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Open-Mouth Jaw Locking in Cats – A Literature Review and Use of Computed Tomography in Three Cases

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Abstract

Case series summary

This report summarises and reviews the published cases of open-mouth jaw locking in cats, and describes three further cases. Case 1 was a five-year-old, 5.3kg male neutered domestic shorthair. Computed tomography (CT) identified changes consistent with temporomandibular joint (TMJ) dysplasia with osseous degenerative changes, and the cat subsequently underwent bilateral partial zygomectomy with bilateral partial coronoidectomy. Case 2 was a ten-year-old, 6.0

kg male neutered Exotic Shorthair. Aside from a fracture of the left maxillary canine tooth crown and absence of the left maxillary fourth premolar tooth, no abnormalities were found on CT scan. The cat also underwent bilateral partial zygomectomy with bilateral partial coronoidectomy. The third case was a one-year-old, 4.0 kg male neutered Persian cat. Changes on CT were consistent with bilateral TMJ dysplasia, and the cat underwent staged bilateral partial zygomectomy with bilateral partial coronoidectomy. There was no recurrence of open-mouth jaw locking in any of the cases on long term follow-up.

Relevance and novel information

Open mouth jaw locking has been reported in cats of a wide range of ages from one to ten years old. Cats with all skull types (brachycephalic, mesatocephalic and dolicocephalic) may be affected, but brachycephalic breeds seem to be over represented. A CT scan with the jaw locked in place is recommended for diagnosis and surgical planning purposes; two of the cases reported here document the first cases of TMJ dysplasia in cats to be definitively diagnosed using CT. Trauma and symphyseal or TMJ laxity may also predispose to development of the condition. Partial coronoidectomy and partial zygomatic arch resection performed alone or in combination are generally successful at preventing recurrence. Bilateral partial zygomectomy with bilateral partial coronoidectomy has not previously been

reported as a surgical treatment, and is recommended when open mouth jaw locking occurs bilaterally.

Introduction

Open-mouth jaw locking is characterised by an inability to close the mouth due to ventrolateral displacement of the mandibular coronoid process relative to the zygomatic arch following full mouth opening (e.g. playing with large objects, yawning). The condition may occur unilaterally or bilaterally, and animals present with the mouth wide open and the mandible tilting downwards on the locked side. A bony prominence (the coronoid process) may be felt adjacent to the ipsilateral zygomatic arch. Signs such as salivation, pawing at the mouth and apparent pain and distress are often seen (1-4). The condition is well documented in dogs, but remains rare in cats, with only 11 previous cases reported in the literature (1-9). This report includes three new cases where computed tomography (CT) was used in the diagnosis and surgical planning of this unusual disorder.

Case series description

Case one

A five-year-old, 5.3kg male neutered domestic shorthaired cat presented to the orthopaedic department of Langford Vets (University of Bristol), following five

episodes of open-mouth jaw locking. The cat had a history of chronic gingivostomatitis, and had undergone extraction of all teeth except the canines, incisors and the mandibular left fourth premolar (308) 17 months prior to presentation. All five episodes of open-mouth jaw locking had occurred within a two-week period, and all but the first episode had required manual re-alignment of the mandible under sedation by the referring veterinary surgeon. The episodes were thought to be associated with yawning and had occurred either at night or in the early morning. The owner reported that the second time the jaw locked it was wider than all other times (>1-2cm); the cat was subjectively painful and/or distressed, was drooling saliva, and vocalising excessively. During all other episodes the cat was unable to eat or drink and was subdued, but no distress or pain response was observed. Between locking episodes the cat exhibited normal behaviour.

On physical examination all cardiovascular parameters were within normal limits. Mild gingivitis was noted adjacent to the remaining teeth. Palpation of the skull did not reveal any abnormalities. The cat was admitted to the hospital for further investigations and was sedated with 5μg/kg IV dexmedetomidine and 0.3mg/kg IV butorphanol. To make a definitive diagnosis and to assess potential underlying causes of the open-mouth jaw locking, CT of the head was carried out using a 16-slice Siemens Somaton CT scanner. Scans were performed with the jaw open and

