ORIGINAL ARTICLE

Cosmetic reconstruction of extensive maxillary defects with cerclage wire alone or in combination with polypropylene mesh in 25 dogs (2017-2023)

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Objectives: This study aimed to describe the use of cerclage wires with or without polypropylene mesh for the reconstruction of maxillectomies with or without concurrent orbitectomy and report the surgical outcomes.

Materials and Methods: Dogs presented for resection of a maxillary/orbital neoplasia and reconstruction were retrospectively enrolled. Data retrieved from medical records included signalment, tumour site and size, type of maxillectomy and reconstruction, results of histological examination, surgical time and surgical complications.

Results: Twenty-five dogs were included. Central-caudal, caudal and rostral maxillectomies were performed in 11, 9 and 5 dogs, respectively. Eight dogs (32%) received a ventral orbitectomy concurrently. Mean surgical time was 70 minutes. No intraoperative complications occurred. Minor early (<48 hours) postoperative complications occurred in 22 dogs (88%) and were oedema of the muzzle ($n = 21$), rhinorrhagia ($n = 11$) and pain causing difficulty in eating ($n = 2$). Five dogs (20%) had minor late postoperative (>48 hours) complications: partial intraoral dehiscence at 10 days that healed by second intention ($n = 2$), reverse sneezing ($n = 2$) and antibiotic-respondent infection ($n = 1$). Five dogs (20%) developed oronasal fistula as a major late postoperative complication. All the dogs were able to eat autonomously 48 hours after surgery; visual function was normal and appearance was restored.

Clinical Significance: The technique that we report relies on readily available, cost-effective materials and can be successfully used for customised reconstruction of maxillary defects in dogs. Rate of complications should be compared to the standard reconstructive technique to determine if the use of maxillary implants results in higher risk of complications.

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INTRODUCTION

Maxillectomy is one of the mainstays in the multimodal treatment of tumours arising from or secondarily involving the incisive, nasal or maxillary bones in dogs (Bergman, 2007; Martano et al., 2018; Riggs et al., 2018; Sarowitz et al., 2017). Orbitectomy may also be necessary if the zygomatic, palatine and/or lacrimal bones are involved (Lantz, 2012). While reconstruction of small maxillary defects is straightforward, achieving functional and cosmetic reconstruction of extensive maxillary defects is a major challenge, especially when the central/caudal maxilla and the orbit are involved (MacLellan et al., 2018; Sarowitz et al., 2017; Thomson et al., 2020). Reconstruction of the soft tissues with labial advancement and apposition to the palatal mucoperiosteum can potentially lead to functional outcome and only minor cosmetic changes (Rigby, Malott, Sample, et al., 2021; Thomson et al., 2020). However, especially if the zygomatic arch is removed, there is a risk for ventral displacement of the ocular globe (Dent et al., 2019); furthermore, if a great amount of the maxillary bone is excised and not replaced the resulting cosmetic changes can be unacceptable for some owners. The use of a temporalis fascia transposition flap and masseter muscle flap has been described for ventral orbital stabilisation following caudal maxillectomy and ventral orbitectomy in two single cases (Dent et al., 2019; Sivagurunathan et al., 2014). Both techniques are valid options to prevent the complications related to ventral globe displacement and allow for satisfactory cosmesis. Despite the benefits of autologous grafting, the temporalis fascia and masseter muscle flap are not suited for surgical defects extending further cranially to the maxillary bone or lateral-caudally to the zygomatic arch, and in these cases, the use of heterologous implants may be required. Tissue engineering is one of the latest frontiers in reconstructive surgery, and custom-made 3D printed scaffolds of biocompatible polymers that can enhance osteogenesis and bone integration have been studied for the reconstruction of extensive facial defects in humans and dogs (Kim et al., 2018; Lee et al., 2017). However, to date, their application in veterinary medicine is questionable due to high costs and limited availability, and the description of their use for reconstruction of maxillary defects in dogs is limited to one single clinical case and a few experimental animals (Kim et al., 2018; Lee et al., 2017).

Wallin-Håkansson and Berggren (2017) described the reconstruction of anterior and lateral-posterior orbitectomies in four dogs with cerclage wire and propylene mesh coated with collagen sheet. The technique allowed for cosmetic reconstruction with long-term functional outcomes, preventing eye globe displacement and facial deformity. Availability of the materials and versatility of the implant are the main advantages of the technique, given the possibility to use a variable number and configuration of cerclage wires to reconstruct bony ridges and facial contours. Based on their results and on the mentioned advantages, the authors of that study suggested that the technique could be useful for cosmetic reconstruction of extensive maxillectomies. However, its application in case of large maxillary defects has not been reported yet. In the original technique, a collagen sheet was used to improve the biocompatibility of the implant, although the authors themselves question the need for this adjunctive material.

At our institution, we are routinely implementing a modification of the reconstructive technique originally described by Wallin-Hakansson, consisting of the use of cerclage wires with or without polypropylene mesh but without collagen sheets, for the reconstruction of large facial defects in dogs, resulting from caudal or central-caudal maxillectomies in association or not with orbitectomy. The aim of this study was to describe the modified technique and to report the surgical complications and outcomes associated with this procedure.

