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Endoscopic diagnostic and surgical orbital approach in canines

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RESEARCH ARTICLE

ABSTRACT

The aim of this study is to describe new diagnostic and surgical orbital approaches using video endoscopy in canines. Four different endoscopic approaches were investigated in this study of video endoscopy in cadavers: dorsal transorbital ligament approach via incision of the orbital ligament (DTOLA), dorsal subpalpebral transconjunctival approach (DSTA), ventral subpalpebral transconjunctival approach (VSTA), and transoral orbital approach (TOA). Two additional approaches, the ventral transpalpebral approach (VTA) and dorsal caudal transmuscular approach (DCTA) along with the DTOLA and DSTA were used in clinical patients. The most technically demanding approach was DTOLA; however, it provided the best visualisation of different anterior and posterior orbital structures. Visualisation of primarily the dorsal orbital wall, dorsal portion of the eye globe, and dorsal extraconal space also was achieved by DSTA. The VSTA enabled good visualisation of the ventral orbital floor and the ventral extraconal and intraconal space. In contrast, the TOA provided relatively poor visualisation of orbital structures, limited to the ventral orbital quadrant. Meanwhile, the VTA provided visualisation similar to the VSTA, while DCTA visualisation was limited to the dorsal and caudal orbital space. Orbital endoscopy is an effective and minimally invasive procedure that can be used for diagnostic and surgical orbital procedures.

KEYWORDS

endoscopy, orbital surgery, orbital ligament approach, transconjunctival orbital approach

INTRODUCTION

Surgical management of orbital diseases in canines is considered to be among the most invasive and complex periocular surgical procedures, frequently requiring a concerted team effort between the ophthalmologist, radiologist and surgeon. Traditionally, surgical and medical treatment of orbital diseases in canines can be challenging due to the relatively limited access to the orbital space and somewhat limited direct evaluation of orbital pathology without the use of advanced imaging modalities such as ultrasound, computerised tomography (CT) and magnetic resonance imaging (MRI) (Ramsey and Fox, 1997; Dennis, 2000; Armour et al., 2011; Gelatt et al., 2011; Winer et al., 2018). Orbital diseases may be of primary origin, a manifestation of a secondary process such as metastatic tumours, or a locally invasive tumour/infection from adjacent anatomical structures (McCalla et al., 1989; Ramsey and Fox, 1997; Attali-Soussay et al., 2001; Gelatt et al., 2011; Kato et al., 2012; Van der Woerdt, 2008).

The canine orbital margin is incomplete (Gelatt et al., 2011; Evans and De Lahunta, 2013). The caudolateral margin is limited by the soft tissue orbital ligament, which extends from the zygomatic process of the frontal bone to the frontal process of the zygomatic bone, while the

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rest of the orbital rim consists of maxillary, frontal, lacrimal, and zygomatic bones (Ramsey and Fox, 1997; Evans and De Lahunta, 2013). In some brachiocephalic dogs, the lacrimal bone does not contribute to the orbital rim structure (Ramsey and Fox, 1997). The specificity of the canine orbital anatomy and soft tissue organisation potentially provides an opportunity for utilising the soft tissue approach to the orbit, without the need for osteotomy as is frequently done in species with a completely enclosed bony orbit (Abuzayed et al., 2012).

The purpose of this study was to describe different endoscopic surgical orbital approaches to the canine orbit with the potential for use in diagnostic (orbital inspection, biopsy of the orbital content), therapeutic (medication application or lavage of infected orbit), and surgical (removal or repair of tumour, orbital abscess, foreign body, bone fragment) applications. We also describe basic endoscopic orbital anatomical features and landmarks in canines that can be visualised during endoscopic surgical procedures, and discuss the advantages and disadvantages of the different approaches. The successful adaptation of the endoscopic orbital approach may provide a powerful new methodology for diagnostic and surgical treatment of canine orbital diseases.

MATERIALS AND METHODS

Canine cadaver study

Seven canine cadavers were used for this study. All dogs were previously euthanised for reasons unrelated to this study at the Veterinary Teaching Hospital, Faculty of Veterinary Medicine, University of Belgrade. The owners provided written consent for their dogs to be used for training purposes at the Veterinary Teaching Hospital upon euthanasia. One dog was a mixed breed, while the rest were purebred dogs: American Staffordshire Terrier, Samoyed, Rottweiler, Siberian Husky, German Shepherd, and Labrador Retriever. The age of euthanised dogs ranged from 6 to 9 years; two of the dogs were male and the rest were female.

A video endoscope (Karl Storz, Tuttlingen, Germany) was used for the orbital endoscopy in cadavers; the video arthroscope had a 2.7-mm diameter, and a 30-degree oblique tip (Fig. 1).

Depending on the surgical approach, the cadavers were positioned in ventral or dorsal recumbency. Several approaches were tested: (a) dorsal trans-orbital ligament approach (DTOLA) with an incision over the orbital ligament; (b) dorsal subpalpebral transconjunctival approach (DSTA); (c) ventral subpalpebral transconjunctival approach (VSTA); and (d) transoral orbital approach (TOA). All four orbital surgical approaches were performed in each cadaver dog (Figs 2–5). Additionally, DTOLA, DSTA, the ventral transpalpebral approach (VTA), and dorsal caudal transmuscular approach (DCTA) were used in clinical patients (Table 1, Figs 2–10).

Dorsal trans-orbital ligament approach (DTOLA)

With cadavers placed in ventral recumbency, a perilimbal subconjunctival suture was placed in the superior region to allow manipulation of the eye globe during orbital endoscopy, which facilitated better visualisation of orbital structures. A skin incision was made approximately 20 mm caudal from the eyelid margin, in the area of the orbital ligament (Figs 2, 3 and 7). A 40-mm-long semicircular incision was made using a Parker's No. 15 blade. Subcutaneous tissue and platysma muscle were bluntly prepared using Mosquito haemostats and Stevens tenotomy scissors. The superior palpebral muscle and the orbicularis oculi muscle were intact. The palpebral nerve was identified and,

