Treatment of caudal mandibular fracture and temporomandibular joint fracture-luxation using a bi-gnathic encircling and retaining device

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Mandible, temporomandibular joint, fracture, luxation

Summary
Fractures of the caudal portion of the mandible and temporomandibular joint (TMJ) fracture-luxation can be challenging to treat with direct fixation methods. This paper describes a simple technique for the indirect treatment of caudal mandibular fracture and TMJ fracture-luxation using a subcutaneous loop of nylon leader line tunnelled around the maxilla, incisive and nasal bones, and under the mandible, placed just caudal to the canine teeth, and crimped ventral to the mandibular skin: a bignathic encircling and retaining device (BEARD). A BEARD was used to treat two immature dogs with simple, unilateral caudal mandibular fractures, six cats with unilateral injury (two with TMJ luxation, three with TMJ fracture-luxation, one with caudal mandibular fracture), and two cats with bilateral injury (comminuted caudal mandibular fracture with contralateral TMJ luxation; bilateral condylar neck fracture). The BEARD treatment failed short-term due to poor tolerance in one cat, and concurrent injuries and poor initial reduction in another cat. One cat was lost to long-term follow-up. Rostral dental occlusion was normal in six out of seven cases, and reported jaw function was normal in seven out of seven cases. The case with poor occlusion had imperfect initial reduction. Complications included dorsal nasal skin swelling or discharge, oesophagostomy tube dislodgement or blockage, BEARD loosening, and regurgitation. Treatment of uni- or bilateral caudal mandibular trauma using a BEARD can lead to clinical union, and normal rostral occlusion, provided that case selection is appropriate and immediate-post-surgical occlusion has been corrected.

Materials and methods
Clinical case details
All of the dogs and cats with caudal mandibular or TMJ injury treated at The Queen’s Veterinary Hospital (University of Cambridge Veterinary School, Cambridge, UK) with a BEARD by the authors between 2005 and 2008 were evaluated. Choice of stabilisation technique was made by the surgeon in charge of the case. The following data were recorded: signalment; aetiology of trauma; time from injury until admission, and from admission until surgery; caudal mandibular or TMJ injury location(s); concurrent injury to mandibular symphysis, canine teeth, maxilla, or other body area(s); use of pharyngostomy diversion for the endotracheal tube; type of feeding tube; duration of hospitalisation; time until BEARD removal; complications.

Introduction
Traumatic mandibular fractures are regularly seen in dogs and are common in cats (1–11). Several stabilisation techniques have been described, including internal fixation with mini-plates and external skeletal fixation (6–8, 10). These techniques can be challenging in cases with a small caudal fracture fragment, or temporomandibular joint (TMJ) injury (fracture or fracture-luxation). Several indirect fixation techniques have been described for use in such cases, including tape-muzzle, interarcade wire, dental composite, and mandibular-maxillary external skeletal fixation (3–5, 10, 11). The treatment aims are to achieve uncomplicated fracture healing with perfect dental occlusion to preserve the remaining dentition, and to allow an early return to normal jaw function (5, 8, 9, 12). This report describes 10 cases with caudal mandibular or TMJ injury that were treated with an unreported, simple, indirect internal-fixation technique, using a bi-gnathic encircling and retaining device (BEARD).
Treatment

