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Dumon silicone stents can improve respiratory function in dogs with grade IV tracheal collapse: 12 cases (2019–2023)

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OBJECTIVE
To evaluate the efficacy, complications, and outcome of Dumon silicone stent placement for dogs with grade IV tracheal collapse.

ANIMALS
12 client-owned dogs.

CLINICAL PRESENTATION
Each dog was diagnosed with grade IV TC unresponsive to medical therapy and had severe obstructive respiratory failure.

RESULTS
12 dogs were included in the study. By the end of the study, 5 of 12 (41.7%) remained alive, while 7 of 12 (58.3%) dogs died. Survival times after stent placement ranged from 97 to 1,310 days (mean, 822.43 days; median, 810 days). Three of the 12 (25%) dogs died spontaneously, while 4 of 12 (33.3%) were euthanized. The cause of death was determined for 6 of 7 (85.7%) dogs and was TC related for 3 of 7 (50%). Causes of death related to TC were progressive airway collapse (2/3 [66.6%]) and incoercible cough (1/3 [33.4%]). Complications occurred in 9 of 12 (75%) cases and included granulation tissue growth (3/12 [25%]), incoercible cough (2/12 [16.7%]), stent migration (1/12 [8.3%]), and stent deformation (1/12 [8.3%]). Reduction of obstructive dyspnea and episodes of asphyxiation was achieved after Dumon silicone stent placement.

CLINICAL RELEVANCE
The placement of an intraluminal Dumon silicone stent was a successful salvage treatment for TC in dogs that did not respond to medical management. Disease progression is inevitable, but substantial improvement of respiratory function may be achieved for months to years.

Keywords: stents, dogs, tracheal collapse, endoscopy, minimally invasive procedures

Tracheal collapse (TC) is a common cause of respiratory difficulty and cough in older small and toy-breed dogs.[1,2] Endoscopy is considered the gold standard for diagnosis of TC, detecting concurrent diseases, and identifying the location, grade, and severity of TC.[3,4] According to the classification by Tangner and Hobson,[5] 4 degrees of gravity are distinguished by the reduction of the tracheal luminal diameter. The treatment of TC varies with the location and grade of collapse. The treatment of choice is conservative medical therapy that includes weight control, avoidance of neck leads, management of comorbidities, and use of various medications (antitussive agents, glucocorticoids, bronchodilators, antibiotics).[2,3,6,7] In patients refractory/unresponsive to medical treatment or with severe (grade IV) TC, surgical treatment or placement of an intraluminal stent should be attempted.[2,3,8] Common surgical options include using extraluminal ring prosthetics or endoluminal stents to reestablish airway patency.[2,8] Intratracheal stents can be distinguished into silicone and self-expanding metal stents.[9] Metal stents are associated with several side effects. Potential complications include migration, stent fracture, stent collapse, stent deformation, tracheal perforation, development of obstructive granulation tissue, and inflammatory and bacterial tracheitis.[2,3,9] In human medicine, the use of metal stents for benign

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airway disease is not recommended and managing airway obstruction involves the use of Dumon silicone stents.[10–12] However, Dumon silicone stents have complications, including migration, obstruction from accumulated secretions, and granulation tissue growth at the proximal or distal ends.[10] Numerous studies have evaluated the efficacy and complications of tracheal metallic stents in treating TC in dogs.[2,13–15] To the authors' knowledge, there are no similar studies in reference to Dumon silicone stents and only 1 study[16] concerning biocompatibility and applicability in normal canine trachea.

This study aimed to investigate the efficacy of Dumon silicone stent placement in dogs with grade IV TC. Additional objectives were the characterization of complications in a 6-month follow-up from stent placement.

Methods

Medical records were retrospectively reviewed of dogs diagnosed with grade IV TC and subjected to Dumon silicone stent placement by the Anicura Hospital I Portoni Rossi of Zola Predosa (Bologna, Italy) between January 2019 and January 2023. Inclusion criteria for stent placement consisted of a diagnosis of grade IV TC unresponsive to medical therapy and severe obstructive respiratory failure. Exclusion criteria for stent placement were severe laryngeal disease (grade III collapse, paralysis, epiglottic retroversion), severe cardiopathy (class B2 of Consensus American College of Veterinary Internal Medicine degenerative mitral disease), and organ failure (renal, hepatic). All cases included were subjected to clinical examination, hematology and serum biochemistry, radiographic study including a lateral projection of the neck and 2 orthogonal projections of the thorax, and endoscopic study of the upper airway tract.