MATERIALS AND METHODS

The study was conducted as a retrospective case series. Records of dogs presented with oral tumours and treated with maxillectomy at one Specialty Institution from January 2017 to February 2023 were reviewed. Inclusion criteria were:

- availability of a preoperative whole-body contrast-enhanced CT to exclude distant metastases and plan the surgical resection.
- reconstruction of the defect performed with cerclage wire alone or in association with polypropylene meshes.
- minimum of 15 days of postoperative follow-up.

Data retrieved from medical records included signalment, tumour site and size, type (rostral, central-caudal, caudal, with/without orbitectomy) of maxillectomy (MacLellan et al., 2018), type of reconstruction (number of cerclage wires, positioning, with/without polypropylene mesh), results of histological examination (tumour type, surgical margins, status of regional lymph nodes), surgical time and surgical complications. Surgical complications were defined as intraoperative when occurring during the procedure, early postoperative (<48 hours after surgery), late postoperative (>48 hours after surgery) (MacLellan et al., 2018) and were further categorised as minor when self-limiting or major when requiring further surgical intervention or if life-threatening. Follow-ups consisted of periodical rechecks, scheduled at 15, 30 days and 3 months after surgery, and of phone calls with the owner or referring veterinarian thereafter. Further clinical rechecks were performed in case of suspected complications. Median follow-up time was calculated. Descriptive statistic was used to summarise the distribution of collected variables. For continuous variables, mean and standard deviation are employed to describe central tendency and dispersion. For categorical variables, the frequency of each modality is reported as the % on the total of cases.

Ethical approval was not required for this study, because included dogs had spontaneous disease and were treated following the current standards of care. Clinical decision-making was

not influenced by the study. The data were collected retrospectively after treatment.

Surgical procedures

One board-certified surgeon (F.M.) performed all the surgical procedures. The decision to reconstruct the maxillary defect with cerclage wires alone or in combination with polypropylene mesh instead of traditional reconstruction was discussed with owners when the planned surgical excision may have led to facial deformity and/or possible functional deficit including ventral eye displacement (if an orbitectomy was planned) or difficulties eating in the first postoperative phase (if an extensive caudal maxillectomy was planned) (Dent et al., 2019; MacLellan et al., 2018; Sivagurunathan et al., 2014; Wallin-Håkansson & Berggren, 2017). Owners had to sign a written informed consent to the surgical procedure. All the procedures were performed following institutional guidelines for animal welfare under the control of the National Ministry of Public Health.

After induction under general anaesthesia, dogs were clipped, aseptically prepared for surgery and moved to the operating theatre. They were positioned either in left or right lateral recumbency so that the affected side of the head would face up, and the head was slightly tilted to the opposite side in case of tumours extending intraorally towards the midline, to gain better intraoral visualisation. In case of a planned bilateral rostral maxillectomy, dogs were positioned in sternal recumbency. For the purposes of this study, a curative-intent surgical approach was planned based on CT measurements of the tumour to excise a minimum of 1 cm of macroscopically healthy soft tissue or bone around the tumour (Martano et al., 2018). Depending on the size and site of the primary tumour, maxillectomy was performed with an intraoral approach with or without commissurotomy. Soft tissues were dissected routinely bluntly and sharply with the use of Metzenbaum scissors, a blade and bipolar electrocautery to expose the planned osteotomy site and osteotomy was performed with an oscillating saw blade. After tumour resection and accurate lavage with saline solution, one to two 1 to 1.5 mm cerclage wires were placed to span the resulting defect. If the resulting defect did not extend significantly in the dorsoventral direction, a single wire was placed at the centre of the defect. However, if the defect was substantial in the dorsoventral direction or involved the zygomatic arch, two wires were used, positioned at the ventralmost and dorsalmost aspects of the defect to ensure full coverage. The wires were secured to holes drilled into the aboral and rostral (or left and right in case of bilateral rostral maxillectomy) bone remnants on the temporal, maxillary or incisive bone depending on the location of the osteotomies. The holes were manually drilled with an 18-gauge Illinois sternal/iliac needle, approximately 2 mm from the bone's cut edge, with careful attention to avoid penetrating the teeth roots. After passing through the corresponding hole, the wire was bent in a hook shape and the free edge was pressed against the bone. The wire(s) were manually shaped to reconstruct the normal face contours (Fig 1). Initially, a surgical polypropylene mesh was used to span the defect between the wires. A 10 × 15 cm or 15 × 15 cm mesh was folded in half and trimmed to fit the space between the wires. The mesh was then secured to them and the bony remnants with non-absorbable monofilament suture (polypropylene USP 3-0) (Fig 2). However, its use was gradually discontinued after it was observed that the wires alone provided sufficient support for the soft tissue, making it preferable to minimise the amount of foreign material. Soft tissues were then reconstructed routinely to cover the bone and the implant. Briefly, for an intraoral approach alone, the oral mucosa was sutured to the vestibular mucosa in a single layer using monofilament absorbable material (poliglecaprone 25). When combined with an extraoral approach, the subcutis and the skin were reconstructed in two separate layers with the same suture. If a commissurotomy was performed, reconstruction was done in three layers – mucosal, subcutaneous and cutaneous – using poliglecaprone 25.