Patients were assessed, and treated perioperatively with intravenous isotonic crystalloids as required at a rate of 2–10 ml/kg/hr. For analgesia, buprenorphine\(^a\) at 0.01–0.02 mg/kg every six to eight hours or methadone\(^b\) at 0.2–0.3 mg/kg every four to six hours was administered. Anaesthesia was induced, and ventrodorsal skull, and left and right oblique lateral mandibular radiographs were made. The mandible and maxilla were inspected and palpated, and the resulting information was used in conjunction with the radiographic findings to diagnose the fracture location. This was then recorded using a modification to a previously reported classification system (Fig. 1; Supplementary Table 1 – available online at http://www.VCOT-online.com) (1, 5, 7, 8, 13). In most cases an oesophagostomy tube was placed (14). Mandibular symphyseal separations were reduced and repaired with a single cerclage wire (9). Where present, TMJ luxation was reduced using a hexagonal cross-section wooden pencil as a rotating pivot. The maintenance of correct dental occlusion was assessed manually with the mouth partially open (tips of maxillary and mandibular canine teeth overlapping). The endotracheal tube was diverted via a pharyngostomy incision in cases where the dental occlusion could not be maintained in normal alignment with the mouth partially open. The skin of the dorsal nose and ventral mandible was clipped, and these areas, along with the mouth, were prepared with 10% povidone-iodine solution\(^c\). An 18 kg (cats) or 27–36 kg (dogs) nylon leader line\(^d\) was tunnelled subcutaneously through a 14-gauge needle pre-contoured into a 45\(^\circ\) curve, and inserted through the skin overlying the ventral midline of the mandible. This process was repeated on the contralateral side, resulting in a subcutaneous suture encircling the nasal, incisive and maxillary bones and both hemi-mandibles with the two free ends of the suture exiting the skin at the ventral midline of the mandible. The mouth was closed firmly, onto the endotracheal tube where present, to achieve normal interdigitation of the canine teeth. The suture was tightened, and one or two uncrimped ‘spacer’ clamps\(^d\) were placed over the free ends of the suture adjacent to the skin. Another clamp was placed just distally, and crimped tightly (Fig. 2). Immediate postoperative radiographs were made at the discretion of the veterinarian.

Postoperative care

All cases were observed closely for 24 to 48 hours postoperatively, and injected subcutaneously with 0.3 mg/kg methadone every four hours, or 0.02 mg/kg buprenorphine every six to eight hours for 24 to 48 hours. Meloxicam\(^e\) was given via the feeding tube once daily for five days at 0.05 mg/kg (cats) or 0.1 mg/kg (dogs). Care was taken with early tube feeding to minimise the risk of regurgitation; liquid food\(^f\) was warmed and administered slowly in small increments every one to four hours, with the animal sitting or lying in sternal recumbency. Clearly written instructions, and blunt-ended scissors, were left on the animal’s cage – to cut the suture should regurgitation or vomiting have occurred. Liquid food\(^f\) was offered orally in cases in which the dog or cat was able to lap with the BEARD in place. Once postoperative comfort and tube-feeding were established, cases were discharged from hospital and nursed at home with the feeding tube and BEARD still in place. The suture was removed once healing was anticipated to have progressed sufficiently to maintain occlusion (clinical union). This was assessed by removing the BEARD, observing occlusion, and palpating stability and pain throughout the range of motion of the mandible. The oesophagostomy tube was removed and the associated wound left to heal by secondary intention. Recommendations were given to the owners to feed the animal a soft food diet, and to avoid any hard food and the chewing of bones for three months.

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\(^{a}\) Vetergesic\(^:\) Alstoe Ltd., York, Yorkshire, UK  
\(^{b}\) Physeptone\(^:\) Martindale Pharma, Romford, Essex, UK  
\(^{c}\) Vetasept; Animalcare, York, Yorkshire, UK  
\(^{d}\) Securos, Fiskdale, MA, USA  
\(^{e}\) Metacam\(^:\) Boehringer Ingelheim, Bracknell, Berkshire, UK  
\(^{f}\) Convalescent Support: Walthams, Royal Canin, Castle Cary, Somerset, UK

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Long-term follow-up

Cases were reassessed by examination where possible, or by conducting a telephone interview with the owner. Owners were asked for yes or no answers as to whether the following were the same as pre-injury (normal) or not: straightness of the lower jaw; jaw closure; jaw opening; yawning; grooming; picking up food; chewing; lapping; playing with toys; biting. A photograph, showing closed-mouth occlusion of the incisor and canine teeth with the lips manually abducted, was requested from each owner.

Results

Case details

Two dogs (aged 11 and 22 weeks) and eight cats (median age three years [range four months to seven years]) were treated. Breeds of cats were Domestic Shorthaired (four), and one of each: Domestic Long-haired, Maine Coon, Bengal, and Egyptian Mau. The two dogs were a Leonberger and a Weimaraner. Four animals were female-neutered, three were female and three were male-neutered (Supplementary Table 1).