Data reviewed from electronic medical records included patient signalment, clinical findings, endoscopic and radiographic findings, stent diameter, length and thickness, complications, and follow-up procedures. Patients were excluded from this study if their digital files were incomplete or lacked follow-up (absence of telephone contacts by owners or clinical checks) in the 6 months following stent placement. Complications were categorized as perioperative when they occurred during the stent application and postoperative when they occurred during the postoperative period.

Dumon stent

The Dumon silicone stent (Novatech) is a dedicated tracheobronchial stent used to treat various tracheal and bronchial obstructive diseases.[17] This prosthesis is made of polydimethylsiloxane (biocompatible silicone) and presents a serrated external surface with teeth protruding for intercalation and fixation in the lumen of the airways **(Figure 1)**. The stents have a highly polished inner surface that prevents adhesion of dense mucus, blood, or other materials from the respiratory tree and smooth extremities to prevent friction-related damage.[5,17] A complete prosthesis set includes several diameters and lengths.

Figure 1—The Dumon silicone stent presents a serrated external surface with teeth protruding for intercalation and fixation in the lumen of the airways.

Endoscopy, stent sizing, and placement

All endoscopic procedures were performed by the same investigator (DL). An endoscopy was performed before stent placement to confirm the diagnosis of TC, assess its extent, and identify abnormalities of the upper airway and bronchi. The patients were subjected to endoscopic study under general total IV anesthesia technique. The dogs were premedicated with 2 µg/kg dexmedetomidine and 0.2 mg/kg methadone IM, and anesthesia was induced with 4 mg/kg of propofol administered IV. Anesthesia was maintained with propofol administered in bolus, fentanyl administered in bolus of 2 µg/kg, or fentanyl in constant rate infusion at a dosage of 5 µg/kg/h. Patients were placed in sternal recumbency with the neck extended and support under the chin to ensure the trachea was as straight as possible. The examination of the larynx and cervical trachea was performed with a 2.7-mm, 18-cm, 30° oblique rigid endoscope (64018 BS; Karl Storz SE and Co KG). The intrathoracic trachea and bronchi examination was performed with a 5.2-mm, 85-cm flexible fiberscope (60001 VL2 Bronco-Fiberscope; Karl Storz SE and Co KG).

Stent sizing (length and diameter) was based on endoscopic findings. The appropriate length of

stent was determined by measuring the extent of the TC from its beginning to its end. To achieve this, a graduated scale on the operating tube of the flexible bronchoscope was utilized. For the diameter measurement, a comparative analysis was conducted between the diameter of a healthy tracheal segment and a known measuring element, such as a biopsy clamp with a predetermined width of 3 mm inserted into the working channel of the endoscope and kept in an open position. A stent 1 cm longer than the extent of the TC was chosen to include normal trachea 0.5 cm cranially and caudally as previously reported in humans.[18]

The placement was made after direct bronchoscopic visualization of the selected site. The stent had to be placed 0.5 cm away from the cricoid cartilage and bronchial bifurcation to prevent interfering with laryngeal function and air passage under the airway tract. The Dumon stent was introduced into the dedicated pusher (Tonn applicator; Novatech). When the size of the dogs did not allow for use of the Tonn applicator, the stent was grasped and placed with a long and thin bayonet clamp through the laryngeal adytum and under direct bronchoscopic visualization. Correct placement was verified with endoscopic visualization of the site. A transtracheal suture was placed through surgical cervical ventral access to ensure fixation of the stent on the tracheal surface. Transtracheal suture was placed in the cranial cervical tract of the trachea with a suture thread of Dafilon 3/0. After the stent's placement, the animals were evaluated with a radiographic study of the cervical-thoracic region of the trachea for evaluation of stent positioning **(Figure 2)**. This image was used as a reference for radiographic revisions performed during follow-up.