After surgery, postoperative pain was assessed every 2 to 4 hours based on the Glasgow scale (Morton et al., 2005) and appropriate analgesia was provided depending on pain score. If the total pain score was below the established threshold for severe pain (6/24), analgesia was provided with buprenorphine (15 µg/kg IV every 8 hours). If the pain score was above the threshold, rescue analgesia was provided with methadone (0.2 mg/kg IV every 4 hours). A board-spectrum antibiotic (cefazolin 25 mg/kg) was administered intravenously perioperatively and postoperatively during hospitalisation. Meloxicam (0.2 to 0.1 mg/kg IV or orally every 24 hours) was also routinely administered during hospitalisation. Dogs were offered soft food at 3 to 4 hours after anaesthesia recovery and were kept hospitalised until able to drink and eat an amount of food sufficient to provide at least 70% of the resting energy requirement. An Elizabethan collar was used during hospitalisation, and the muzzle was clinically examined every 4 hours for signs of excessive oedema, bleeding, discharge or dehiscence. Postoperative care instructions included the use of an Elizabethan collar for the first 10 to 15 days to avoid self-trauma, a strict soft foods diet and avoidance of chewing toys for 15 days postoperatively. Non-steroidal anti-inflammatory drugs and antibiotics were given orally for 15 days after discharge and then discontinued in the absence of clinical signs of infection or inflammation.

Measure of outcomes

To assess the cosmetic outcome, a subjective evaluation was performed by the primary surgeon (F.M.) based on several key parameters, including facial symmetry, absence of noticeable concavity or asymmetry and overall alignment of facial features. The evaluation also considered the presence of any visible scars or deformities, as well as normal positioning of the eyes, lips and nose. In dogs where the defect involved the orbit, eye positioning and movement were specifically noted. These parameters were judged during routine postoperative rechecks at 2 weeks, with the cosmetic result considered satisfactory if the facial contour appeared normal and no significant aesthetic impairments were observed. Photographs taken before and after surgery were also reviewed to ensure consistency in the evaluation.