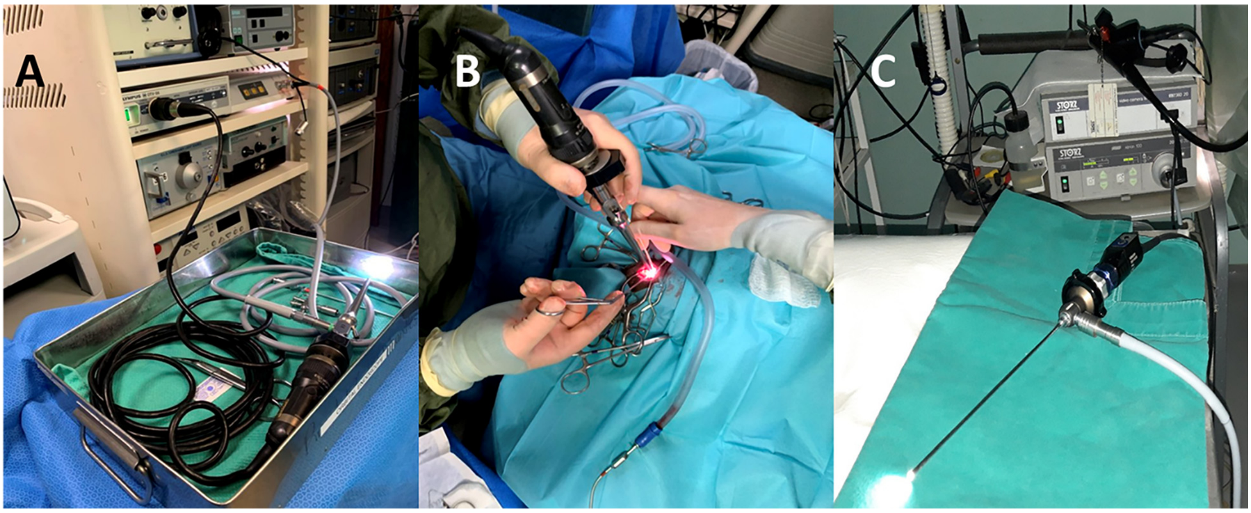

Fig. 1. Orbital endoscopic surgery setup. (A) Instrument tray with an Olympus endoscope system for surgery in a clinical patient; (B) photograph of the operative field during orbital endoscopy shows the relatively small working space. An assistant helps with suction and tissue retraction; (C) instrument tray for Karl Storz endoscope (2.7-mm diameter, 30-degree oblique tip) used for the orbital endoscopy study in cadavers

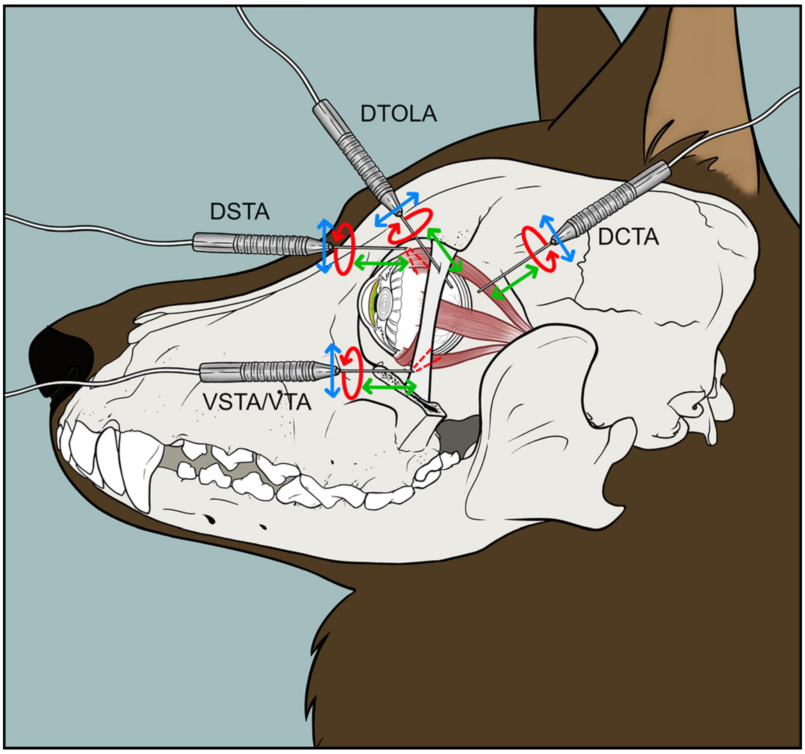

Fig. 2. Schematic presentation of the different endoscopic approaches in this study that showed good visualisation of different orbital structures: dorsal trans-orbital ligament approach via incision of the orbital ligament (DTOLA), dorsal subpalpebral transconjunctival approach (DSTA), ventral subpalpebral transconjunctival approach (VSTA), ventral transpalpebral approach (VTA), and dorsal caudal transmuscular approach (DCTA). Green, red and blue arrows indicate the different motions of the endoprobe used during imaging with the goal of obtaining the best possible visualisation of different orbital structures

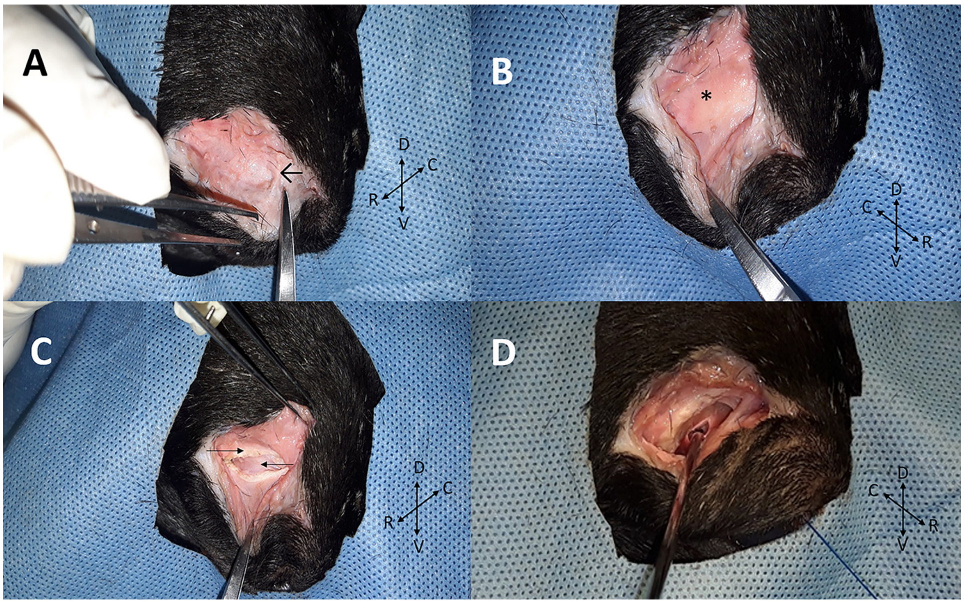

Fig. 3. Dorsal trans-orbital ligament approach (DTOLA). Pictures A, C (left eye), B, D (right eye). Crossed arrows indicate orientation (D – dorsal, V – ventral, R – rostral, C –caudal). (A) A semicircular skin incision was made over the orbital ligament region. The arrow shows branches of the palpebral nerve, which must be carefully identified, prepped, and pushed away from the surgical field using umbilical tape; (B) the asterisk points to the orbital ligament; (C) a horizontal incision was made over the orbital ligament (small black arrows show the edges of the orbital ligament); (D) orbital fat and fascia are exposed, and a perilimbal suture is used for manipulation of the eye globe during orbital endoscopy

