—	1.12 (1.01-1.24)	.03	—	—
Chemotherapy		3.71 (0.82-16.77)	.09		
Yes	791 (21-2657)			64	64
No	Not reached			94	94
Local recurrence		2.17 (0.48-9.87)	.32		
Yes	867 (282-2657)			90	56
No	Not reached			94	94

20.0% of cats treated with maxillectomy in the present study, including 41.7% of cats treated with unilateral maxillectomy, 14.3% of cats treated with bilateral maxillectomy, 33.3% of cats treated with segmental maxillectomy, 8.3% of cats treated with caudal maxillectomy and 12.5% of cats treated with total unilateral maxillectomy. Furthermore, only 15.0% of cats had a feeding tube inserted for a median of 9 days (range, 2-42 days), only one of these cats had a feeding tube for longer than 15 days and all cats returned to voluntary eating. Based on these findings, insertion of a feeding tube may not be necessary at the same time as the maxillectomy procedure, unlike cats treated with mandibulectomy. While insertion of a feeding tube may occasionally be required, it may be preferable to insert a feeding tube for supplemental nutrition in the 15% of cats with persistent hyporexia rather than the 85% cats returning to voluntary eating and not requiring supplemental nutrition. The potential complications of esophagostomy tubes should be considered when contemplating their routine use in maxillectomy cases. In one study, which included 123 cats, 45.5% of cats had esophagsotomy tube-related complications, including 17.8% of cats with stomal infections.[17]

Wound dehiscence (20.0%), upper lip trauma from contract with the ipsilateral mandibular tooth (15.0%) and epistaxis (11.7%) were other common complications reported in the present series. The rate of wound dehiscence was comparable with cats treated with mandibulectomy (12.5%)[9] and, depending on the study, dogs treated with maxillectomy (11.0% to 23.0%).[4,18,19] The reason for this is unknown, but self-trauma from licking the intra-oral wound, especially considering the coarseness of the tongue of a cat because of the backward facing papillae,[20] is one possibility. In one study of dogs treated with maxillectomy, the wound dehiscence rate was 32.8%, but 55.0% of these cases were also treated with adjuvant radiation therapy.[19] No cat with wound dehiscence in the present study was also treated with radiation therapy. Wound dehiscence was typically minor and was managed conservatively in the majority of cases with surgical revision required for only 16.7% of cats with this complication.

The incidence of tooth-related trauma was similar in the present study to cats treated with mandibulectomy (18.4%)[9] and dogs treated with maxillectomy (10.0%-13.4%).[18,21] Lip trauma following maxillectomy may be caused by post-operative swelling, post-operative neuropraxia with denervation of maxillary soft tissues, and anatomic relocation of the upper lip with medialization of the upper lip into the occlusal plane of the ipsilateral mandibular canine tooth as a result of excessive tension on or inadequate release of the labial mucosa-submucosal flap.[18,22] Monitoring cats with lip trauma is recommended initially as conservative management can be successful, especially if the lip trauma is a result of post-operative swelling which subsequently subsides. Conservative management was successful in the management of 44.4% of cats with lip trauma in the present series and in 63.6% of dogs with post-maxillectomy lip trauma.[18] Crown height reduction or extraction of the ipsilateral mandibular canine tooth may be required in cats in which lip trauma is caused by medialization of the upper lip or if this trauma does not resolve as post-operative swelling subsides.

4.2 | Oncologic outcome

Benign and malignant tumours account for 5.6% to 17.9% and 82.1% to 94.4%, respectively, of oral tumours in cats.[1-3] Of the malignant tumours, SCC is the most common, accounting for 61.2% to 75.0% of all oral tumours, followed by FSA (2.8% to 12.9%), malignant melanoma (2.6% to 2.8%) and OSA (0.0% to 2.6%).[1-3] This distribution of tumour types is similar to the tumours in 42 cats treated with mandibulectomy,[9] where SCC was the most common malignant tumour (50.0%) and only two cats had benign tumours (4.8%). In contrast to these findings, a higher proportion of cats with benign tumours were treated with maxillectomy (31.7%) and, of the malignant tumours, FSAs were more commonly treated (30.0%) than SCCs (21.7%). A selection bias may have been responsible for this finding as benign tumours, FSAs, and OSAs are often localized and well circumscribed, and hence more amenable to surgical resection than the majority of SCCs.