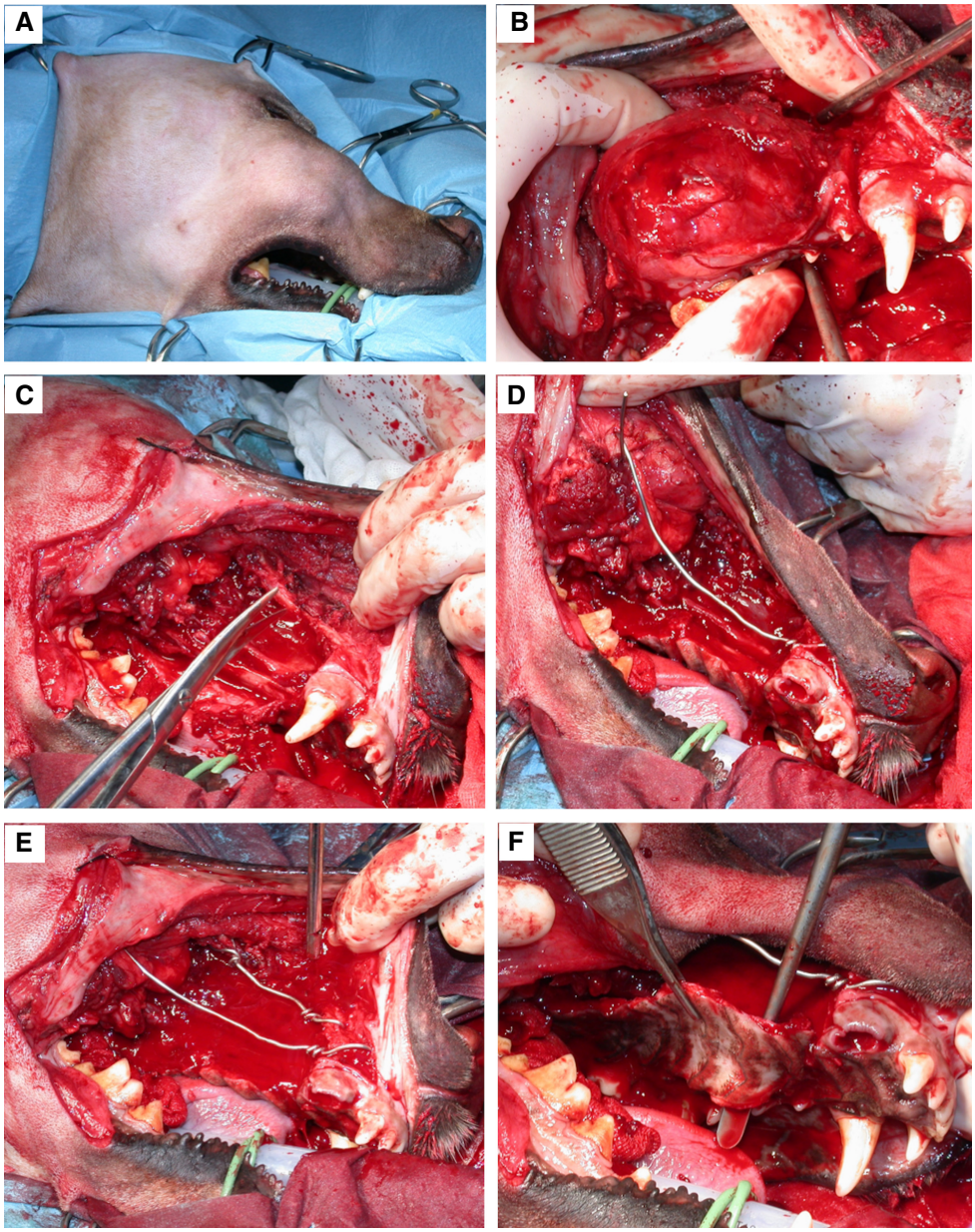

FIG 1. Intraoperative view of maxillectomy with orbitectomy and reconstruction in a dog: (A) the dog has been positioned in lateral recumbency and prepared for surgery; (B) a central-caudal maxillectomy with orbitectomy has been performed to remove the tumour. The resulting maxillary defect (C) has been reconstructed with two cerclage wires: The first wire is positioned ventrally to span the defect (D) and a second wire is used to reconstruct the maxilla and orbit dorsally (E). Finally, the soft tissues are closed with a bipedicle sliding flap of the palatine artery (F).

To assess the functional outcome the following variables were assessed during hospitalisation and at the rechecks: ability to eat and absence of pain; absence of sings of rhinitis (sneezing, nasal discharge); normal eye movements and visual function; absence of epiphora.

RESULTS

Study population

Twenty-five dogs underwent maxillectomy and reconstruction with cerclage wires alone or in combination with polypropylene meshes. There were ten (40%) mixed-breed dogs, two (8%) American Staffordshire terriers, two (8%) Jack Russel terriers and one each of Central Asian shepherd dogs, English setter, Scottish terrier, Labrador retriever, golden retriever, Maremma sheepdog, cocker spaniel, greyhound, Siberian husky, bull terrier and great Dane. Nine (36%) dogs were neutered females, eight (32%) were neutered males, six (24%) intact males and two (8%) intact females. The median body weight was 24 kg (range 6 to 57 kg) and the median age at presentation was 8.5 years (range 4 to 15 years). (Table 1). Tumours were confined to one side of the maxilla in 22dogs (92%), they extended beyond the midline of the palate in two dogs (8%). In eight dogs