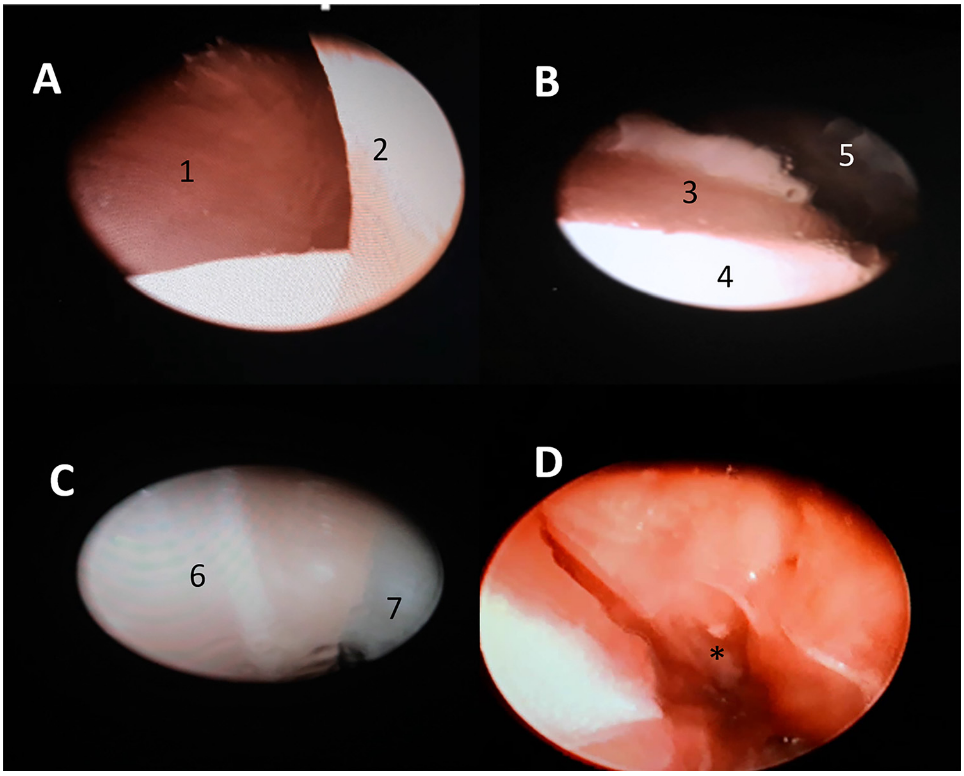

Fig. 4. Dorsal trans-orbital ligament approach. (A) (1) m. rectus dorsalis; (2) extraocular fat; (B) (3) m. dorsalis oblique; (4) sclera; (5) extraconal space; (C) (6) m. rectus lateralis; (7) sclera; (D) asterisk indicates intraconal space

where necessary, retracted with umbilical tape to avoid damage during the procedure. The palpebral artery (a. palpebralis superior lateralis) lies on the top of the orbital ligament, as does a branch of the angular ocular vein (v. palpebrae superior medialis), the accidental damage of which can cause significant bleeding. Careful ligation of this artery and vein is therefore necessary in cases where their location limits the orbital ligament, orbital fascia resection,

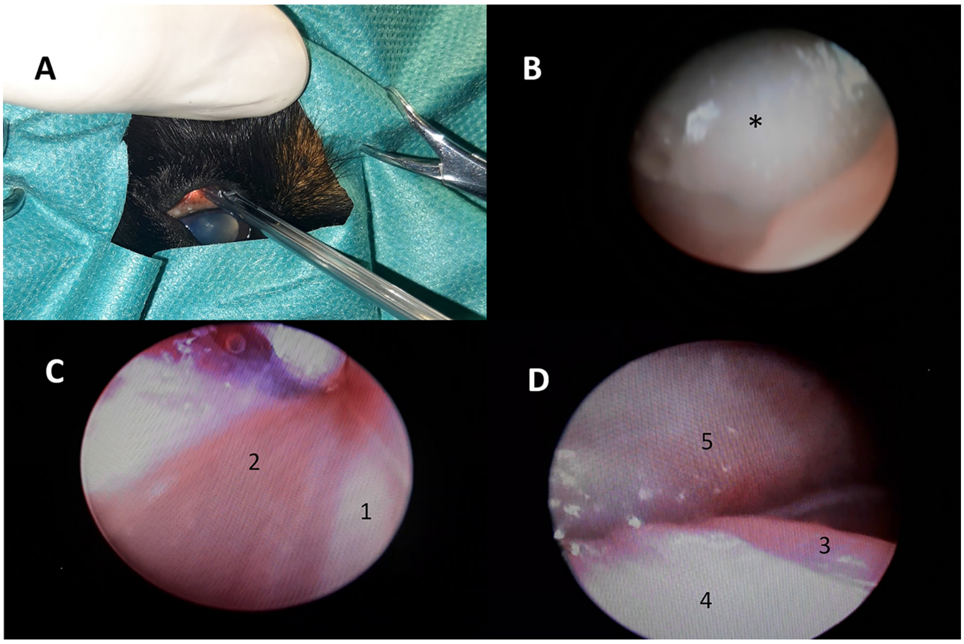

Fig. 5. Dorsal subpalpebral transconjunctival orbital approach (DSTA) (right eye). (A) Position of the endoscope during dorsal subconjunctival approach entry in the orbit. (B) The asterisk indicates the orbital ligament (ventral view). (C) Extraconal structure evaluation using the DSTA: (1) orbital fat, (2) m. rectus dorsalis; (D) (3) m. oblique dorsalis, (4) eye globe, (5) dorsal orbital floor

Table 1. Signalment and clinical presentation of clinical patients (SF – spayed female, NM – neutered male, US – ultrasound, CT –computer tomography, DTOLA – Dorsal trans-orbital ligament approach, VTA – ventral transpalpebral approach, DCTA – dorsal caudal transmuscular approach, DSTA – Dorsal subpalpebral transconjunctival approach; OS – oculus sinister, left eye; OD – oculus dexter, right eye; OU – oculi utriusque, both eyes)

	Breed	Sex/Age	Clinical signs	Image modality	Procedure	Endoscopic approach	Diagnosis	Outcome
1	Golden Retriever	SF/7 years	Exophthalmos OS for 4 months	US	Surgical mass removal	DTOLA	Zygomatic mucocele	Resolution/Lost to follow up after 6 months
2	Shih Tzu/Maltese mix	NM/9 y	Exophthalmos OD, caudal orbital, and subcutaneous mass for 2 months	US	Surgical mass removal	DCTA	Lobular orbital adenoma	Resolution/Currently 18 months follow up
3	Beagle	SF/10 y	Exophthalmos OS for 3 months	US/CT	Biopsy	VTA	Extraocular myositis and poorly differentiated orbital tumour, dry eye OU	Euthanasia – 4 months after the procedure due to seizures
4	Rat Terrier	NM/13 y	Exophthalmos OS for 3 months	US/CT	Biopsy	DSTA	Nasal and orbital adenocarcinoma	Euthanasia 14 days after the procedure due to seizures

and access to deeper orbital structures. The orbital ligament was incised lengthwise to enable access to the retrobulbar space. Gelpi retractors were inserted into the incision to enable good visualisation of the surgical site and allow for the introduction of the endoscope into the orbital space (Fig. 3). Upon the entrance, the main blood vessels to be carefully identified and avoided are branches of the external ethmoidal artery and dorsal external ophthalmic vein, which extends caudally, along the dorsomedial orbital margin (Evans and De Lahunta, 2013). In the dorsal part of the orbit, the dorsal external ophthalmic vein is dilated and forms an ophthalmic plexus, the accidental damage of which can result in significant bleeding during the resection and manipulation of orbital tissues (Evans and De Lahunta, 2013). Neural structures that should be avoided during the DTOLA are the frontal and infratrochlear nerves, branches of the ophthalmic nerves, and the zygomaticotemporal nerve (branch of the maxillary nerve), which run rostro-dorsally in the periorbital space and toward the region of the orbital ligament (Evans and De Lahunta, 2013). YASARGIL microform neurosurgery instruments were used for fibrous conus sheath resection and tissue manipulation.