Aetiology of trauma was as follows: road traffic accident (cases C1, C7 and C8), dog bite (D1 and C5), suspected road traffic accident (C4), kick by a horse (D2), and trauma sustained whilst inside a functioning dishwasher (C3). Median time from trauma to presentation was two days (range 0 to 7). Additional injuries detected at physical examination included: unilateral Horner’s syndrome (D2 and C1); maggot infested prolapsed globe, bilateral mucopurulent nasal discharge, granulating degloving injury of rostral mandible (C2); multiple incisor teeth crown fractures, oronasal fistula from bite wound (C5); scleral haemorrhage (C6 and C8); and anisocoria (C8). One case (C7) was initially treated with closed TMJ reduction and no stabilisation, but TMJ reluxation within 12 hours prompted surgery. Median time from admission to anaesthesia for radiography and surgery was one day (range 0 to 2).

Fracture location

The types of injuries diagnosed for each case are detailed in Supplementary Table 1. Both dogs had a simple mandibular fracture. Two cats had bilateral caudal mandibular or TMJ injury (C3 and C8). Six cats had unilateral caudal mandibular/TMJ fracture-luxation, two of which were comminuted fractures (C5, C8). Five cats had concurrent symphyseal separation. Temporomandibular joint luxation had occurred in two cases (C1, C6) and TMJ fracture-luxation in three cases (C2, C4, C7) (Fig. 3). Maxillary fracture was detected in two cases (C2, C5). Four cats had fractured and lost the crown of one canine tooth (C2, C3, C4 and C6).

Treatment

Five cases had endotracheal diversion via pharyngostomy (Supplementary Table 1). Postoperative occlusion was deemed perfect in eight cases. Occlusion was not perfect in two cases, both of which had multiple injuries and concurrent maxillary fracture (C2 and C5). All cases had an oesophagostomy tube placed apart from C2, which had such severe head trauma that a gastrostomy tube was the preferred choice. Postoperative ventrodorsal skull and lateral oblique mandibular radiographs were made in five feline cases; the radiographs showed good reduction and perfect occlusion in four cases (C4, C6, C7 and C8) (Fig. 4). Poor reduction and occlusion was apparent in case C5.
Complications requiring BEARD removal and replacement

The oesophagostomy tube dislodged in two out of nine cases and became blocked in one out of nine cases. This required naso-oesophageal tube placement (D1), BEARD removal and oesophagostomy tube replacement, then BEARD replacement (C6), and no further action as the cat was able to lap liquid food (C1). Swelling or discharge from the needle hole in the dorsal nasal skin occurred in four out of 10 cases. This was treated with 20 mg/kg clavulanate amoxicillin\(^8\) orally twice daily in two out of four cases, and resolved in four out of four cases within one to three days of BEARD removal. Loosening of the BEARD occurred in one out of 10 cases. No regurgitation occurred in hospital (0/10), though case C4 regurgitated once whilst at home without any consequence and cutting of the BEARD was not required. This cat could lap food so tube-feeding was discontinued at this point.

BEARD failures requiring alternative repair technique

The BEARD was removed before clinical union in two cases. Case C2 had multiple concurrent injuries and needed further orofacial surgery to treat an orbital abscess, a degloving injury of the rostral mandible, and to treat ongoing malocclusion and poor mandibular function with bilateral TMJ excision arthroplasty. This case was lost to long-term follow-up. Case C8, a Bengal cat, had exceptionally poor compliance with the BEARD, oesophagostomy tube, and hospitalisation, so the BEARD was removed. Dental bonding subsequently failed (by fracture of the dental composite) in this cat, and interfragmentary wiring failed to produce perfect rostral occlusion. This case had no reported clinical problems 15 months after surgery, despite having imperfect rostral dental occlusion. Both of these cases were deemed a failure through poor case selection.