After the placement, medical therapy was performed to reduce inflammation, promote mucusciliary clearance, and suppress cough. Postoperative medications included anti-inflammatories like budesonide 0.5 mg (Aircort) via aerosol 3 times a day and prednicortone (Deltacortene) 0.5 mg/kg twice a day until the minimum effective dose was obtained, and an antitussive like butorphanol (Dolorex) PO 0.2 mg/kg twice a day if needed.

Follow-up

Follow-up information was collected from the owner for each dog by means of phone calls. Pet owners were contacted every 2 weeks for the first 3 months and then once a month for 6 months. On the basis of the clinical condition described by the owner, endoscopic and radiographic controls were decided. Collected information included the presence and severity of clinical signs, medications administered, complications, survival time, and cause of death when applicable.

Statistical analysis

Only descriptive statistics were provided. The results were expressed as mean and median for continuous variables, and number (percentage) for other variables.

Results

A review of the medical records revealed 12 dogs with grade IV TC that were subjected to the placement of intraluminal Dumon stent of the operative unit of Interventional Pulmonology of the Anicura Hospital I Portoni Rossi during the study period **(Table 1)**. Four dog breeds were represented. The most common was Yorkshire Terrier (41.7% [5/12]), Pomeranian (25% [3/12]), Poodle (25% [3/12]), and Maltese (8.3% [1/12]). Males (41.7% [5/12]) and females (58.3% [7/12]) ranged in age from 36 to 120 months (mean, 81 months; median, 80 months). Three (25% [3/12]) dogs had cervical TC, 1 (8.3% [1/12]) had thoracic TC, 5 (41.7% [5/12]) had cervical-thoracic TC, 1 (8.3% [1/12]) had cervical TC and bronchial collapse, and 2 (16.7% [2/12]) had cervical-thoracic TC and bronchial collapse.

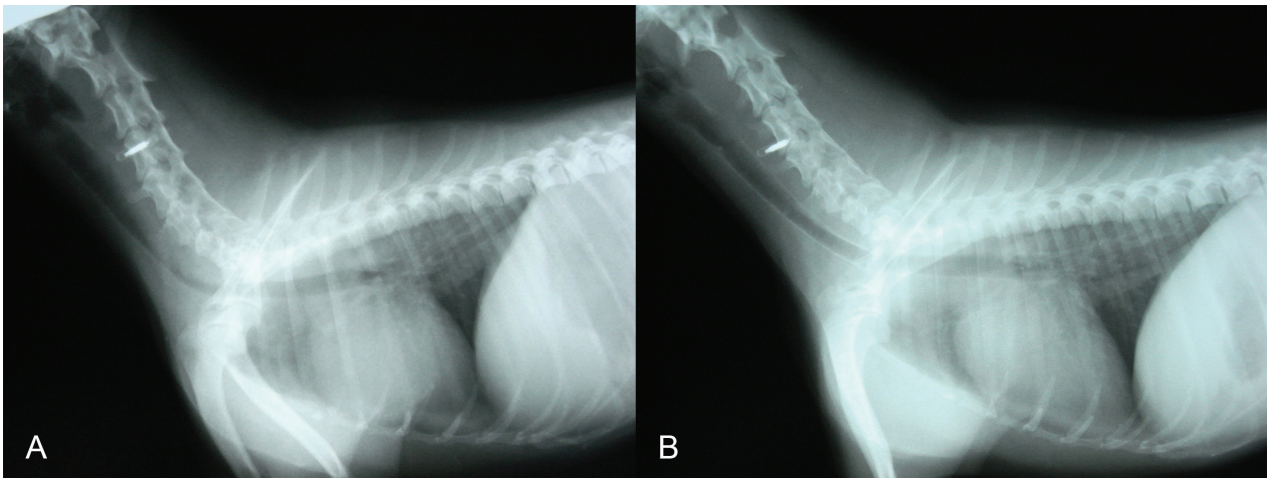

Figure 2—Lateral thoracic radiographic images of a dog with tracheal collapse (TC) before (A) and immediately after (B) endoluminal placement of a Dumon silicone stent. A—Lateral radiographic view showing cervical TC. B—Appropriate stent placement is confirmed.