Dorsal subpalpebral transconjunctival approach (DSTA)

A 10-mm transconjunctival incision was made in superior fornix, between the bulbar and the palpebral conjunctiva (Figs 2, 5 and 10). Blunt preparation of the subconjunctival tissue was performed using Mosquito haemostat forceps until the orbital cavity was reached beyond the eye globe, allowing the endoscope to be introduced.

Ventral subpalpebral transconjunctival approach (VSTA)

A 10-mm transconjunctival incision was made in the inferior fornix, between the bulbar and the palpebral conjunctiva, anterior to the nictitating membrane (Figs 2 and 6). Blunt preparation of the subconjunctival tissue was performed using Mosquito haemostat forceps until the orbital cavity was reached under the eye globe, allowing the endoscope to be introduced.

Transoral orbital approach (TOA)

For the transoral approach, cadavers were positioned in dorsal recumbency. The oral cavity was opened using a mouth opener (Canine Mouth Gag 160 mm, Miltex®, Integra, Inc., York, PA, USA). A 2-cm-long surgical incision was made behind the last molar, using a Bard-Parker No. 15 surgical blade. Blunt preparation of soft tissue was performed using Mosquito haemostat forceps until the retrobulbar space was reached, allowing the endoscope to be introduced.

Dorsal caudal transmuscular approach (DCTA)

With a patient in ventral recumbency, a skin incision was made approximately 10 mm caudal to the orbital ligament

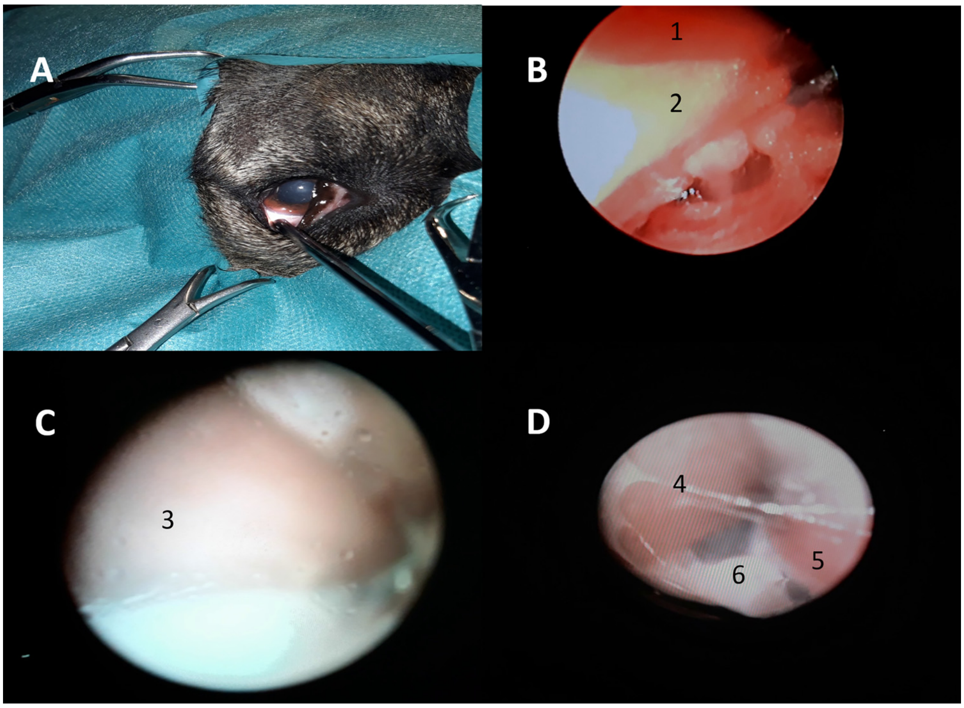

Fig. 6. Ventral subpalpebral transconjuctival approach (VSTA) (right eye): (A) The position of the endoscope during orbital entry for the ventral approach; (B) (1) m. rectus ventralis; (2) orbital fat; (C) (3) m. rectus medialis is visible under endoscopic magnification; (D) (4) m. oblique ventralis; (5) m. rectus ventralis; (6) ventral orbital fat

(Fig. 8). A 40-mm-long semicircular incision was made using a Bard-Parker No. 15 surgical blade. Subcutaneous tissue and platysma muscle were bluntly prepared using Mosquito haemostats and Stevens tenotomy scissors with the goal of isolating the palpebral nerve. This was followed by the placement of Gelpi retractors into the incision to enable good visualisation of the surgical site, followed by the resection and removal of the tumour tissue growth in the intermuscular fibre region. Further blunt preparation and separation of the frontal and temporal muscle fibres were pursued along the field of the tumour growth, which allowed for introduction of the endoscope into the orbital space for visualisation and removal of any tumour tissue remnants. A perilimbal subconjunctival suture was placed in the superior region to allow eye-globe manipulation during the orbital endoscopy, which enabled better visualisation of orbital structures.

Ventral transpalpebral approach (VTA)

A 30-mm-long inferior transpalpebral skin and ventral conjunctival incision was made between the eye globe and the ventral orbital rim (Fig. 9). Blunt preparation of the

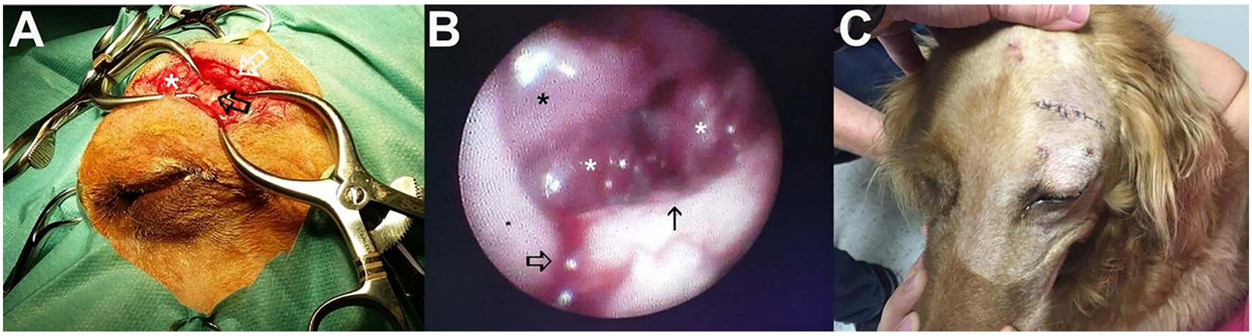

Fig. 7. DTOLA in a Golden Retriever with a zygomatic mucocele. (Table 1, Case 1) (left eye). (A) Skin, subcutaneous tissue, platysma, and frontalis muscles were bluntly separated to expose the orbital ligament. Gelpi retractors were used to extend the operating window. White asterisk and arrow mark branches of the palpebral nerve, while the black arrow points to the resected orbital ligament and orbital fascia resulting in orbital fat tissue prolapsing in the surgical field. (B) Endoscopic view of the orbital content: open black arrow indicates the mucoid content from the resected mucocele, closed black arrow points to the resected orbital fascia, white asterisks point to a cystic zygomatic gland, which is pushing against the orbital fat (black asterisk). (C) Appearance of the patient and surgical incision seven days after the procedure