Short-term outcome

In the eight cases that were discharged to their owners care at home with the BEARD and oesophagostomy tube in place, median time from surgery to discharge was three days (range 2 to 11). Reassessment and BEARD removal occurred after a median of 19.5 days (range 11–26). The presence of the naso-oesophageal tube was associated with snorting and head-shaking in case D1. In this case the BEARD was removed 11 days post-surgery, after radiographs showed early evidence of mineralisation within the fracture gap. At reassessment, clinical union had occurred and occlusion was perfect in seven out of eight cases. Occlusion had worsened in one case (C5), which was deemed a treatment failure from poor case selection. The replacement of the BEARD once it had been removed to assess clinical union was not required for any cases.

Long-term outcome

Of the eight cases managed at home with a BEARD, one case (C1) was lost to follow-up after BEARD removal. Case C5 was re-examined 364 days after surgery, and the remaining cases had follow-up by telephone questionnaire and digital photography at a median of 316 days (range 51–1065) after surgery. In the owner’s opinion, the jaw was perfectly straight and could close normally in six out of seven cases, and was not straight and could not close normally in one case (C5). Photographic images showed that rostral dental occlusion was perfect in six out of seven cases and poor in one case (C5) (Fig. 5 and Fig. 6). Jaw opening was reportedly normal in six out of seven cases, and was perceived as being slightly reduced in one case (C7). The owner of this cat reported a gradual ongoing improvement in jaw opening since BEARD removal 51 days previously. Jaw function (yawning, grooming, picking up food, chewing, lapping, playing with toys, biting) was reportedly normal in seven out of seven cases, and owner satisfaction was high in seven out of seven cases despite the loss of occlusion in C5.

\(^8\) Symulox: Pfizer, New York, NY, USA
Caudal mandibular fractures (in regions 5, 6 or 7; Fig. 1), and TMJ fracture-luxations, can be challenging to treat (1–13). The herein reported BEARD technique is minimally invasive at the fracture site, and thus is useful in animals with deciduous teeth. The technique also preserves the remaining dentition, and can be used in animals with medium length muzzles (cats), missing or damaged canine teeth, and in cases with concurrent mandibular symphyseal separation.

Other techniques used for treatment of these types of injuries are tape muzzle, interarcuate wiring, dental bonding, or maxillary-mandibular external skeletal fixation. However the size, temperament and face shape of cats mean that a tape muzzle is of limited or no use in this species (3–5, 10, 11). The equipment and expertise required, patient morbidity, complications, post-operative care, cost, and outcome of these techniques are likely to be different – a suitable cohort study would be necessary to provide comparison. Each of these interarcuate techniques are examples of indirect stabilisation, however they may not be suitable for mandibular fractures rostral to region 5 (Fig. 1). The muscles of mastication apply forces to the caudal mandible. If a mandibular fracture were located rostral to the muscles of mastication then it is likely that fracture strain would be greater than in a fracture of the mandible within the muscles of mastication, where forces are simultaneously applied to the caudal and rostral fragments (9). Mandibular fractures rostral to region 5 are more accessible for alternative techniques such as external skeletal fixation, mini-plating, interdental wiring, and acrylic splinting (6, 8, 9).

The predominant stimulus for proliferation of bone marrow stromal cells during fracture healing is perfusion, and cell differentiation is affected by strain magnitude which naturally decreases with the increased stiffness of callus ossification (15). An experimental model of mandibular fracture healing in dogs showed that, biomechanically, less rigid fixation techniques healed fully, but more slowly and with larger radiographic callus than rigid techniques (16). Semi-rigid repair of mandibular condylar fracture with TMJ luxation has been compared favorably with rigid repair of such trauma in humans (17). The effect of semi-rigid repair on TMJ articular fracture healing is not clear. A recent meta-analysis of condylar fractures in people could not distinguish between open and closed treatment of mandibular condylar fracture (18). The interarcuate stabilisation techniques listed above all offer a biological approach to fracture repair, with the advantage of non-disturbance of the fracture site and preservation of local blood supply (19, 20). The rigidity of repair offered by each technique is probably different, with external skeletal fixation, dental bonding and interarcuate wiring likely to be more rigid than tape muzzle or BEARD, though this has yet to be compared experimentally. The rigidity of fractures repaired using a BEARD in this study was perceived to increase by using pharyngostomy diversion of the endotracheal tube, allowing tight full-closure of the mouth. The risks of this intervention are discussed below.