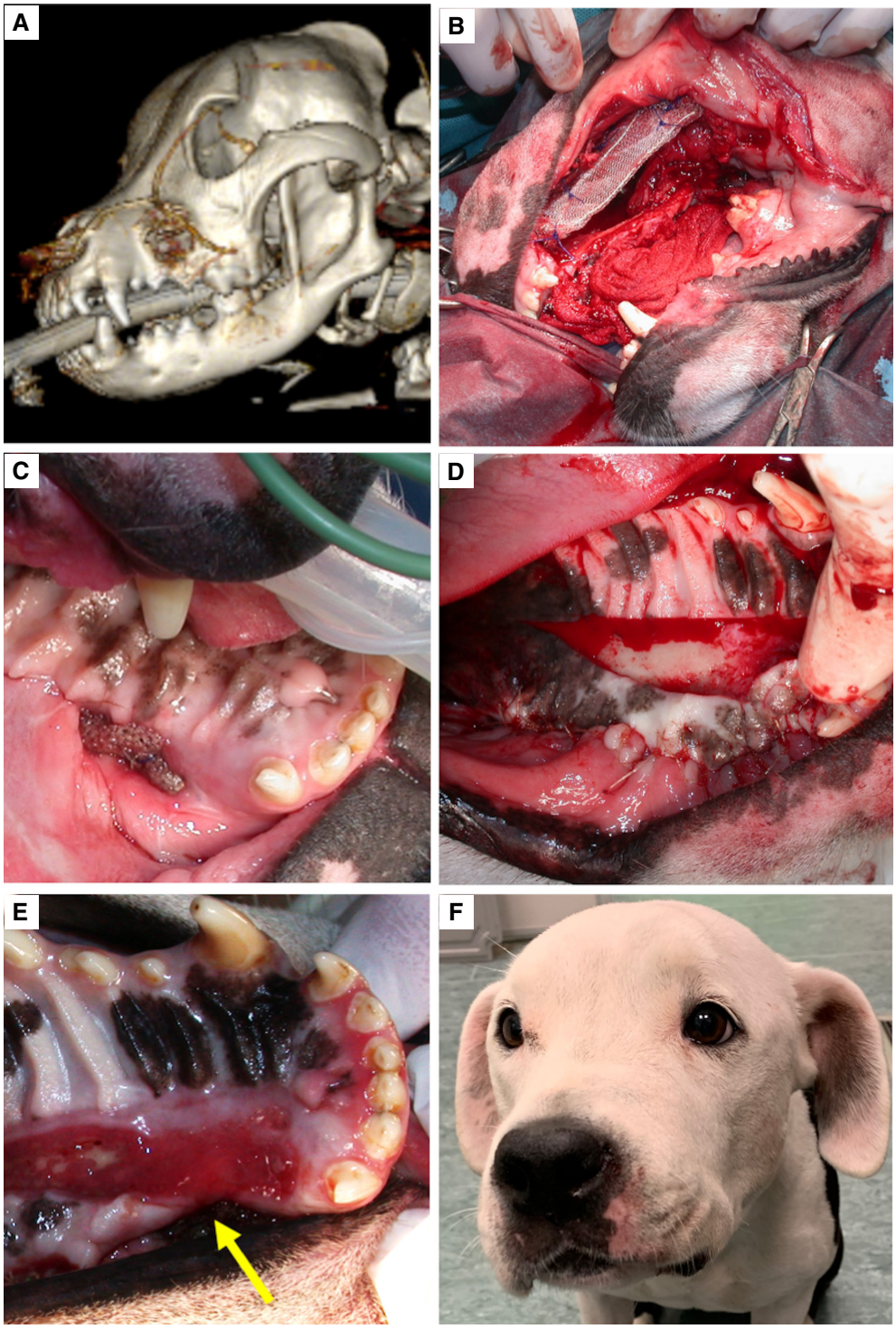

FIG 2. Mid-facial reconstruction with two cerclage wires and polypropylene mesh following central-caudal maxillectomy with orbitectomy in a dog: (A) three-dimensional reconstruction of the preoperative CT of the skull, showing a tumour involving the maxillary bone and extending from tooth 206 cranially to 208 caudally; (B) intraoperative view after maxillectomy with orbitectomy; the resulting defect has been reconstructed with two cerclage wires and a polypropylene mesh; (C) oronasal fistula with mesh exposure at 15 days; (D) the fistula has been corrected with a bipedicle sliding flap of the palatine artery; (E) at 50 days, a small fistula (yellow arrow) persisted; the fistula was revised with simple linear closure and healed uneventfully; (F) cosmetic result after complete healing.

(32%), the tumour extended to the ipsilateral orbit. None of the included cases exhibited invasion of the labial mucosa. The mean tumour size at the longest diameter was 4 cm (range 1 to 8 cm). At histopathology, tumour types were as follows: six oral fibrosarcoma (24%), six squamous cell carcinoma (24%), four undifferentiated sarcoma (16%), three osteosarcoma (12%), two

Table 1. Signalment data, type of maxillectomy and reconstruction, early (<48 hours) and late (>48 hours) surgical complications of the study population

Signalment	Maxillectomy extension (modified Triadan system)	N° wires (ø)	Mesh	Early complications	Late complications
Mixed breed, FN, 8 years	206 to 209	1 (1.5)	Yes	Oedema, rhinorrhagia	ONF at 15 days, surgically revised, then second intention healing of small asymptomatic fistula
American Staffordshire T., FN, 9 years	204 to 209 + orbitectomy	2 (1)	Yes	Oedema, rhinorrhagia	ONF at 15 days, healed after 2 surgical revisions at 30 and 50 days
Central Asian shepherd, MI, 4 years	106 to 109 + orbitectomy	2 (1.5)	Yes	Oedema, rhinorrhagia, pain	Small medial dehiscence at 15 days, second intention healing
Mixed breed, FN, 4 years	106 to 109	1 (1)	Yes	Oedema, pain	ONF at 15 days, healed after 3 surgical revisions at 15, 30, 45 days
English Setter, MN, 13 years	206 to 209 + orbitectomy	2 (1)	Yes	Oedema	-
Scottish terrier, MI, 13 years	106-109	1 (1)	Yes	Oedema	-
American Staffordshire T., FI, 6 years	206 to 209 + orbitectomy	1 (1)	Yes	Oedema, rhinorrhagia	-
Mixed breed, FN, 7 years	106 to 109	1 (1)	No	Oedema	-
Jack Russel terrier, MN, 12 years	106 to 109	1 (1)	No	Oedema	-
Labrador retriever, FN, 10 years	104 to 109 + orbitectomy	2 (1)	Yes	Oedema, rhinorrhagia	Small medial dehiscence at 15 days, second intention healing
Maremma sheepdog, MN, 8 years	204 to 207	1 (1.5)	No	Oedema	-
Mixed breed, MN, 5 years	106 to 109 + orbitectomy	2 (1)	No	Oedema, rhinorrhagia	Reverse sneezing, self-limiting
Mixed breed, MN, 11 years	204 to 207	1 (1)	No	Oedema	-
Mixed breed, FN, 9 years	104 to 109	1 (1)	Yes	Oedema	ONF at 15 days, healed after surgical revision. New fistulation at 3 months, heled after revision. At 9 months implant infection and mesh removal. Partially healed, owner refused further revision in absence of clinical signs
Cocker spaniel, MI, 15 years	201 to 204	1 (1)	No	Oedema	-
Greyhound, MN, 10 years	101 to 106	1 (1.5)	No	Oedema	-
Siberian husky, MN, 8 years	101 to 107	1 (1)	No	-	-
Mixed breed, FN, 6 years	204 to 210 + orbitectomy	2 (1.5)	No	Oedema, rhinorrhagia	Infection at 60 days, responsive to antibiothics
Mixed breed, MI, 6 years	104 to 110 + orbitectomy	2 (1.5)	No	Oedema, rhinorrhagia	-
Jack Russel terrier, MI, 1 year	204 to 210	2 (1.5)	No	Oedema	Reverse sneezing, self-limiting
Bull terrier, FI, 7 years	204 to 210	1 (1)	No	-	-
Mixed breed, MN, 10 years	204 to 210	2 (1)	No	Oedema	ORF at 15 days, healed after 2 surgical revisions at 25 and 35 days
Mixed breed, MN, 7 years	104 to 204	1 (1.2)	No	Rhinorrhagia	-
Golden retriever, FN, 12 years	104 to 204	1 (1.2)	No	Rhinorrhagia	-
Great Dane, FN, 11 years	203 to 209	2 (1.2)	No	-	-

FI Female intact, FN Female neutered, MI Male intact, MN Male neutered, ONF Oronasal fistula

ameloblastoma (8%), one melanotic melanoma (4%), one mast cell tumour with bone infiltration (4%), one extramedullary plasmacytoma (4%) and one multilobular osteosarcoma (4%). Surgical margins were tumour-free in 21 (84%) specimens and infiltrated in the remaining four (16%) cases. Excised regional lymph nodes were negative for metastases in 24 cases (96%), while the node excised for the mast cell was overtly metastatic (HN3).