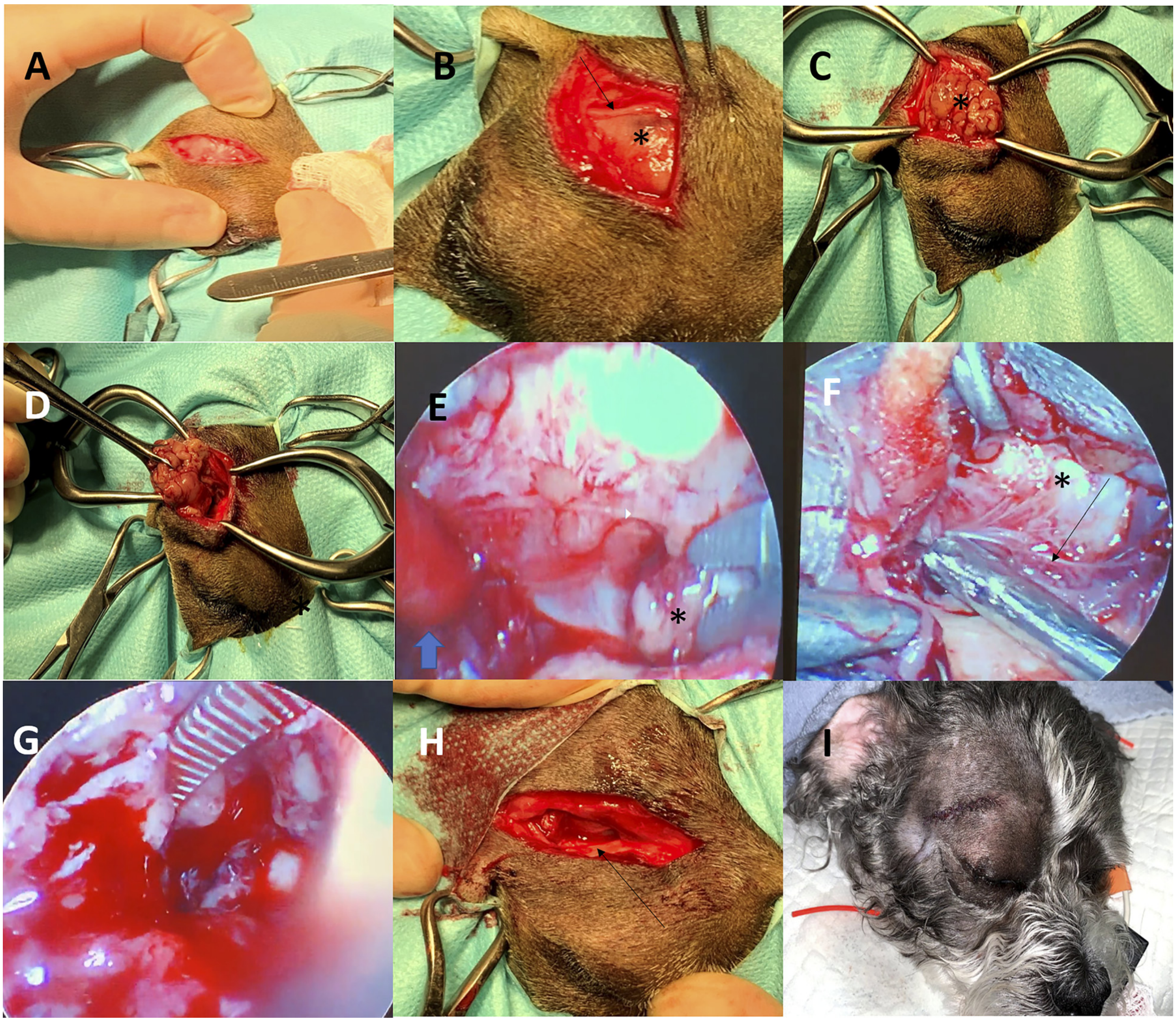

Fig. 8. Caudal orbital tumour removal with dorsal caudal transmuscular approach (DCTA). (right eye) (Table 1, Case 2). (A) Skin incision caudal to the orbital ligament; (B) black asterisk marks the tumour capsule, black arrow points to branch of the auriculopalpebral nerve; tumour growth resulted in the separation of frontalis and temporalis muscles. (C) Exposure of tumour mass (black asterisk indicates exposed tumour tissue); (D) blunt dissection of tumour mass; (E) endoscopic tumour removal: a cotton tip applicator was used for tissue retraction; black asterisk marks remanence of the tumour tissue being removed by alligator tissue forceps; (F) visualisation of the surgical field was maintained with a suction probe (black arrow); black asterisk indicates orbital fat tissue; (G) endoscopic orbital view without suction probe – there was moderate orbital bleeding, which reduced operating field visualisation, and if left uncontrolled could have created a risk of orbital haematoma formation and compressive optic neuropathy development; (H) surgical appearance of the incision at the end of surgery—arrow points to the orbital rim and caudal border of orbital ligament; (I) surgical closure was performed in four layers using an absorbable suture (Vicryl 4-0): orbital fascia closure (layer 1), temporal and frontal muscle closure (layer 2), subcutaneous tissue closure (layer 3), skin closure (layer 4)

subconjunctival tissue was performed using the Mosquito haemostat forceps until the orbital cavity was reached under the eye globe, allowing the endoscope to be introduced.

Clinical case studies

The second part of the study describes four clinical cases presented to the Animal Eye Consultants of Iowa, in which orbital endoscopy was used as a diagnostic procedure (biopsy of the orbital mass) and/or for surgical mass removal purposes (Table 1). All owners provided written consent for all diagnostic and surgical procedures in their pets.

All clinical canine patients received a complete ophthalmic examination performed by a board-certified ophthalmologist (SG). Examinations included slit-lamp biomicroscopy (SL-15, Kowa Co., Nagoya, Japan), tonometry (TonoPen Vet, Reichert Technologies, Depew, NY, USA), indirect ophthalmoscopy (Vantage Plus, Keeler USA, Pike Malvern, PA, USA), Schirmer tear test I (Schering-Plough Animal Health, Kenilworth, NJ, USA), fluorescein dye test (Flu-Glo®, Akorn, Lake Forest, IL, USA), and neuro-ophthalmic examinations included ocular movement and ocular retropulsion evaluation. Diagnostic imaging was performed in all patients by ocular and orbital

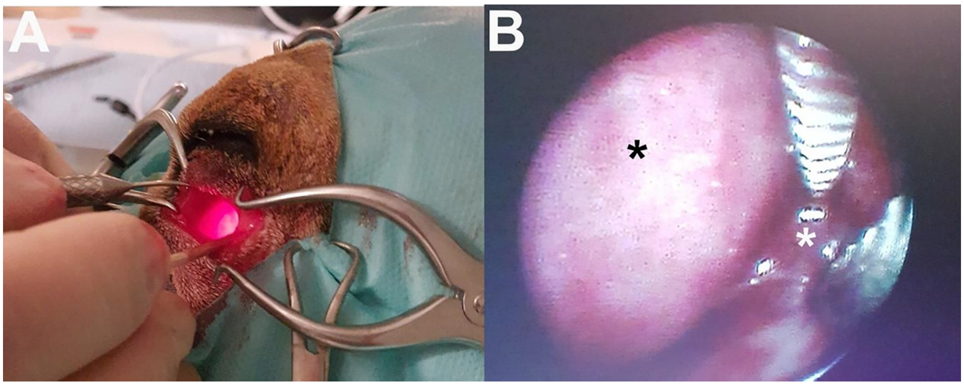

Fig. 9. Ventral transpalpebral approach (VTA). (Table 1, Case 3) (left eye). (A) A 35-mm skin incision was made and blunt dissection of the subcutaneous tissue was performed. Westcott tenotomy scissors were used to resect the conjunctiva attached to the ventral orbital rim. An 18-gauge Endo Optiks probe was used for the inspection of the orbital floor. Haemostasis was achieved using sterile cotton tip applicators. (B) Endoscopic view of the orbital floor: black asterisk marks the eye globe, white asterisk the soft orbital tissue/orbital mass on the orbital floor, which was collected for biopsy