Table 1—Characteristics (breed, sex, age, localization of collapse, stent characteristics, follow-up, and complications) of the 12 dogs included in the study.

Patient	Breed	Sex	Age (mo)	Localization of collapse	Diameter (mm), length (cm), thickness (mm)	Complications	Follow-up (d)
1	Yorkshire Terrier	M	72	C	10, 8, 1.5	Stent migration	1,275 (†)
2	Yorkshire Terrier	M	48	C + T	10, 8, 1.5	Stent deformation	745 (†e)
3	Poodle	F	120	C	9, 10, 1.5	Development of thoracic TC and bronchial collapse	1,110 (†)
4	Yorkshire Terrier	F	96	C + T + B	10, 8, 1.5	Development of laryngeal collapse and bronchial collapse	420 (†)
5	Pomeranian	M	84	C + T	11, 8, 1.5	Obstruction from granulation tissue growth	1,310 (†e)
6	Yorkshire Terrier	M	48	C + B	10, 8, 1.5	Paroxysmal cough	97 (†e)
7	Maltese	F	100	T	10, 8, 1.5	Paroxysmal cough	810 (†e)
8	Poodle	F	108	C + T + B	9, 8, 1.5	Obstruction from granulation tissue growth	650
9	Yorkshire Terrier	M	78	C + T	10, 10, 1.5		360
10	Pomeranian	M	100	C	11, 8, 1.5	Obstruction from granulation tissue growth	350
11	Pomeranian	M	36	C	10, 8, 1.5		280
12	Poodle	F	70	C + T	9, 10, 1.5		240

B = Bronchial collapse. C = Cervical tracheal collapse. F = Female. M = Male. T = Thoracic tracheal collapse. TC = Tracheal collapse. † = Spontaneous death. †e = Euthanized.

Stent

In 4 (33.3% [4/12]) patients, stents were placed only in the cervical trachea; of these, 3 (25% [3/12]) dogs had cervical TC, while 1 (8.3% [1/12]) had cervical TC and a bronchial collapse. In 1 (8.3% [1/12]) patient, a Dumon silicone stent was placed only in the thoracic trachea. In 7 (58.4% [7/12]) dogs, Dumon silicone stents were placed in the entire trachea; of these, 5 (41.7% [5/12]) patients had cervical and thoracic TC, while 2 (16.7% [2/12]) had cervical and thoracic TC and bronchial collapse.

Dumon silicone stents had a thickness of 1.5 mm, diameter ranging from 9 to 11 mm, and length ranging from 8 to 10 cm (Table 1). The most used stents were those with a diameter and length of 10 mm and 8 cm (50% [6/12]). Stents with a diameter and length of 11 mm and 8 cm (16.7% [2/12]), 9 mm and 10 cm (16% [2/12]), 10 mm and 10 cm (8.3% [1/12]), and 9 mm and 8 cm (83% [1/12]) were also used.

Complications

No perioperative complications occurred in patients (0% [0/12]). Postoperative complications occurred in 75% (9/12) of dogs (Table 1). In 50% (6/12) of cases, complications were associated with the procedure and included the development of obstructive granulation tissue (25% [3/12]), stent migration (8.3% [1/12]), stent deformation (8.3% [1/12]), and paroxysmal cough (16.7% [2/12]). Tracheal contact granulomas occurred at 350, 650, and 1,310 days after placement (mean, 770 days; median, 650 days) and were treated with laser surgery. Stent migration occurred 10 days after stent placement, and the issue was successfully resolved by repositioning the stent and applying an additional transtracheal suture 1 cm behind the original stitch. The deformed stent was replaced by a new one 400 days after the first stent placement. Paroxysmal cough occurred at 97 and 810 days after stent placement (mean, 453 days; median, 453 days). The mean time for complications associated to stent placement was 518 days (median, 400 days). Two (25%) dogs had complications related to the progression of the disease and not to the presence of the stent; these complications included the development of thoracic TC and bronchomalacia (8.3% [1/12]) that occurred 1,110 days after stent placement and development of laryngeal collapse and bronchomalacia (8.3% [1/12]) that occurred 410 days after stent placement. The mean time for complications not related to the presence of the stent was 760 days (median, 760 days). The remaining patients (25% [3/12]) did not have postoperative complications.