closed, however it was not possible to recreate the open-mouth jaw locking under sedation. CT images were analysed by an ECVDI board certified specialist using OsiriX (Pixmeo, Geneva, Switzerland) open source DICOM viewer. On the closed mouth images, the retroarticular processes of the temporal bone were elongated bilaterally and extended more rostrally and ventrally than normal, partially enclosing the condyloid process of the mandible. Both condyloid processes were irregular and flattened dorsally (Figure 1). No abnormalities of the mandibular symphysis were identified. On the open-mouth images, the right temporomandibular joint (TMJ) space was completely collapsed and the left TMJ space was narrow, but the coronoid processes were not displaced lateral to the zygomatic arches. The changes were consistent with TMJ dysplasia with osseous degenerative changes. The sedation was reversed with 250µg/kg IM atipamazole, and the patient was returned to the feline ward overnight. The following day, the cat was pre-medicated with 0.2mg/kg IV methadone and 5µg/kg IV dexmedetomidine, and general anaesthesia was induced with 1mg/kg IV alfaxalone. The patient was intubated with a 5mm internal diameter endotracheal tube and anaesthesia maintained using isoflurane (1 - 1.8%) in 100% oxygen (1.5 - 2.5 L/min) via a T-piece circuit. Throughout the anaesthetic the cat was monitored with non-invasive blood pressure monitoring, a lead II ECG, oral temperature probe, capnograph, and pulse oximeter. Compound sodium lactate solution was

administered at 12 ml/hr and a 50 ml bolus was given over ten minutes during anaesthesia to address hypotension. Under anaesthesia it was possible to recreate open-mouth jaw locking manually on both sides. The CT was repeated with the jaw locked on the left side, which showed ventrolateral displacement of the coronoid process of the mandible and subluxation of the left TMJ (Figure 2). A diagnosis of open-mouth jaw locking due to impingement of the coronoid process on the ventrolateral aspect of the zygomatic arch was made, which was thought most likely to be secondary to the TMJ dysplasia. The cat was prepared for surgery of both lateral aspects of the face by clipping the hair over the surgical sites and aseptically preparing the skin. The cat was initially positioned in right lateral recumbency and draped for surgery of the left lateral facial area. The mouth was locked open on the left side by the anaesthetist, and a 5 cm incision through the skin and subcutaneous tissue was made over the ventral border of the rostral portion of the zygomatic arch, where the displaced coronoid process could be felt. The fascial attachments to the arch were elevated, taking care to preserve the dorsal buccal branch of the facial nerve. A 3 cm incision was made into the periosteum, which was subsequently lifted from the zygomatic bone using a periosteal elevator. Visualisation of the coronoid process of the mandibular ramus in contact with ventral lateral zygomatic arch was obtained, enabling identification of the structures that required removal (Figure 3). Using an air powered 3 mm

sphere-shaped diamond spinal bur, a full bone width portion of the rostral zygomatic arch measuring 10 mm in length was removed. This was followed by removal of the dorsal 4 mm of the coronoid process. The periosteum and subcutaneous tissues were closed separately with 4-0 poliglecaprone 25 (Monocryl, Ethicon, NJ) in simple continuous pattern. Four 4-0 nylon cruciate sutures were placed to appose the skin edges. The patient was repositioned into left lateral recumbency, and the procedure repeated for the right side, using the same technique. Meloxicam 0.1mg/kg SC was administered prior to recovery. Analgesia post-operatively was provided by methadone 0.2 mg/kg IV every 4 hours over 20 hours and subsequently with buprenorphine 0.02 mg/kg IV for the following 12 hours. The initial injection of meloxicam was followed with 0.05 mg/kg PO meloxicam, which was dispensed for the owner to administer once daily for 5 days. The patient began eating the following morning, and was discharged later that day. To minimize postoperative pain, a soft diet was recommended for two weeks following surgery. When at home, the owner noted an inability to settle, including periods of running around in an agitated manner and excessively licking itself. Oral buprenorphine was prescribed by the referring veterinary surgeon, which reportedly alleviated the signs initially, and the meloxicam was continued. The cat had been trying to scratch at the face, mostly on the left side, but had not been able to remove the buster collar. By day ten post-operatively the wounds

were healing satisfactorily and the sutures were removed. The altered behavioural signs had continued and so a ten-day course of gabapentin (50 mg PO twice daily) was prescribed. After completion of the gabapentin course, two sessions of acupuncture and two sessions of cold-laser therapy were undertaken at the referring veterinary surgeon. In total, the meloxicam was continued for six weeks post-operatively. At seven weeks post-operatively, the owner reported that the patient had recovered fully and there were no further signs of pain or discomfort. The patient continued to eat and yawn normally throughout recovery with no apparent discomfort. At the three and ten months telephone call follow-up, there had been no recurrence of jaw locking, and the patient was able to yawn and eat without showing pain or discomfort, and was behaving normally.