Surgical technique

Maxillectomy type and orbitectomy were classified as previously reported (MacLellan et al., 2018; O'Brien et al., 1996). Fifteen dogs (60%) had a central unilateral maxillectomy, five dogs (20%) had a caudal unilateral maxillectomy, Three dogs (12%) had a rostral unilateral maxillectomy and two dogs (8%) had a rostral bilateral maxillectomy. A total of eight dogs (32%) received a ventral orbitectomy concurrently.

Configuration of the implant used to reconstruct the maxillary defect was as follows: one cerclage wire without polypropylene mesh in 10 dogs, one cerclage wire with polypropylene mesh in five dogs, two cerclage wires without mesh in six dog and two cerclage wires with polypropylene mesh in four dogs. Two cerclage wires were used in all eight dogs that received a ventral orbitectomy and in 2/11 dogs that had a caudal maxillectomy.

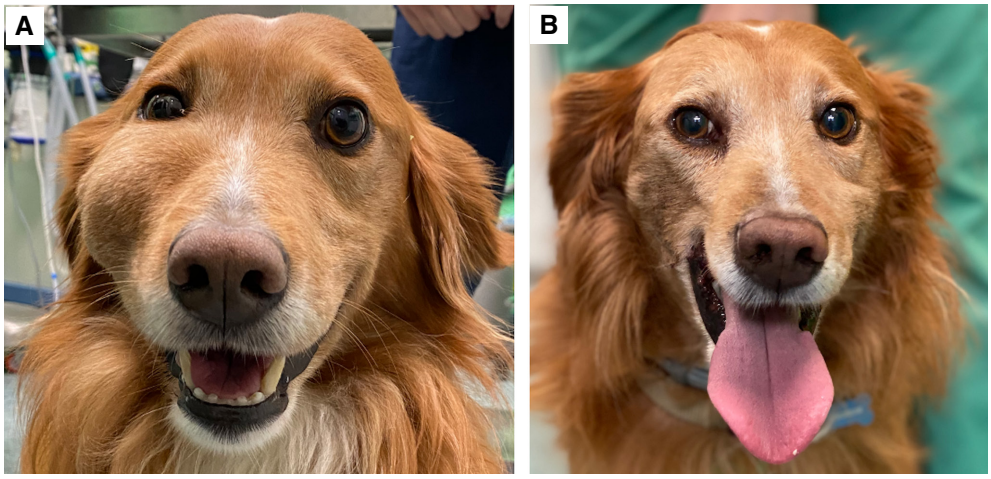

FIG 3. The aesthetic result of maxillary reconstruction with cerclage wires: (A) deformation of the left maxillary profile at presentation, due to a huge tumour of the caudal maxilla; (B) cosmetic result 2 weeks after tumour removal (central-caudal maxillectomy with orbitectomy) and reconstruction with two cerclage wires; despite a mild concavity of the left maxillary profile, the main facial ridges have been recreated with the wires to resemble the contralateral profiles.

A polypropylene mesh was used in a total of nine dogs (36%), the first to be treated with this technique. Initially, the mesh was intended to provide additional support for soft tissue healing. However, its use was gradually discontinued at our institution after it was observed that the wires alone were sufficient to maintain soft tissue stability, making the implantation of the mesh – additional foreign material – unnecessary. Implant configurations are detailed in Table 1.

Surgical outcomes

Median surgical time was 70 minutes (range 30 to 120 minutes). No intraoperative complications were recorded. Intraoperative blood loss was unremarkable in all animals with no hemodynamic changes occurring during the anaesthetic episode. Median hospitalisation time was 2 days (range 1 to 7 days). Surgical complications are detailed in Table 1. Twenty-two animals (88%) developed minor early postoperative complications. Oedema of the muzzle occurred in 20 cases (80%), with concurrent rhinorrhagia occurring in eight cases (32%) and concurrent pain in two cases (8%). Two dogs (8%) showed rhinorrhagia but did not developed oedema. Oedema was managed with intermittent application of cold packs for the first 24 hours. Rhinorrhagia was managed by placing sterile Q-tips into the nasal cavities for 2 to 3 hours. The swabs were inserted while the animal was awake, deep enough to stay in place but easily retrievable. This procedure was well tolerated in all cases. The oedema and rhinorrhagia solved within 72 hours in all animals. The two dogs that had pain concurrent to oedema received a caudal maxillectomy and caudal maxillectomy with orbitectomy, respectively. The pain was successfully managed in both cases with methadone 0.2 mg/kg IV q4 hours and both dogs were eating properly within 48 hours.