Follow-up

Follow-up times after stent placement for all 12 dogs included in the study ranged from 97 days (recorded minimum survival time) to 180 days (6 months). By the end of the study, 5 of 12 (41.7%) dogs were alive, while 7 of 12 (58.3%) were dead. The mean survival time for the 7 dogs that died was 822.43 days (median, 810 days). The minimum survival time recorded was 97 days, while the maximum survival time was 1,310 days (Table 1). Cause of death was determined for 85.7% (6/7) of dogs, and of these, 50% (3/6) were related to TC and 50% (3/6) were unrelated to TC. Four (33.3% [4/12]) dogs were euthanized after 97, 745, 810, and 1,310 days after stent placement. Euthanasia was performed due to incoercible cough (25% [1/4]), worsening of bronchial collapse (50% [2/4]), and hepatic carcinoma (25% [1/4]). Spontaneous deaths occurred in 25% (3/12) of cases; for these patients, death occurred at 410, 1,100, and 1,275 days after stent placement. The causes of death were, respectively, unknown, kidney failure, and bite trauma to the neck and chest. Patients alive (5/12) had a

good follow-up with an improvement in respiratory function perceived by owners. This improvement was observed by owners for 240, 280, 350, 360, and 650 days from stent placement.

Discussion

To our knowledge, this was the first tracheal stenting report investigating endoluminal silicone Dumon stent placement in dogs with grade IV TC. During the 3 years of the study, 12 dogs with grade IV TC were subjected to the placement of endoluminal Dumon silicone stents and included in the study.

Four breeds were represented in the included dogs, and Yorkshire Terrier accounted for 47.1% (5/12) and was the prevalent breed; these data were according to that reported in the literature.[2,19] Age at the time of stent placement ranged between 2 and 10 years, supporting previous evidence that this condition may manifest at any time with a variable rate of progression.[5] Involvement of the bronchial wall is termed bronchomalacia and is reported in 45% to 83% of dogs with TC.[3] Cervical TC presented alone (25% [3/12]) and in association to collapse of the thoracic trachea (50% [6/12]) and bronchi (25% [3/12]). Two (16.7% [2/12]) dogs were affected by diffuse malacia, cervical-thoracic TC, and bronchial collapse. Our information supports previous evidence that malacia can affect the trachea, bronchi, or both.[3] Cervical TC was present in 91.7% (11/12) of patients included in the study, supporting the authors' opinion that endoluminal stent placement is necessary when patients manifest obstructive dyspnea.

Endoluminal stents are medical devices for maintaining the patency of tubular organs.[20] Tracheal stenting can be performed using fluoroscopy, endoscopy, or digital radiography.[21] Self-expanding nitinol stents are often preferred because these devices can be placed quickly and noninvasively.[2,3,9] Previous and numerous studies described intraluminal stenting with metal stents under fluoroscopic guidance in dogs with terminal TC with evidence of numerous side effects and success rates ranging from 61% to 89%.[4,13] In human medicine, it is currently recommended to use Dumon silicone stents to manage malignant and benign airway obstruction in adults and children.[11,12] Indeed, metallic stents are associated with more side effects compared to silicone Dumon stents, including issues such as stent fracture, stent collapse, and tracheal perforation. Additionally, the metal meshes tend to become incorporated into the mucosa, making their removal impossible once they are positioned.[2,3,11,12] In humans, Dumon silicone stent placement is made after direct bronchoscopic visualization of the selected site; the insertion is usually achieved by pushing the stent off from a loader using a prosthesis pusher (Tonn applicator; Novatech).[17] In our study, the stent was placed under bronchoscopic guidance as previously described for humans, and rigid bronchoscopy and general anesthesia were needed.[17] When the small size of the dogs did not allow the use of the Tonn applicator, the stent was folded and placed with a long and thin bayonet clamp through the laryngeal adytum and under direct bronchoscopic visualization. Our work suggests that Dumon silicone stenting is a possible minimally invasive and easy technique in dogs with TC, as already evidenced in human medicine for airway stenosis.[22] Perioperative complications were not observed in any patients.