Case two

A ten-year-old, 6.0 kg male neutered Exotic Shorthair cat presented to the orthopaedic department of Langford Vets (University of Bristol), following an 18 months history of open-mouth jaw locking. The first locking episode was reduced by the referring veterinary surgeon under general anaesthesia. An uncomplicated (without pulp exposure) fracture of the maxillary left canine tooth was identified, and a mild degree of TMJ laxity was found on manipulation of the mandible. There was no recurrence for 13 months following this incident, and the patient exhibited

normal behaviour. However, over the five months prior to referral there had been a further five open-mouth jaw locking episodes, each occurring approximately one month apart. The owner reported that the episodes usually happened overnight and the jaw would never unlock spontaneously. The owner was able to manually reduce the open mouth jaw locking at home on two occasions, but the other occasions required reduction of the jaw under sedation by the referring veterinary surgeon. The patient did not appear to be distressed when the jaw was locked, and would continue to eat even immediately after manual reduction of the jaw. There was no history of trauma, and no difficulty in yawning or eating had ever been perceived. The patient had a five-year history of chronic kidney disease which was stable, and was being treated with benazepril (2.5mg PO once daily). The cat had also undergone a right keratectomy, conjunctival graft and Hotz-Celsus procedure for a sequestrum and entropion two years prior to onset of the open-mouth jaw locking. Physical examination of the cat was unremarkable. There was no evidence of instability or luxation of the mandible at presentation. The cat was admitted for further investigations. A blood sample was obtained from the jugular vein for biochemistry analysis. The results showed a mild azotaemia with a mild hyperphosphataemia (urea 12.6 mmol/L (reference range 6.5 – 10.5 mmol/L), creatinine 195 µmol/L (reference range 133 – 175 µmol/L), phosphate 1.68 mmol/L (reference range 0.95 – 1.55 mmol/L)). An increase in creatinine kinase

was also noted (530 IU/L (range 50 – 150 IU/L)). The cat was sedated with 5 µg/kg IV dexmedetomidine and 0.3 mg/kg IV butorphanol. A further 2.5 µg/kg IV dexmedetomidine was administered to maintain sedation. Computed tomography of the head was carried out, first with the jaw closed, and then with the jaw locked open on the right side. It was also possible to lock the jaw on the left side. On the closed mouth images the skull was noted to be markedly brachycephalic. The left maxillary canine tooth crown was fractured (uncomplicated crown fracture), and the left maxillary fourth premolar tooth was absent. Both TMJs were normal, and there were no abnormalities of the mandibular symphysis. On the open, locked jaw images, the right coronoid process of the mandible was displaced ventrolateral to the right zygomatic arch (Figure 4 and Figure 5), and the right TMJ was luxated with the condyloid process of the mandible rostral to the mandibular fossa of the zygomatic process of the temporal bone (Figure 4). The left TMJ was subluxated with the condyloid process again displaced rostrally, but remaining in contact with the mandibular fossa. No underlying cause of the open-mouth jaw locking could be determined from the images. The patient was administered 250 µg/kg IM atipamazole. Following this the patient was discharged to allow time for the owners to consider whether to opt for surgical intervention. Two weeks later the cat was admitted for surgery. A premedication of 0.3 mg/kg IV methadone and 3 µg/kg IV dexmedetomidine was administered. General anaesthesia was induced

via 1.8 mg/kg alfaxalone IV. The patient was intubated with a 3.5 mm internal diameter endotracheal tube, and anaesthesia maintained using isoflurane (1.3-2%) with 100% oxygen at 3 L/min via a T-piece circuit. Throughout the anaesthetic the cat was monitored with non-invasive blood pressure monitoring, a lead II ECG, oral temperature probe, capnograph, and pulse oximeter. Compound sodium lactate solution was administered at 20 ml/hr, and 20 mg/kg of cefuroxime was administered IV every 90 minutes until the end of surgery. A temporary tarsorrhaphy was performed bilaterally to prevent damage to the eyes, and the surgical sites were prepared as for the first case. An approach through the skin and underlying soft tissues was created in a similar fashion as for case one. An air powered 3 mm sphere-shaped diamond spinal bur was used to remove 4 mm from the dorsal aspect of the coronoid process. A partial zygomectomy was performed involving resection of a 10 mm long portion of the rostroventral margin (approximately one quarter of the width of the zygomatic arch) to prevent locking. The surgery was repeated on the contralateral side. The temporary tarsorrhaphy sutures were removed at the end of surgery. Buprenorphine was administered at 20 μg/kg IV every six hours post-operatively, and the cat began eating within 12 hours of surgery. It was discharged the following day with a two-day course of sublingual buprenorphine (20 μg/kg to be given every 8 hours). The cat's renal disease precluded the use of non-steroidal anti-inflammatories. It was

recommended that the cat be fed soft food for two weeks. The cat continued to eat at home, and no post-operative complications were encountered. At the four and ten months telephone call follow-up, there had been no recurrence of jaw locking, the patient was able to yawn and eat without apparent pain or discomfort, and was behaving normally.