Ten dogs (40%) developed late postoperative complications. Minor late postoperative complications occurred in 5 dogs (20%), and consisted of small dehiscence of the intraoral suture at 15 days that healed spontaneously within 1 week in two cases (8%); reverse sneezing from day 5 to day 7 in two cases (8%); minimal purulent discharge at the caudal end of the intraoral suture at 60 days that responded to antibiotic therapy based on sensitivity test in one case (4%). Five dogs (20%) developed a major late postoperative complication, consisting of an intraoral fistula that was noted at the 15 days examination and was surgically revised. In three dogs (12%), the oronasal fistula healed completely within 2 months from surgery after two to three surgical revisions (Fig 2C). In one dog (4%), a small oronasal fistula persisted after the first revision although it was asymptomatic, and it was not further surgically treated. One dog (4%) required a second surgical revision at 90 days due to persistent oronasal fistula that was causing discomfort to the animal; at 9 months the polypropylene mesh was removed after diagnosis of a surgical site infection (based on bacteriological culture on samples taken during surgical revision) that was causing severe pain and dysphagia to the dog. After removal of the mesh, the dog improved clinically although a small oronasal fistula persisted. The owner refused further surgical correction, given the absence of clinical signs related to the fistula.

Follow-up

All dogs were eating properly within 48 hours postoperatively. Eye positioning and movements were normal in the eight dogs that received orbitectomy. All animals had regained normal facial appearance with acceptable symmetry at 2 weeks postoperative recheck, and the cosmetic outcome was subjectively judged satisfactory (Figs 2D and 3). Two of the dogs that received a caudal maxillectomy had mild lateral concavity of the face in the immediate postoperative period, although normal/symmetrical facial conformation was restored by 2 weeks. In another two dogs that had a caudal maxillectomy with orbitectomy, the cerclage wires were recontoured during a surgical revision for fistulation to enhance the cosmetic result. At the end of the study, 16 dogs were alive and free from disease after a median of 145 days (range 15 to 1095 days); one dog was lost to follow-up at 120 days and was free from disease at that time; seven dogs were euthanased

due to tumour progression (local recurrence $n = 5$; distant metastases $n = 2$) and one dog had died for tumour unrelated causes. The median time to tumour progression was 150 days (range 90 to 420 days) an the median follow-up time was 150 days (range 15 to 1095 days).

DISCUSSION

In the present case series, extensive facial defects resulting from maxillectomies, with or without orbitectomy, were reconstructed using cerclage wire alone or in association with polypropylene mesh in a cohort of dogs presented with oromaxillofacial cancer. While most cases had favourable cosmetic and functional outcomes, it is important to note that 16% of dogs did not achieve complete tumour removal, 20% developed oronasal fistulas and one case required mesh removal due to surgical infection. Despite these complications, the reconstructive technique that we described was effective in restoring facial appearance and functionality in the majority of cases. These outcomes highlight the challenges inherent in managing complex oromaxillofacial tumours, where both oncologic and reconstructive goals must be carefully balanced.

The fact that 84% of the dogs in the present study developed oedema of the muzzle in the early postoperative period is not unexpected, given that the same complication was reported in almost 40% of dogs receiving maxillectomy in a previous study, with a higher risk of developing oedema after caudal maxillectomies and/or orbitectomies (MacLellan et al., 2018). Mild to moderate swelling of the muzzle occurred also in the four dogs that underwent orbitectomy reconstruction with wires and mesh in Wallin-Håkansson's study (Wallin-Håkansson & Berggren, 2017). As in those previous studies, oedema of the muzzle was self-limiting in all cases and did not compromise the overall cosmetic and functional outcome of our patients. Eleven dogs had mild rhinorrhagia in the immediate postoperative; however, it was self-limiting and did not cause significant variations of the PCV. Only two dogs in the present study were painful in the immediate postoperative period and had difficulty eating. The difficulty eating was solved within 48 hours, with all included dogs being able to eat normally before discharge. Our results compare favourably with previous reports that suggested a higher hazard of these complications for caudal resections and orbitectomy (Wallin-Håkansson & Berggren, 2017) and suggest a good tolerability of the reconstructive technique. None of the nine dogs that received orbitectomy developed short-term epiphora or lacrimation. Epiphora and excessive lacrimation have been reported frequently after orbitectomy and traditional reconstruction (MacLellan et al., 2018; O'Brien et al., 1996; Sivagurunathan et al., 2014), but were not observed after reconstruction of the orbit with cerclage wires and polypropylene mesh, temporalis fascia flap or masseter muscle flap (Dent et al., 2019; Sivagurunathan et al., 2014; Wallin-Håkansson & Berggren, 2017) underscoring that ventral orbital stabilisation techniques can improve short-term functional outcome.

Oronasal fistula was observed in five dogs (20%) in this study, a rate comparable to previous literature. A recent study reported fistula formation in 11% of dogs following maxillectomy, with a higher risk associated with caudal maxillectomies (MacLellan et al., 2018). Another study found the incidence of incisional dehiscence and fistula formation after maxillectomy to be 26.1% (Cray et al., 2021). Notably, in these studies, reconstruction was performed using classical techniques without the use of implants. The surgical technique described in this study, which incorporates implant-based reconstruction, does not appear to reduce the risk of fistula formation compared to traditional methods. One possible contributing factor is the use of wires, which may have introduced additional tension at the surgical site, potentially affecting wound healing and increasing the likelihood of fistula formation. To determine whether this reconstruction technique reduces or increases the risk of fistula formation compared to traditional approaches, a case-control study directly comparing both methods would be necessary. Such a study should include stratification of cases based on the extent of the maxillectomy to account for its potential impact on outcomes. This analysis was beyond the scope of the present study but would be of interest for future research.