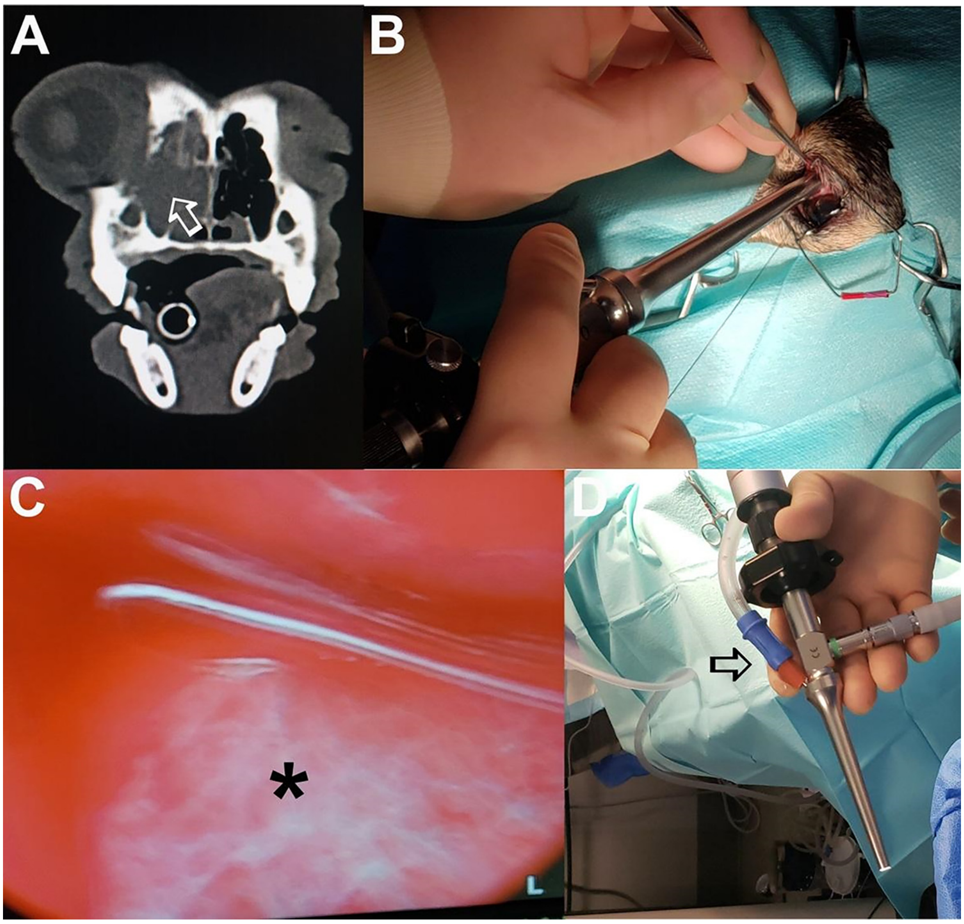

Fig. 10. DSTA approach for orbital tumour biopsy. (Table 1, Case 4). (A) CT imaging from this patient shows a nasal mass with orbital extension and destruction of the medial orbital wall (white arrow). (B) After creating a 15-mm conjunctival incision using the Westcott tenotomy scissors, an otoscopic video probe was introduced into the dorsomedial subconjunctival space, and guided medially toward the tumour region. (C) Endoscopic view of the lobulated orbital mass (black asterisk), with moderate orbital bleeding immediately after the biopsy procedure. (D) Attachment of the suction tip to the otoscope body allows continuous suction during the orbital inspection (black arrow). Excessive suction may result in excessive orbital tissue apposition and cause difficulties during the orbital inspection. The presence of dual ports may allow for combined suction and inflation, resulting in the better visibility of orbital structures

ultrasound (n = 4) in combination with orbital CT imaging (n = 2, Table 1).

Surgery was performed under general anaesthesia in all patients, with patients positioned in ventral recumbency. Generous periocular clipping of hair was performed with the standard sterile surgical preparation of the orbital operating field. For the orbital endoscopy in clinical patients, an Olympus video endoscopy system (Olympus OTV-S6 with OTV-S6H-1L camera head, Olympus Surgical Technologies America, Inc., Southborough, MA, USA) was used in combination with a video arthroscope 2.7 mm in diameter, 30° oblique tip (Karl Storz, Tuttlingen, Germany), or video otoscope 6 mm, 0° flat tip with the Storz compatible infusion port (DailyMed, Hangzhou, China) (Fig. 1, Cases 2 and 4, Table 1).

In two patients, an E2 endoscopic system combined with an endoscopic 18-g curved probe (1,024 mm diameter) (Cases 1 and 3, Table 1) was used for the endoscopic inspection (Endo Optiks® Inc., Little Silver, NJ, USA; Figs 6 and 8). Standard postoperative treatment included systemic antibiotics and non-steroidal anti-inflammatory medications for 14 days, combined with topical ocular lubricants applied four times daily (QID) for 14 days.

RESULTS

The endoscopic approach was utilised effectively for the inspection of orbital structures and surgical biopsy/mass removal. Each approach provided good visualisation of different orbital anatomic structures, with some limitations of the regional orbital visibility. The transoral orbital approach (TOA) had the most limitations in terms of instrument manipulation and visibility of different orbital structures.

DTOLA

The DTOLA was the most technically demanding surgical approach due to the need for surgical resection of multiple tissue layers. It provided good visualisation of the dorsal, lateral, and medial orbital quadrants, with the poorest visibility of the ventral orbital quadrant (Figs 2, 3 and 7).

The endoscopic DTOLA approach readily identified the following anatomic structures and landmarks: extraocular muscles (dorsal rectus muscle, dorsal oblique muscle, lateral rectus muscle), orbital fat, sclera, and intra- and extraconal space (Figs 3 and 7). Endoscope motility is possible in all directions (dorsal, ventral, medial, lateral) in this approach.

If a pathological process is located in the intraconal space, resection of the periconal fibrous sheet will be necessary. During the resection of the sheet many vital structures are at risk of damage, starting with the optic nerve as the biggest structure, which is surrounded by the numerous branches and anastomoses of the internal ophthalmic artery and vein, and the oculomotor and ophthalmic nerves. Very careful dissection using blunt neurosurgical straight or curved dissectors is therefore required (Evans and De Lahunta, 2013).