Case three

A one year old, 4.0 kg male neutered Persian cat presented to the Veterinary Clinic Città di Codogno (Codogno, Lodi, Italy) with a three months history of recurrent open mouth jaw locking. Initially the cat was able to unlock the mandible spontaneously, with quick relapses. The referring veterinarian was also able on a few occasions to manually unlock the mandible without the need for sedation or anaesthesia. One month before presentation, the cat had been treated at the referring practice with a bilateral maxillo-mandibular fixation device, whereby a non-absorbable suture was passed full-thickness from the upper to lower lips, to impede full mandibular extension. However, five days after the removal of the labial sutures, a further episode of open mouth jaw locking occurred, with recurrence happening almost every night thereafter. A radiographic examination of the skull (ventro-dorsal, right and left lateral oblique and rostro-caudal open mouth projections) was performed by the referring veterinarian and showed

subluxation of the left temporomandibular joint and displacement of the right coronoid process of the mandible ventrolateral to the zygomatic arch when the mouth was locked open. A week before presentation, the cat had fallen from a table and developed a hind limb lameness which was treated conservatively with non-steroidal anti-inflammatories.

On presentation, the cat was in excellent body condition. Slight relative mandibular prognathism and anterior reverse scissor bite were visible. The range of motion of the mandible was considered normal, and the symphysis was stable on manipulation. The owners indicated that the mandible locked mostly on the right side (with slight right ventrolateral rotation of the mandible), but the precise frequency of right and left dislocations could not be determined. A blood sample was obtained from the jugular vein for biochemistry analysis. The results showed mild hypercalcemia (10.7 mmol/L (reference range 7 mmol/L – 10 mmol/L), leukocytosis (21.8 x10^9/L (reference range 5.0 - 18.0 x10^9/L)), neutrophilia (14.9 x10^9/L (reference range 2.5 - 12.5 x10^9/L), increased red blood cells count (9.69 x10^{12}/L (reference range 4.0 - 9.0 x10^{12}/L)), and increased MPV (9.6 fl (reference range 4.0 fl - 7.0 fl)).

The cat was referred to a specialist centre (Clinica Veterinaria dell'Orologio - Sasso Marconi, Bologna, Italy) for CT the same day. The imaging was carried out with the mouth closed, the mouth open and finally with the mandible locked open on the

left side. Subluxation of the left TMJ joint and displacement of the left coronoid process of the mandible ventrolateral to the left zygomatic arch were seen when the jaw was locked open. The right and left mandibular condyloid process and mandibular fossa of the mandibular process of the temporal bone were flattened (Figure 6). The mandibular symphysis was normal. The following day the cat was admitted for surgery. A premedication of 0.1 mg/kg IM morphine, 3 mg/kg IM ketamine and 4 μg/kg IM dexmedetomidine was administered. General anaesthesia was induced using 2 mg/kg IV propofol. The patient was intubated with a 3.5 mm internal diameter endotracheal tube, and anaesthesia was maintained using isoflurane (1-2%) with 100% oxygen at 1.5 L/min via a T-piece circuit. Throughout the anaesthetic the cat was monitored with non-invasive blood pressure monitoring, a lead II ECG, anal temperature thermometer, capnograph, and pulse oximeter. IV Lactated Ringer's Solution was administered at 10 ml/hr throughout the procedure, and one dose of cefazoline (30 mg/kg) was administered IV. Under anaesthesia it was possible to recreate open-jaw locking manually on both sides. A click noise at the right TMJ was produced during locking on the right side. Ventro-dorsal radiographs of the locked temporomandibular joints were obtained with dental radiographs (Kodak size DF50, Ultra-Speed dental films) placed extraorally (Figure 7). Given that the mandible was reported to lock on the right side, surgical treatment was initially performed unilaterally.

The cat was positioned in left lateral recumbency and right left maxillary nerve block was administered through a cutaneous, sub-zygomatic approach using 0.05 ml of 2% lidocaine and 0.15 ml of 0.5% bupivacaine solution. The skin was prepared for surgery on the right side of the face as described for the previous two cases. An approach through the skin and underlying soft tissues was created in a similar fashion as for the other cases. A #2 tungsten dental bur on a high-speed drill was used to remove 5 mm of bone from the dorsal aspect of the coronoid process and a 10 mm full thickness section of bone from the mid-portion of the zygomatic arch, to prevent locking. After ensuring that right jaw locking could not be reproduced manually by maximally opening the mouth, rotating the mandible towards the right side, and closing the mouth, the periosteum and subcutaneous tissues were closed separately with 5-0 poliglecaprone 25 (Monocryl, Ethicon, NJ) in a simple continuous suture pattern. The skin was then closed using skin staples. Postoperative analgesia was achieved by administration of IM meloxicam (0.1 mg/kg once) and morphine (0.2 mg/kg every 8 hours for 24 hours). The cat was discharged the following day and the clients were instructed to continue meloxicam treatment (0.05 mg/kg PO once daily for 5 days), daily disinfect the wound and have the cutaneous staples removed 10 days following surgery. It was recommended that the cat be fed its normal dry diet.