Concurrent injuries

Bi-gnathic encircling and retaining devices were used successfully in three out of five cases with concurrent mandibular symphyseal separation, though the reason for failure in the other two cases was not associated with the symphyseal separation. Loss or damage to one canine tooth did not prevent the success of BEARD in three out of four cases in this study. Dental composite may not have been a suitable technique for these cases as it normally requires all four canine teeth to be intact (5).

The presence of concurrent maxillary fracture may make restoration of rostral occlusion, and hence fracture reduction, problematic. Both cases with maxillary fracture in this study had imperfect rostral occlusion after initial reduction, and went on to treatment failure. The presence of the BEARD could dislodge a maxillary fracture fragment, and the rigidity of the construct may be decreased, leading to malunion and malocclusion. Nasal obstruction can occur after head trauma and in the presence of maxillary fracture, which limits the ability to breathe through the nose. Although difficult to quantify, the presence of impeded nasal breathing is likely to predispose the surgeon to place a slightly looser BEARD with the inevitable consequence of providing a less stable repair and more likelihood of loss of reduction. Repair of the maxillary fracture using an alternative technique might be more appropriate, but use of a BEARD concurrently might still be possible. More work is needed to further assess the use of a BEARD in cases with concurrent maxillary fracture.

Complications

Degree of mouth opening

All interarcuate techniques prevent opening of the mouth after surgery. The mouth...
can have a variable aperture in cases treated with a BEARD, depending on the tightness – which can be increased if more rigidity is required. Five cases in this study had the mouth fully closed, requiring a pharyngostomy diversion of the endotracheal tube. Patients with a partially opened mouth may experience lower morbidity, be able to lap food, have improved ability to thermoregulate, and avoid aspiration or asphyxiation should vomiting or regurgitation occur. It is reasonable to assume that the risk of aspiration pneumonia, and even asphyxiation, after vomiting or regurgitation will be higher in cases with a closed mouth than in cases with a partly opened mouth. However, even when the mouth is fully closed, the dental and lip conformation of dogs and cats does not preclude transit of liquid or air from the oral cavity via the interdental spaces to the buccal pouch, meaning oral breathing and oral cavity drainage is still possible (21). This study suggests that the incidence of severe complications is low, as only one case had a single inconsequential episode of regurgitation whilst at home. However, every effort must be made to avoid this potentially high-morbidity event. Hyperthermia was not documented in any case. Ambient temperature control might be necessary if a BEARD is used in warmer climates, particularly in obese or nervous dogs.

The fact that the suture can be cut and the mouth opened instantaneously is an advantage of the BEARD when compared to other interarcuate techniques, although such cutting may still be too late (3–5, 10, 11). The authors are now considering use of an adjustable clamp in place of the crimped clamp. In the event of vomiting or regurgitation, this would allow for conscious clamp removal, mouth opening and clearing, BEARD re-tightening, and re-clamping. It would also allow the BEARD tightness to be re-established if loosening occurs.

**Implant failure and loss of reduction**

Suture loosening that occurred in one case could have resulted from stretching of the suture, clamp slippage, or suture shearing over the dorsal maxilla, but the cause was not clear from the case records (22, 23). The steep angle of the nasal planum in cats means that attempted jaw-opening results in shearing forces between the suture and the subcutaneous tissues over the nasal and maxillary bones. The fact that loosening was not common in this case series suggests that the subcutaneous tissues are strong enough to resist the shear forces generated by attempted mouth opening. It is also possible that attempted mouth-opening causes pain at the nasal planum suture site or at the fracture site, and thus the animal may learn to avoid this noxious stimulus.