Local tumour recurrence was reported in 18.3% of cats (Table 8), including 11.1% of cats with complete histologic excision and 31.2% of cats with incomplete histologic excision of their tumours. There was no significant association between the completeness of excision and local tumour recurrence; however, with almost one third of cats with incomplete histologic excision of their maxillary tumour developing local tumour recurrence, further treatment should be considered for these cats. Eight cats were treated with adjuvant radiation therapy, including six cats with incompletely excised tumours. One of these cats, a cat with a benign amyloid-producing odontogenic tumour treated with a palliative radiation protocol, subsequently developed local tumour recurrence. The combination of mandibulectomy and radiation therapy resulted in the best reported survival times for cats with mandibular SCC with a MST of 14 months[23] compared with 217 days or less for cats treated with mandibulectomy alone or other modalities;[9,11-16,24-27] however, only seven cats were included in this study and six of these cats were euthanized because of local tumour recurrence. The role of radiation therapy in the treatment of cats with incompletely excised oral tumours requires further investigation.

Post-operative metastasis was reported in only two cats, both with SCC, representing an overall post-operative metastatic rate of 4.9% for cats with malignant tumours and 15.4% of cats with SCC. Metastatic sites included the regional lymph nodes in both cats and the lungs in one cat. These findings are similar to those reported in cats with mandibular tumours[9] where metastasis was not reported in cats with either FSA or OSA, but 19.0% cats with SCC had metastasis to the regional lymph nodes. Adjuvant chemotherapy is not indicated for cats with either oral FSA or OSA considering the 0% metastatic rate for both tumour types in the present study and a study of 42 cats with mandibular tumours,[9] and is likely not indicated for cats with oral SCC treated surgically with metastatic rates less than 20.0%.

The majority of cats were either alive at the end of the study or had died of unrelated reasons (81.7%). Local tumour recurrence accounted for disease-related deaths in nine of 11 cats; this is similar to cats treated with mandibulectomy where 33.3% of cats were euthanised because of local tumour recurrence.[9] The local recurrence rate in cats with SCC treated with maxillectomy (7.7%) is substantially lower compared with cats treated with mandibulectomy (38.1%).[9] Based on the findings of this and other studies, the major challenge in the management of feline oral tumours, particularly SCC, is local tumour control rather than metastatic disease.[9,23] The relatively high rate of local tumour control in the present study may account for the very encouraging survival times in cats with malignant maxillary tumours.

Disease-related survival times were not reached for cats with benign tumours, malignant tumours, SCC, FSA and OSA, and there was no significant difference in survival times based on histologic diagnosis. This differs from the findings in cats treated with mandibulectomy where cats with mandibular SCC (MST 217 days) had a significantly worse outcome than cats with either mandibular FSA or OSA (MSTs not reached),[9] and in dogs treated with maxillectomies where dogs with malignant tumours were 21 times more likely to have a disease-related death than dogs with benign tumours.[19] Despite the worse outcome for cats with mandibular SCC, cats with malignant oral tumours, including SCC, had a very good chance for long-term survival if they remained disease-free at 1 year. The 1- and 2-year survival rates were the same for cats with mandibular SCC (43%), FSA (67%) and OSA (83%).[9] Similarly, the 1- and 2-year survival rates were the same in cats with maxillary SCC (83%), FSA (94%) and OSA (80%); however, these survival rates were higher than cats treated with mandibulectomy. The survival times and rates for cats treated with either mandibulectomy or maxillectomy are numerically superior to cats treated with other modalities. The MSTs for cats with oral SCC treated with palliative radiation therapy were 60 to 174 days,[12-14] 112 days for cats treated with palliative radiation therapy and gemcitabine as a radiation sensitizer,[24] 136 days for cats treated with palliative radiation therapy and anti-angiogenic therapies,[25] 86 days for cats treated with an accelerated radiation therapy protocol,[26] 130 to 160 days for cats treated with an accelerated radiation therapy protocol with carboplatin,[15] 106 days for cats treated with stereotactic radiation therapy,[16] 113 days for cats treated with intratumoural injection of radioactive holmium microspheres[27] and 123 days for cats treated with toceranib phosphate.[11] Furthermore, tumour-related deaths were reported in only 18.3% of cats treated with maxillectomy and 33.3% of cats treated with mandibulectomy,[9] which compares favourably with tumour-related deaths in 77.8% to 100.0% of cats treated with other modalities.[11,12,14-16,26,27]