DSTA

A smaller initial incision on the conjunctiva and decreased tissue manipulation makes this approach less traumatic than the DTOLA. This approach provided good visualisation of the dorsal rectus and oblique muscles, extraconal space, orbital ligament and fat, dorsal orbital wall, and dorsal part of the eye globe (Fig. 5). It did not provide a good visualisation of the posterior part of the orbit, intraconal space, or the ventral part of the orbit.

Compared to the DTOLA, the DSTA had limited intraconal access, and provided poor access to posterior parts of the orbit. An additional DSTA limitation was the reduced maneuverability of the endoscope relative to the DTOLA. In the DTOLA, endoscope motility is possible in all directions (dorsal, ventral, medial, lateral), while in the DSTA, anatomical barriers reduce endoscope movements. Specifically, dorsal movements are restricted by the orbital rim of the frontal bone and the orbital ligament, while ventral movements are limited by the position of the eye globe. The other reason for the limited visibility might be the angle at which the endoscope enters the orbit. The endoscope in this approach is inserted into the orbit parallel to the eye globe, or at a relatively narrow angle, while with the DTOLA, that angle is much larger, allowing for more flexible manipulation and a larger field of view. These limitations may be partially overcome by using an 18-gauge curved endoscopic probe, which allows for more natural sliding along the eye-globe curvature (Figs 7 and 9).

The surgical incision for the DSTA is small (1 cm) so the potential for bleeding is minimal, although the conjunctiva is very well supplied with blood vessels. The main blood vessels that supply the dorsal part of the conjunctiva are multiple branches of the dorsal palpebral artery, which travels between the superior eyelid and frontal bone, and may project thicker branches in different conjunctival regions, resulting in more significant bleeding during surgical preparation and resection (Evans and De Lahunta, 2013). Similar to the DTOLA approach, the potential risk during surgical dissection and endoscope manipulation is injury of the dorsal muscle artery branches of the external ethmoidal artery, lacrimal artery, and dorsal external ophthalmic vein. The nerve structures that should be carefully avoided are the frontal and infratrochlear nerves.

VSTA

The VSTA can be very useful for visualisation of the ventral part of the orbit. Anatomic structures that can be visualised and surgically manipulated using this approach include the ventral rectus and oblique muscles, medial rectus muscle, ventral portion of the eye globe, and intra- and extraconal space. The dorsal part of the orbit cannot be visualised using the VSTA (Fig. 5).

During this approach, particular attention should be paid to avoiding injury to the maxillary artery and vein, which extend along the ventral orbital wall (Evans and De Lahunta, 2013). The ventral ophthalmic vein extends along the ventral wall of the orbit between the extraocular muscles and anastomoses with the dorsal ophthalmic vein in the ophthalmic plexus, and intraconal endoscopic manipulation may potentially result in injury (Evans and De Lahunta, 2013). Additional vital structures that must be carefully avoided during the VSTA approach are: the ventral muscular branch of the ethmoidal artery, which runs between the ventral and lateral rectus muscles, supplying them and the medial rectus; the ventral fasciculi of the retractor bulbi; the gland of the third eyelid; and the zygomaticofacial nerve passing along the ventral orbital floor, which innervates the lower eyelids and the zygomatic arch.

TOA

Limited range of endoscope motion was a major limitation during the TOA. This approach provided some visualisation of anatomical structures in the posterior orbital space; however, positioning in dorsal recumbency was necessary to allow the orbital content to be removed by the gravitational force from the ventral orbital floor. Due to the limitations in terms of imaging, endoscope manipulation, and possible manipulation of surgical instruments, the TOA seems to be an inferior approach compared to all previously described endoscopic approaches. Critical structures to be carefully avoided with this approach are the same as those described for the VSTA.

VTA

This approach provides good visualisation of the ventral part of the orbit. Anatomical structures that can be visualised include the ventral portion of the eye globe, extraconal space, and ventral rectus muscle (Fig. 8). The dorsal part of the orbit cannot be visualised using VTA. Potential injury of the facial vein, superior labial vein, and infraorbital vein should be avoided during skin and subcutaneous tissue resection. Critical structures of the ventral orbital quadrant to be avoided are the same as described for the VSTA.

DCTA

The DCTA provided good visualisation of the caudal orbital space, but had limited value for the observation of the anterior and ventral parts of the orbit (Fig. 7). During the skin and subcutaneous tissue resection, potential injury to the rostral auricular plexus and palpebral nerve must be avoided. As damage of the palpebral artery and vein can cause significant bleeding, ligation of these vessels may be necessary if the structures limit the approach to orbital structures of interest. Deeper in the orbit, blood vessels that should be avoided include the external ethmoidal artery, dorsal muscular branches, and dorsal external ophthalmic vein (Evans and De Lahunta, 2013).

DISCUSSION

A small number of articles have described the use of endoscopy in orbital and periorbital procedures in dogs (White et al., 1984; Braunstein et al., 1995; Strom et al., 2018). Braunstein et al. (1995) reported the use of a flexible endoscope via medial and lateral transconjunctival approaches for orbital exploration and biopsy in experimental dogs. White et al. (1984) and, more recently, Strom et al. (2018) investigated the use of the endoscope to resolve nasolacrimal obstruction in dogs. Recently, Espinheira Gomes et al. (2020) has described a transcaruncular endoscopic orbital approach for visualisation and biopsy specimen collection in a dog with orbital sarcoma, introducing orbital endoscopy into veterinary medicine as a potential method for use in obtaining histopathology orbital specimens, and potentially for minimally invasive orbital surgery.

Traditionally, histopathological diagnosis of orbital processes is obtained from CT- or ultrasound-guided sample collection. Ultrasound-guided fine-needle aspiration (FNA) and biopsy allow real-time visualisation of orbital structures, and can monitor needle progression toward the lesion, which is very important to avoid additional complications such as injury to the optic nerve or the eye globe (Gupta et al., 1999; Boroffka et al., 2007; Betbeze, 2015; Winer et al., 2018). During CT-guided FNA or core needle biopsy, there is no possibility of real-time visualisation, which can sometimes result in multiple attempts before the needle tip is placed within the lesion. Retrobulbar haemorrhage is a common complication of US- and CT-guided FNA and core needle biopsy, but in most cases, these haemorrhages resolve spontaneously (Gupta et al., 1999; Cirla et al., 2016; Timmis et al., 2018).

Contrary to the ultrasound- and CT-guided biopsy techniques, visualisation of biopsy instruments in this study was excellent during the endoscopic approach, providing good control of the biopsy procedure and limiting the risk of injuring sensitive orbital and ocular structures. The major limitation of the orbital endoscopy-guided biopsy procedures is the need for a more involved surgical procedure, and limited visualisation of all orbital quadrants from the single point of entry. However, this limitation can be almost completely eliminated by careful planning of the orbital points of entry based on preoperative imaging. Furthermore, in situations where intraoperative histopathology is available, an immediate transition toward a full surgical removal of the orbital mass can be pursued during the same anaesthetic procedure.