Two weeks following discharge a new episode of jaw locking happened, this time to the left side. The referring veterinarian was able to manually reduce the locking by gentle traction on the left mandibular canine tooth. This happened four more times until the cat was brought back to our attention three weeks after the initial surgical procedure. The skin wound on the right side of the face appeared completely healed. Jaw locking could not be induced manually on either side in the animal awake, but once under anaesthesia (using the same anaesthetic protocol described for the first surgical procedure) the mandible could easily be locked to the left side by opening the mouth maximally and slightly rotating the mandible towards the left side. A click noise at the right TMJ was again heard, which was thought most likely to be due to subluxation of the TMJ, although it was not possible to definitively determine this. The mandible could not be locked to the right side. Dental occlusal size radiographic films were used again with an extra-oral technique, which confirmed left sided locking. The surgery was repeated on the left side as described previously for the right side, except for the skin closure that was performed by placing sutures using 4-0 nylon (Ethilon, Ethicon, NJ). The cat was discharged the following day with the same medication and instructions given after the first procedure. There has been no recurrence of jaw locking eight years following surgery.

Literature Review

Of the cases described in the literature, including the additional three reported here, nine were male (six neutered) and five were female (three neutered), with a median age of three years and mean age of 4.4 years. Seven cats were Persian, two Siamese, two domestic shorthaired, and there was one Siamese crossbreed and one Exotic shorthair (Table 1).

Open-mouth jaw locking in cats has been assumed to be a result of TMJ dysplasia with or without excessive TMJ laxity (N=5 cases), although maxillofacial trauma (N=5), mandibular symphyseal laxity (N=3), changes in occlusion due to tooth extraction/loss (N=2), and developmental abnormalities (N=2) have been hypothesised to be contributing factors in other reports (1-9). Breed-specific (Persian and Siamese) skull conformation has also been theorised to be a possible contributing factor (1,2,4).

Before the advent of CT, radiography was used to aid in the diagnosis of the condition, but due to the limitations of this imaging modality, identification of the inciting cause was difficult. Only one of the reported cases suspected to have TMJ dysplasia actually had radiographic changes consistent with the disease (8), and of the four cats reported to have undergone CT, no abnormalities of the TMJs were found (1,3,4).

Manual mandibular replacement and application of a tape muzzle for a few weeks may be tried for single occurrences of open mouth jaw locking, though the author has had no success with this approach. Surgery is recommended for recurrent cases. The surgical procedures described in the literature are summarised in Table 1. Partial zygomectomy has been reported to either involve removal of a partial width segment (1,5,6,7) or full width segment (2,3) of the zygomatic arch. Long term outcomes after surgery were reported to be excellent in all of the published cases (1-9) and the additional three cases reported herein. One case had short-term recurrence of open-mouth jaw locking following bilateral partial (full width) zygomectomy; this occurred several times five weeks following discharge, but each episode lasted only for a few seconds and reduced spontaneously. No additional episodes were noted at the six months follow up (2). Post-operative dental malocclusion was noted in the case that underwent bilateral condylectomy. This cat subsequently underwent reduction of the canine crowns, but there was a persistent shift of the mandible to the right side. However, the owner reported the cat to be content and displaying normal behaviour (8). In the case which underwent symphysiotomy, symphysiectomy and intermandibular arthrodesis, discomfort during yawning/meowing (as perceived by the owner), and slight pain on opening the mouth on veterinary examination was noted two weeks after discharge. The cat had reportedly recovered at the 9 and 33 months follow up

phone calls (3). One of our cases showed signs consistent with pain for seven weeks post operatively. At the three and ten months telephone call follow-up the cat was behaving normally, and had displayed no further signs of pain.

Discussion

This report summarises the documented cases of open-mouth jaw locking in cats, and describes three further cases. To the author's knowledge, two of the additional cases reported here document the first cases of TMJ dysplasia in cats to be definitively diagnosed using CT. Furthermore, bilateral partial zygomectomy with bilateral partial coronoidectomy has not previously been reported as a surgical treatment. All three cases were investigated using CT, and were successfully treated, with no long-term recurrence of open-mouth jaw locking.