Occlusion worsened in one case in this study with multiple orofacial injuries (C5), which did not have pharyngostomy diversion during BEARD placement and had poor reduction immediately postoperatively. It is not clear whether suture loosening contributed to the worsening in this case. The other cases where the BEARD was placed without pharyngostomy diversion of the endotracheal tube (C1, C4, C7) had no loss of reduction despite having some ability to open the mouth, and were all cats with TMJ luxation or fracture-luxation. Generally, TMJ luxations are expected to be stable, once reduced, as a result of joint congruity, although joint capsule and collateral ligament damage may allow reduction under load. The unstable TMJ luxation cases in this series may have had an undiagnosed fracture; computed tomography would have been a more sensitive diagnostic tool than radiography (24).

**Implant-related complications**

Swelling and discharge associated with the suture occurred in four out of 10 cases. Complications reported after the use of external skeletal fixation and interarcade wiring, but not seen with the BEARD technique include damage of the tooth roots or nasal chambers, and osteomyelitis (4, 10, 11). Tape muzzles have been reported to cause facial dermatitis (3).

**Oesophagostomy tube**

The oesophagostomy tube complication rate of three out of nine cases is higher than reported elsewhere (25). The use of a silicone oesophagostomy tube may allow better security of the finger-trap suture and thus limit the risk of tube dislodgement (26). However, if the mouth is not fully closed by the BEARD, then oesophagostomy might not be necessary as lapping of liquid food should be possible.

**Outcome measurement**

The retrospective nature of this study, and the small number of cases treated, limits the strength of any conclusions that can be made. Radiographic documentation of bone healing was not performed routinely in this study. Detailed interpretation of radiographs of this area is difficult due to the superimposition of many bony structures. Computed tomography is a more suitable technique for assessment of caudal mandibular and TMJ fractures, but was not available during the study period (24). Instead, the BEARD was removed according to an educated assessment as to when fracture stability was likely to be sufficient, according to the age of the patient and initial instability of the trauma. Once the BEARD had been removed, there was a risk of over-stressing the fracture site and causing re-fracture and loss of reduction hence occlusion, though none of the six successful cases followed to this stage developed this problem. Three of these cases involved TMJ luxation or fracture-luxation, and could be expected to be less at risk of such a problem, as in these instances stability depended on TMJ congruency and periarticular fibrosis rather than callus strength. No firm recommendations on BEARD duration can be made using these results, although the fractures in older animals, and cases with less rigid fracture-repair constructs (possibly those with missing canine teeth, bilateral injury, or concurrent maxillary fracture) might gain strength more slowly (27).

The other outcome measures used in this study were owner-derived photography to assess rostral dental occlusion, and owner questionnaire to assess mandibular function. The photographs provided clear and reliable assessment of rostral occlusion. The use of an owner questionnaire could have introduced bias into the results (28). Objective measurements, such as mouth opening (maximum distance be-
tween the maxillary and mandibular incisor teeth) and range-of-motion of the mandible (goniometer), could have been made, though normal values for these parameters do not yet exist for the dog or cat and there are difficulties in encouraging owners to return for a re-examination at a referral centre some distance from their home, especially when the patient is perceived to be doing well. The duration of follow-up is too short to detect the true incidence of TMJ ankylosis (29).

Failed cases

The combined short- and long-term failure rate of three out of 10 cases is high, with one other case lost to long-term follow-up. However, the technique is previously unreported, and these cases are at the start of the learning curve. It is clear that case selection is paramount – each of the failed cases may have been due to poor case selection. Initial restoration of perfect rostral dental occlusion is of great importance – both cases where this was not achieved went on to fail. These cats had concurrent maxillary fracture, and neither had pharyngostomy diversion of the ET tube. Whilst a tighter version of the ET tube. For personal or educational use only. No other uses without permission. All rights reserved.

Conclusions and clinical relevance

Treatment of uni- or bi-lateral caudal mandibular or TMJ injuries using a BEARD can lead to clinical union, perfect occlusion and subjectively normal jaw function, provided that case selection is appropriate and immediate-post-surgical occlusion is perfect. The BEARD technique offers an alternative to other methods of interarcuate stabilization, is easy and quick to perform and to teach, is inexpensive, and uses minimal specialist equipment. The authors strongly recommend 24 to 48 hour monitoring of the patient after BEARD placement.

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