Prognostic factors in the present study included mitotic index, treatment with adjuvant chemotherapy and local tumour recurrence. Mitotic index is an indirect measure of cell proliferation and is prognostic in a variety of human and canine cancers. Mitotic index was prognostic for cats with malignant maxillary tumours for both PFI and survival time, which is consistent with the findings of a study of 20 cats with oral SCC treated with stereotactic radiation therapy.[16] Mitotic index requires further investigation in cats with oral tumours, particularly SCC, as this may provide the basis for a histologic grading scheme and direct adjuvant treatment options. Overall, cats treated

with chemotherapy had a significantly shorter PFI (521 days) and MST (791 days) compared with cats not treated with chemotherapy (PFI and MST not reached); however, treatment with chemotherapy was not significant for cats with malignant tumours. While not significant, the MST for cats treated with mandibulectomy alone was not reached at 2920 days compared with 217 days for cats treated with mandibulectomy and adjuvant chemotherapy.[9] Similarly, the MST was less in cats treated with palliative radiation therapy and chemotherapy (80 days) compared with palliative radiation therapy alone (157 days).[13] The worse outcome for cats with oral tumours treated with chemotherapy is likely a result of selection bias. Adjuvant chemotherapy was included in the treatment protocol of eight cats in the present study, including six cats with incomplete histologic excision of their tumours and one cat with a benign amyloid-producing odontogenic tumour. The use of systemic chemotherapy as a surrogate for local tumour control, especially in a cat with a benign tumour, is likely to fail as evidenced by the development of local tumour recurrence in four of the six cats with incomplete histologic excision, including the cat with an amyloid-producing odontogenic tumour. This is further supported by the significantly shorter survival time in cats with local tumour recurrence (MST 867 days with 1- and 2-year survival rates of 90% and 56%, respectively) compared with cats with no local tumour recurrence (MST not reached with 1- and 2-year survival rates of 94% and 90%, respectively). This finding supports and emphasizes the importance of local tumour control in cats with surgically treated oral tumours and the need to consider non-chemotherapy-based adjuvant treatment options to optimize local tumour control, such as surgical revision or radiation therapy, in cats with incompletely excised oral tumours.

Limitations of this study are inherent to its retrospective and multi-institutional design. Staging tests, especially lymph node assessment for cats with malignant tumours, were done inconsistently and incompletely and hence it is possible that the incidence of preoperative nodal metastasis was underestimated. Follow-up exams and staging tests were inconsistent in the post-operative period and necropsy was not performed in any cat, so local recurrence, metastasis, and disease-related deaths may have also been underestimated. While the majority of cats were treated with maxillectomy alone, some cats were treated with adjuvant chemotherapy or radiation therapy and these may have influenced complications and survival. A selection bias may have influenced the type of tumours treated and the outcome. Selection for smaller, well-circumscribed tumours may have resulted in a greater proportion of benign and low-grade malignant tumours, such as FSAs and OSAs, being treated with maxillectomy and this may have resulted in a more successful outcome with better local tumour control and survival rates. The encouraging outcomes for cats with SCC may have been because of a selection bias for smaller and less diffuse SCCs and may not be representative of the expected outcomes for cats with SCCs irrespective of the size of the SCC. Cats treated with chemotherapy had a significantly decreased PFI and MST, and this may have been because of a selection bias with chemotherapy being used more commonly in cats with incomplete excision of their maxillary tumours.

This retrospective study describes the complications and oncologic outcomes for 60 cats treated with maxillectomy for oral and nasal tumours. The complication rate was lower than reported for mandibulectomy in cats and other treatment modalities for cats with oral SCC, and more similar to the complications reported in dogs treated with maxillectomy. The outcomes of cats treated with maxillectomy were excellent with good local tumour control rates and prolonged survival, even in cats with SCC. Maxillectomy is a viable treatment option for cats with resectable, non-metastatic maxillary tumours.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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