Proposed aetiologies of open-mouth jaw locking

TMJ dysplasia

TMJ dysplasia is widely reported to be the causal factor of open-mouth jaw locking in dogs (10-13), and has also been theorised to be the cause in cats (2,5,7,8). Dysplasia may allow a wider range of motion of the TMJs, permitting the displacement of the coronoid process ventrolateral to the zygomatic arch. However, in the reported literature dysplastic changes have only been

documented in one cat (8). This may in part be due to the limitations of radiographic examination of the skull, although of the four previously reported cases for which CT was utilised, none of the cats were found to have identifiable dysplastic changes. This suggests that in at least a portion of cases, TMJ dysplasia may not the cause of open-mouth jaw locking. Another explanation may be that osseous dysplastic changes had not yet developed at the time of diagnostic imaging; there was an absence of detectable dental/bone abnormalities in seven of the previously reported cases, and all but one of these were between one and three years old. The domestic shorthaired cat reported here (case 1) did have osseous abnormalities of the TMJs. The cat was five years old, therefore the changes were consistent with bilateral TMJ dysplasia with the later development of degenerative changes to the bone. However, the third case reported here showed bilateral flattening of both the condyloid process and the mandibular fossa of the zygomatic process of the temporal bone (indicative of TMJ dysplasia), and this cat was only one year old.

Symphyseal laxity and vertical mandibular range of motion
It has been suggested that a degree of symphyseal laxity is required for jaw locking to occur (2,3,11). This laxity may be enhanced by dental and skeletal malocclusion due to altered levering forces (14). Unfortunately, symphyseal laxity was not

specifically measured in the cases described here. Vertical mandibular range of motion (vROM) appeared subjectively normal. The normal vROM in cats has been shown to be 62 ± 8 mm (median 63, range 41–84) (15). An abnormally wide vROM could predispose a case to open mouth jaw locking, as the tip of the coronoid process may extend past the distal aspect of the zygomatic arch, but this hypothesis needs to be further evaluated.

Head trauma

Case 2 did not have any identifiable abnormalities of either TMJ. The only findings were a fracture of the left maxillary canine tooth, and the absence of the left maxillary fourth premolar tooth. Trauma has been implicated as a cause of open-mouth jaw locking (3, 6, 9). The fractured and absent teeth in this case may have been related to a previous traumatic episode, and therefore one could speculate that this may have contributed to the subsequent jaw locking. History of head trauma was not reported in case 1 and a mild trauma happened to case 3 but after multiple episodes of jaw locking.

Genetics and conformation

In dogs, a genetic component is likely to play a part in the aetiology of open mouth jaw locking, as chondrodystrophic and brachycephalic breeds are reportedly

affected most frequently (1). Genetics and skull conformation may also play a part in cats, since of the 11 cases reported in the literature and three reported here, nine were of brachycephalic breeds (eight Persians and one Exotic Shorthair), three were Siamese (or Siamese crosses) and only two were domestic shorthaired cats.

The mechanism for brachycephalic dog and cat breeds developing open-mouth jaw locking remains elusive. Features of a feline brachycephalic skull include mesioversion of the maxillary canine teeth, maxillary brachygnathism and dorsorotation of the jaws (16), which results in abnormal dental occlusal relationships, particularly between the canine teeth. It remains speculative as to whether the application of abnormal masticatory forces due to malocclusion can in fact have an effect on symphyseal and TMJ laxity, and increase the risk for open mouth jaw locking. In three of the cases published, symphyseal laxity was identified, and all three cats were Persian (1, 3, 4). Cases 2 and 3 were brachycephalic, and in the absence of other findings it is possible that symphyseal or TMJ laxity may have been the cause of the jaw locking. The genetic link between Siamese breeds and open-mouth jaw locking is even less clear. The Siamese type skull can be classified as long nosed or dolicocephalic. One case was noted to have a flattened left zygomatic arch on radiographs, thought either to be developmental or as a consequence of trauma (9). The Siamese 'type' case had radiographic

confirmation of TMJ dysplasia with degenerative osseous changes (8), and no abnormalities were found in the third Siamese cat (4). A proposed mechanism of open-mouth jaw locking in Bassett Hounds (a hypochondroplastic breed with rhizomelic limb shortening but a relatively normal or dolicocephalic skull) is that a greater angle between the axis of rotation of the TMJ and the long axis of the condyloid process causes greater movement of the lateral aspect of the condyle. This may cause stretching of the lateral ligament and joint capsule, which may lead to joint laxity and open-mouth jaw locking as a consequence (9, 10, 11). However, a more recent paper found that periarticular new bone formation and narrowing of the joint space develop more frequently at the medial rather than the lateral aspect of the TMJ of dogs, therefore contradicting the assumption that the obliquity of the TMJ results in excessive movement at the lateral aspect of the condylar process (17). Future studies to objectify the differences in anatomic conformation between varying shape skulls, and the relationship between dental occlusion and mandibular stability, are required to test these hypotheses.