In the use of self-expanding metallic stents, an accurate measurement of the tracheal diameter and length is essential for selecting an appropriate stent size.[13] These stents are made of metal mesh that is reconstrainable and undergoes foreshortening. Foreshortening refers to the decrease in the length of the stent, which occurs as it expands to its maximum diameter.[23] The Dumon silicone stent is made of polydimethylsiloxane (biocompatible silicone) and does not present the characteristics described above.[17] Therefore, measurements for stent selection as previously described are not necessary.[21] In our work, measurements were estimated by endoscopic findings. A complete set of Dumon silicone stents includes several diameters and lengths.[17] This is important given the considerable variability of breeds in veterinary practice. Stent sizes for the 12 dogs included in our study ranged from 9 to 11 mm (diameter) and 8 to 10 cm (length), while all stents had a thickness of 1.5 mm. Reduced variability in the size of the stents is due to the predisposition of small and toy breeds to TC.[3]

Postoperative complications have been seen with the use of Dumon silicone stents for the treatment of malignant and benign airway obstruction in human medicine. Similar postoperative complications were seen in our series of dogs including stent migration, stent deformation, granulation tissue formation around the stent, and poor patient tolerance.[14,24,25] Migration is caused by inappropriate sizing or misplacement of the stent and can be life-threatening.[23] For the placement of a nitinol stent, the usual practice involves obtaining the maximal tracheal diameter from positive-pressure thoracic radiographs. It is crucial to make an accurate measurement of the tracheal lumen to determine the appropriate size for the prosthesis.[14,15] As previously reported, stent migration for self-expanding metallic stents in dogs occurred up to 37%.[2] Despite a less precise measurement in our study, the data showed that this complication occurred in 8.3% (only 1/12) of patients. This may be due to the reduced number of patients included in the study or the different characteristics of Dumon silicone stents compared to metallic ones. However, it is possible that a more accurate measurement of tracheal length and diameter could have resulted in a decreased rate of stent migration. Stent migration was resolved by repositioning the stent and applying a transtracheal suture. The significant advantage of Dumon silicone stents compared to metallic stents is the ability to easily reposition and remove using rigid grasping forceps.[10] Stent deformation occurred in 8.3% (1/12) of cases. The deformed stent was replaced with another Dumon silicone stent. This complication was not observed with metallic stents, which are more rigid and difficult to deform but can

break because of the continuous mechanical stimulation caused by coughing.[26] In our study, the development of exuberant granulation tissue occurred in 25% (3/12) of cases, predominantly at the stent ends **(Figure 3)**. Localization to the stent ends may have been in response to the edges of the stent in this area or to increased motion and friction between the mucosa and implant on-site. In similar studies, the prevalence of granulation tissue ingrowth was 50% and granulation tracheal tissue responded well to corticosteroid treatment.[9,26] In our case, we preferred to remove the newly formed tissue through endoscopy-guided laser surgery. Indeed, overgrowth tissue was obstructive and severely hampered respiratory function. The use of laser allowed for an immediate intervention at the time of diagnosis, whereas steroid therapy entails longer healing times. Progressive TC beyond the stent was a critical complication and the reason that dogs in the present study required euthanasia. A further cause for euthanasia was incoercible cough. Cough was an expected complication given the continued presence of a foreign object (stent) in the trachea. The cough was controlled by medical therapy. Additional complications have been noted with metallic stents in humans and dogs, including problems with placement and removal and stent fracture.[14,24] In our study and that of Xavier et al,[16] these complications were not registered with the use of silicone stents. Three of 12 (25%) dogs did not have postoperative complications. On the basis of these data, we can conclude that the Dumon silicone stent is associated with a lower rate of complications, which can be managed by medical therapy, repositioning, or laser surgery.

Survival rates in the study were like those previously reported for metallic stents.[2,26] Mean survival time in our series was 822.43 days. Euthanasia was performed in 4 (33.3% [4/12]) dogs. Only 1 dog subjected to euthanasia was associated with stent placement (incoercible cough). Euthanasia was performed in a mean of 740.5 days from stent placement. Spontaneous death was registered in 25% (3/12) of cases and associated with causes not correlated with disease or stent placement. Death occurred in a mean of 931.66 days from stent placement. The remaining 41.7% (5/12) of dogs were considered by owners to have a good outcome at follow-up 2 years from stent placement. As reported by the owners during phone calls, surviving dogs had an improved quality of life as indicated by an improvement in respiratory function, which was subsequently confirmed by the veterinarian during clinical checkup.