Infection was documented in two cases: in one case, it was responsive to antibiotics, while in the other, partial removal of the implant (mesh) was necessary. In all other cases, the implant was well tolerated. Our result is similar to a 7.5% to 8% surgical site infection rate previously reported after reconstruction without permanent implants (MacLellan et al., 2018; Rigby, Malott, Hetzel, & Soukup, 2021).

Good functional results can be achieved with the traditional reconstruction of the soft tissues without the use of implants to reconstruct the bony defect (Riggs et al., 2018; Sarowitz et al., 2017; Thomson et al., 2020). With traditional apposition of the soft tissue only, however, there is potential for functional deficits such as ventral globe displacement, especially if extensive caudal resection involving the orbit is performed (Wallin-Håkansson & Berggren, 2017). Moreover, the resulting facial deformity may be unacceptable for some owners, leading to the exclusion of their dogs from treatment. Hence, the use of the reconstructive technique reported here could be desirable in some cases to improve cosmetic results and reduce the risk of functional defects. Although in the present study no functional complications were reported, a direct comparison between the traditional reconstructive techniques and the technique described here is beyond the aim of the study. Further studies directly comparing the two techniques are needed to quantify the actual functional benefits of reconstruction with implanted materials.

The technique that we report is based on a previously described technique (Wallin-Håkansson & Berggren, 2017), consisting of the use of cerclage wire in combination with polypropylene mesh coated with collagen sheets. In that study, orbitectomy defects were successfully reconstructed in four dogs, and the technique allowed for good functional and cosmetic outcomes, with none of the dogs experiencing ventral globe displacement or significant aesthetic changes (Wallin-Håkansson & Berggren, 2017). Although in Wallin-Håkansson's paper the authors suggested the suitability

of the technique for the reconstruction of wider defects extending to the maxilla, no further studies have been previously produced to assess its feasibility and utility for maxillectomy reconstruction. The possibility to customise the implant case-by-case and the accessibility of the materials guided the decision to apply a similar technique in the present case series of dogs. In the present study, the technique was applied to reconstruct more extensive defects than what was previously reported, hence confirming the suitability of the technique for larger defects resulting from maxillectomies, and its adaptability to a multitude of defect configurations.

The technique that we describe differs from the original one (Wallin-Håkansson & Berggren, 2017) in that cerclage wires were used alone in most of the cases and collagen sheets were never used. Collagen sheets were used in the original technique to improve the biocompatibility of the implant, although the actual benefits of its use were not addressed in that study. Based on this lack of evidence collagen sheets were not used in the present case series. Future studies should systematically compare the incidence of surgical complications after reconstruction with or without coating the implant with collagen sheets. In our study, a polypropylene mesh was used only in the initial cases. The choice was observed based on the original technique described by Wallin-Håkansson and Berggren (2017). However, it was later observed that the mesh did not provide additional stability to the soft tissues. Consequently, we opted to use cerclage wires alone to minimise the amount of foreign material in the reconstruction, with the goal of potentially reducing the risk of infection and dehiscence. As this study did not include a direct comparison of complications and of cosmesis with and without mesh, future studies could further investigate whether the absence of mesh influences the outcome.

A potential drawback of this technique is its impact on animals who may require adjuvant radiation therapy. The presence of metal implants in the maxillary defect could interfere with radiation planning and may necessitate the removal of the implant before or after radiation treatment. This can complicate the treatment course and impact the overall clinical management. Therefore, careful patient selection is crucial when considering this technique, especially in cases where radiation therapy is a likely part of the treatment plan. This factor should be taken into account to avoid potential complications and ensure optimal patient outcomes.

The main limitations of the study are related to its retrospective nature and to the relatively small sample size. While a cohort of 25 dog is reasonable to describe the technique, it was not sufficient to allow for direct comparison of outcomes based on clinical variables such as tumour size and site, skull conformation and implant configuration. Additionally, a lack of a control group prevented an objective assessment of whether the use of mesh influenced complication rates or clinical outcomes. Future studies should consider a case-control design, with separate groups for reconstructions performed without implants, with cerclage wires only and with cerclage wires and mesh, to provide more robust data on its impact. Another limitation of this study is that the cosmetic and functional outcome were subjectively assessed; defining standardised and objective outcome measures in the frame of a prospective study would improve the assessment of this technique's efficacy. In conclusion, the technique we describe offers a potential option for cosmetic and functional reconstruction of extensive facial defects in dogs, utilising readily accessible materials such as cerclage wires and polypropylene mesh. While further studies, including controlled comparisons, are needed to fully assess its advantages and limitations, this technique may be considered for reconstruction following extensive maxillectomies with or without orbitectomy to help reduce facial deformity and functional complications in pet dogs.

Author contributions

F. Massari: Conceptualization (lead); data curation (supporting); investigation (equal); methodology (equal); writing – review and editing (equal). **L. E. Chiti:** Conceptualization (supporting); data curation (lead); formal analysis (lead); investigation (equal); methodology (equal); writing – original draft (lead). **D. Drudi:** Data curation (equal); investigation (equal); methodology (equal); writing – review and editing (equal).

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Conflict of interest

No conflicts of interest have been declared.

Data availability statement

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

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