Muscular pathology

In one report pterygoid muscle spasticity was demonstrated using electromyography in a case of open-mouth jaw locking in a human and suspected in three dogs due to the absence of other identifiable causes (9).

Diagnosis and imaging modalities

Radiography was the imaging modality used in the investigation of open-mouth jaw locking in the early case reports. As TMJ disease has been reported to be a potential causal factor of open-mouth jaw locking, oblique lateral radiographic views are required for assessment of the TMJ (14). However, this is technically demanding. CT is superior to radiography for assessment of the TMJ and to rule out other potential underlying causes, and makes the initial diagnosis of open-mouth jaw locking easier. As well as providing greater detail of the osseous structures, the ability to assess the skull in transverse, sagittal and dorsal planes, and to create 3D reconstructions means that a precise and comprehensive evaluation of the entire skull can be performed. This in turn enables a more accurate diagnosis and prognosis, and permits surgical planning (4,14). Cone beam CT has also been demonstrated to be an effective diagnostic imaging modality for TMJ evaluation in cats. This diagnostic modality uses an X-ray tube-detector system that rotates 360° around the patient's head and acquires images that are analysed by a specific computer program (18).

Surgical management

Surgical options for open-mouth jaw locking include unilateral or bilateral partial coronoidectomy, partial zygomectomy, and a combination of partial coronoidectomy and partial zygomectomy. Regarding zygomectomy, both resection of a full width segment of the zygomatic arch (2, 3, 13), and removal of a partial width segment (1, 5, 6, 7) have been reported. Bilateral zygomectomy as a sole treatment has been associated with temporary recurrence post-operatively (2), whilst recurrence following bilateral coronoidectomy has not so far been reported. Other reported surgical treatments are imbrication-plication of the lateral aspect of the TMJ capsule, maxillomandibular fixation devices and mandibular condylectomy (in dysplastic patients). Imbrication-plication has not been found to be successful in preventing recurrence (12). Maxillomandibular fixation devices rely on healing of periarticular soft tissues to prevent recurrence following TMJ luxation or subluxation in traumatic cases, and are likely to be ineffective in cases affected by TMJ dysplasia or symphyseal laxity (3). Bilateral condylectomy performed in a case of TMJ dysplasia was reported to cause dental malocclusion in one report (8). Symphysiotomy, symphysiectomy, and intermandibular arthrodesis were successful in one cat with open-mouth jaw locking associated with excessive laxity of the mandibular symphysis (3). Two of the additional cases reported here underwent bilateral resection of a full width segment of the zygomatic arch and partial coronoidectomy, whilst case 2

underwent bilateral resection of a partial width segment of the zygomatic arch and partial coronoidectomy. Previous case reports have described partial coronoidectomy as a sole surgical treatment of open-mouth jaw locking in cats, with no occurrence of post-operative complications (4,9). Regarding case 1, it was necessitated by the owners' stipulated requirement that the cat only undergo one surgery as finances would not permit further surgery if the condition recurred; A full thickness partial zygomectomy in addition to the partial coronoidectomy was therefore performed. The decision for case 2 and 3 was influenced intra-operatively; the mandible was repeatedly manipulated during burring and it was found that preventing the coronoid process from engaging with the zygomatic arch was most readily achieved by removing apposing bone from each structure; case 3 required a full thickness partial zygomectomy whereas a partial thickness partial zygomectomy was sufficient for case 2. Whilst none of the cats described here had experienced recurrence of the open-mouth jaw locking at the time of follow-up, case one showed signs of discomfort for seven weeks post-operatively. This may indicate that in some cases the induced bone trauma following full width partial zygomectomy causes more post-operative pain than partial width partial zygomectomy, although it is not possible to make definitive conclusions from only one case. Post-operative pain or behavioural changes were not reported in the other published cases that underwent full width partial zygomectomy, nor were

they seen in case 3. Other differentials for the discomfort could have been soft tissue inflammation or trauma to a branch of the maxillary branch of the trigeminal nerve. Objective pain assessment should be performed in future cases in order to draw more substantiated conclusions relating pain and the type of surgical procedure performed. Post-operative dietary recommendations can include feeding a soft diet and avoiding hard food to minimise post-operative pain, however these recommendations may not always be necessary unless the patient shows pain at chewing consistent food.