Our study had several limitations, including its retrospective nature. The dogs were not randomized, and there was a small dataset to examine. Six dogs were excluded for inadequate follow-up; for this reason, the cases included in the study were reduced. The data and measured outcomes were collected before the study started and, therefore, were not standardized. Finally, another potential confounding factor was that the results were compared with those of other studies, which differed in the characteristics of the population examined.

Nevertheless, we conclude that the Dumon silicone stent can be successfully used as a palliative treatment for dogs with terminal cervical TC and should be considered in patients not responsive to medical treatment. Dumon silicone stents, unlike stents in nitinol, seem to be appropriate since removal or replacement is always possible. Despite the presence of a stent, there will invariably be disease progression, but substantial improvement in respiratory function (reduction of obstructive dyspnea and episodes of asphyxiation) may be achieved for a medium-long period. Dumon silicone stents have efficacy for treating grade IV TC with approximately

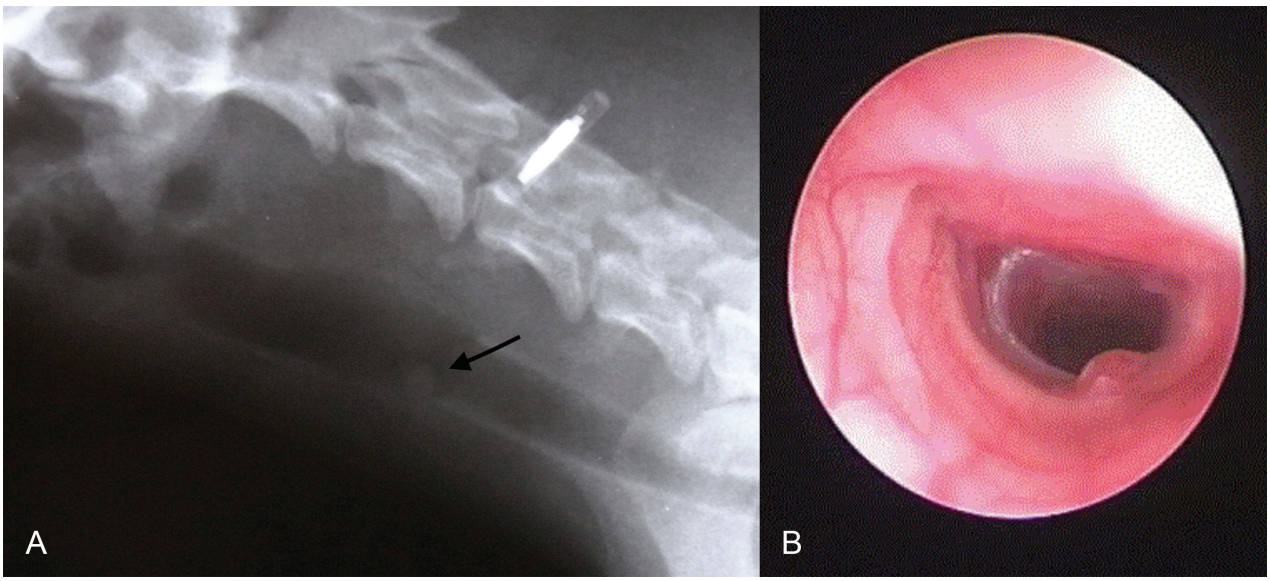

Figure 3—Development of exuberant granulation tissue. A—Lateral thoracic radiographic view of a dog with TC after placement of an endoluminal Dumon silicone stent. Notice the granulation tissue ingrowth at the stent ends. B—Bronchoscopic view of the granulation tissue ingrowth in a trachea of a dog after placement of an intraluminal Dumon silicone stent.

50% incidence of complication. Regular bronchoscopy follow-up should be conducted.

Our results suggest that using a Dumon silicone stent for grade IV TC is possible, effective, well tolerated by the patient, and associated with minimal and acceptable complications.

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