In human ophthalmology, the most common indications for the surgical use of an endoscope are orbital fracture repair (Fernandes et al., 2007; Prabhakaran et al., 2007; Ramakrishna et al., 2016), orbital decompression (Wee et al., 2002; Kasperbauer and Hinkley, 2005), foreign body retrieval (Levin et al., 2019), removal of an orbital apex lesion (Tsirbas et al., 2005), and endoscopic tumour removal (Signorelli et al., 2015; Sun et al., 2017) using various surgical approaches (transpalpebral, transconjuctival, transnasal, transcaruncular, transmaxillar). For the endonasal endoscopic orbital approach, sphenoethmoidectomy with resection of the middle turbinate is necessary to provide a working space for surgical instruments (Zoli et al., 2021). Human nostrils are generally much wider than those of dogs and cats, allowing for the introduction of multiple instruments (Chamanza and Wright, 2015). The transconjunctival endoscopic orbital approach in humans allows access to the anterior and posterior part of the orbit (intraconal space and optic nerve) (Pillai et al., 2008; Lyson et al., 2014), which was not supported by the results obtained in our study of DSTA and VSTA, most likely due to the much deeper orbit in the majority of canine breeds used. In brachiocephalic breeds, however, it would potentially be possible to achieve visualisation of the complete orbital content using the DSTA and VSTA. The transpalpebral endoscopic orbital approach in humans provides good exposure of intraconal and extraconal orbital space, and has been recommended for tumour removal, biopsy, and decompression/drainage of the orbital content, with ptosis being the most frequently reported complication (Bradoo et al., 2015; Dallan et al., 2016; Zoli et al., 2021).

This study utilised DTOLA and DCTA with similar efficacy in both cadaver canine orbits and clinical patients without evidence of postoperative ptosis development. The DTOLA proved to be the most complex, but also the most useful surgical approach for orbital endoscopic surgery and biopsy of the anterior, posterior, intraconal, and extraconal dorsal part of the orbit compared to the other approaches. The DTOLA does not require partial orbitotomy with resection of the zygomatic arch, and it shortens the time of surgical intervention and postoperative recovery compared to non-endoscopic traditional surgical techniques (Gilger et al., 1994; Ramsey and Fox, 1997; Håkansson and Håkansson, 2010; Gelatt et al., 2011; McDonald et al., 2016; Charnock et al., 2020).

During orbital endoscopy in dogs in this study, several problems were routinely encountered. First, manipulation of the endoscope and orientation in the orbital space during procedures can be challenging, especially in the early phases of training with the endoscope. The endoscopic view of the normal canine orbit has not been previously described, and in general, orbital surgeries are relatively rarely performed by practicing veterinary ophthalmologists, making the surgical procedure more challenging overall. Furthermore, the presence of orbital pathology can significantly change the appearance or location of orbital structures, so detailed knowledge of orbital anatomy is extremely important. We found it particularly useful to look for the eye globe and extraocular muscles as a good point of reference, and if there are any doubts about the anatomical location of a specific structure, retracting the endoscopic probe until orienting points were visible increased the proper orientation significantly.

Second, the presence of blood or tissue debris can dramatically reduce visibility of orbital structures, so meticulous suction and haemostasis are very important during the orbital endoscopic procedure. Third, the working incision for orbital endoscopy is rather small, limiting the introduction of a majority of the traditional surgical instruments into the orbit. This is why we focused on evaluating and testing many microsurgical instruments used for neurosurgery and orbital surgery in humans, with the goal of determining the best possible tools for successful tissue manipulation and surgical resection, while minimising the risk of trauma to sensitive canine orbital structures.

Orbital surgical endoscopic procedures usually require an assistant to handle the endoscope and suction probe while the surgeon is performing the surgery. The need for an assistant can potentially be avoided by introducing a ‘fixation arm’ to hold the endoscope and allow the surgeon to use both hands, or with an endoscopic instrument designed so that imaging, flushing, and suction can be performed with a non-dominant hand, while the dominant hand is used for surgical removal of a mass, or biopsy collection (Gaab, 2013). The use of an endoscope/otoscope with a working channel makes it possible to introduce different types of instruments through the working channel; however, this approach significantly limits the number of instruments that can be deployed during the procedure. We found it more effective to deploy a smaller-diameter endoscope without a working channel (Endo Optiks® 18-g curved probe), which allowed for most orbital surgery instruments to be inserted parallel to the endoscope. Furthermore, the curved shape of the Endo Optiks probe allowed for much better avoidance of the curvature of the eye globe, providing an additional advantage during the procedure.

The disadvantages of the small-diameter endoscopic probe are decreased width of the field of view and image resolution. The surgical intraconal approach is considered the most demanding procedure during orbital endoscopy, due to the high density of critical structures packed into the small intraconal space. We effectively employed a 65 Beaver blade and YASARGIL microform neurosurgery scissors for the resection of the fibrous conus sheath, and in general found the YASARGIL microform neurosurgery instruments very useful for manipulation and resection within the orbital space. In order to increase the exposure and visualisation of intraconal structures, a micro retractor could be also potentially be used, as recently reported (Banks et al., 2019).

The removal of orbital masses remains the major challenge during orbital surgery, due to the very limited space for the introduction of multiple instruments; however, development of ultrasonic tissue aspirator units with small-diameter profile has introduced significant improvements to orbital microsurgeries in humans (Samy et al., 2007; Cho et al., 2010; Murchison et al., 2013; Vrcek et al., 2015; Ibáñez-Botella et al., 2019). These devices allow possible simultaneous or separate irrigation and aspiration, and removal of soft and hard tissue fragments, mimicking intraocular phacoemulsification techniques for surgical lens removal. They enable an ophthalmic surgeon to make the rather natural transition from intraocular to intraorbital surgical work (Vrcek et al., 2015; Oechtering et al., 2018). We found the use of this technology quite effective, for the removal of soft tissue structures from the orbital space (unpublished observation). The continuous irrigation associated with the use of an ultrasonic tissue aspirator, however, may result in significant hydration and swelling of the soft orbital tissue, which may limit visualisation of the target tissue. An additional advantage of the ultrasonic tissue aspirator is that it allows the surgeon to perform a two-handed surgical procedure, with the non-dominant hand using the endoscopy unit, while the dominant hand performs tissue aspiration (SG, personal observation).

Another possible way to access poorly visible orbital tumours would be to use CT or MRI image-guided stereotaxis systems, which allows the surgeon increased precision, better intraoperative orientation, and precise information about the tumour margins (Karcioglu and Mascott, 2006; Servat et al., 2014). Whatever the surgical approach, one of the main challenges during orbital surgery remains the maintenance of haemostasis/control of orbital haemorrhage. The orbit is a closed space, and eventually, any bleeding stays inside the orbit as a result of the coagulum-induced tamponade. However, excessive intraorbital pressure that can develop as a result of bleeding may result in compression and occlusion of vital vascular structures, resulting in ischaemic damage to the retina and optic nerve (Gelatt et al., 2013; Charnock et al., 2020).

In our experience, the endoscopic surgical approach is characterised by minimal bleeding during the surgical entry into the orbit. Biopsy and resection of orbital tumours/masses may result in significant bleeding, however, which needs to be carefully controlled. While we did not encounter a major issue with uncontrolled bleeding, creating an inferior transconjunctival or retromolar opening may allow for excessive blood/discharge egress from the orbital space, resulting in significantly decreased risk of compressive optic nerve/vascular injury.

In this study, we demonstrated that while endoscopic surgical approaches have their own limitations, they are relatively safe and minimally invasive. A detailed understanding of the orbital anatomy is necessary to maximise the utilisation and efficacy of the endoscopic approach and avoid iatrogenic injury.

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