Conclusions

In conclusion, open-mouth jaw locking is seen in cats with a wide age range (from one to 10 years - mean average of 4.4 years). Cats with all skull types (brachycephalic, mesatocephalic and dolicocephalic) may be affected, but brachycephalic breeds seem to be over represented. Trauma, temporomandibular dysplasia and symphyseal laxity may predispose to development of this condition. When available, a computed tomographic scan with the jaw locked in place is recommended for diagnosis and surgical planning purposes. Whilst the presence or absence of TMJ dysplasia does not alter the surgical treatment when open-mouth jaw locking due to ventrolateral coronoid displacement is diagnosed, CT permits rapid identification of coronoid displacement, the degree of overlap

between the coronoid process and zygomatic arch, and allows evaluation of the skull for other abnormalities which may necessitate additional procedures e.g. fractures or TMJ luxation. Coronoidectomy and zygomatic arch resection performed alone or in combination is generally successful at preventing long term recurrence of this condition. We recommend bilateral coronoidectomy with or without partial zygomectomy for open-mouth jaw locking when the mandible can be manually locked on both sides under anaesthesia. The surgery should be unilateral if locking is only possible on one side, though the owner should be warned of possible future contralateral locking. The decision to perform a partial zygomectomy (and whether to remove a partial or full width segment of the bone) should depend on intra-operative findings or the necessity for a single surgery (e.g. concurrent patient health concerns regarding anaesthesia or owner requirements).

References

1. Beam RC, Kunz DA, Cook CR, et al. Use of three-dimensional computed tomography for diagnosis and treatment planning for open-mouth jaw locking in a cat. *J Am Vet Med Assoc* 2007; 230: 59–63.

2. Oakes MG, Lewis DD and Pechman RD. Intermittent open mouth locking in a Persian cat. *Vet Comp Orthop Traumatol* 1990; 3: 19–21.

3. Reiter AM. Symphysiotomy, symphysiectomy, and intermandibular arthrodesis in a cat with open-mouth jaw locking - case report and literature review. *J Vet Dent* 2004; 21: 147–58.

4. Soukup JW, Snyder CJ and Gengler WR. Computed tomography and partial coronoidectomy for open-mouth jaw locking in two cats. *J Vet Dent* 2009; 26: 226–233.

5. Lobprise HB and Wiggs RB. Modified surgical treatment of intermittent open-mouth mandibular locking in a cat. *J Vet Dent* 1992; 9: 8–12.

6. Kraus KH and Tomlinson JL. Open-mouth jaw locking in a cat. *Calif Vet* 1988; 42: 11–30.

7. Lantz GC. Intermittent open-mouth locking of the temporomandibular joint in a cat. *J Am Vet Med Assoc* 1987; 190: 1574–1574.

8. Eisner ER. Bilateral mandibular condylectomy in a cat. *J Vet Dent* 1995; 12: 23–26.

9. Hazewinkel H, Koole R and Voorhout G. Mandibular coronoid process displacement: signs, causes, treatment. *Vet Comp Orthop Traumatol* 1983; 6: 33–39.

10. Lantz GC and Cantwell HD. Intermittent open-mouth lower jaw locking in five dogs. *J Am Vet Med Assoc* 1986; 188: 1403–1405.

11. Robins G and Grandage J. Temporomandibular joint dysplasia and open-mouth jaw locking in the dog. *J Am Vet Med Assoc* 1977; 171: 1072–1076.

12. Thomas RE. Temporo-mandibular joint dysplasia and open-mouth jaw locking in a Bassett Hound: a case report. *J Small Anim Pract* 1979; 20: 697–701.

13. Stewart WC, Baker GJ and Lee R. Temporomandibular subluxation in the dog: a case report. *J Small Anim Pract* 1975; 16: 345–349.

14. Schwarz T, Weller R, Dickie AM, et al. Imaging of the canine and feline temporomandibular joint: a review. *Vet Radiol Ultrasound* 2002; 43: 85–97.

15. Gracis M, Zini E. Vertical mandibular range of motion in anesthetized dogs and cats. *Front Vet Sci* 2016; 3:51.

16. Schlueter C, Budras KD, Ludewig E, et al. Brachycephalic feline noses: CT and anatomical study of the relationship between head conformation and the nasolacrimal drainage system. *J Feline Med Surg* 2009; 11: 891–900.

17. Arzi B, Cissell DD, Verstraete FJM, et al. Computed tomographic findings in dogs and cats with temporomandibular joint disorders: 58 cases (2006-2011). *J Am Vet Med Assoc* 2012; 242: 69–75.

18. Roza MR, Silva LA, Januario AL, et al. Cone beam computed tomography in the diagnosis of temporomandibular joint alterations in cats. *J Feline Med Surg* 2011; 6:393–8.