Use of CO_2 Laser as an Adjunctive Treatment for Caudal Stomatitis in a Cat

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Summary:

Lasers have become a popular tool in veterinary practice, particularly the carbon dioxide (CO_2) laser. In humans, the CO_2 laser is used most commonly in oral and maxillofacial soft tissue surgery due to its favorable interactions with oral soft tissues. Other types of lasers are better suited for use on hard tissues such as enamel and dentin. This article reviews the history of laser use, physics of laser-tissue interaction, delivery systems, and laser types used in dentistry and oral surgery. This is followed by a case report describing the use of CO_2 laser as an adjunctive treatment for therapy of refractory caudal stomatitis in a cat. ***J Vet Dent 24(4); @#$ - %&*, 2007***

History and Laser Physics

Lasers have been used in medicine since 1961, and basic research in laser dentistry began in 1964.[1] Laser is an acronym which stands for light amplification by stimulated emission of radiation.[2] In humans, lasers have been used to treat medical conditions for over 30-years, but their use in dentistry and oral surgery did not become mainstream until relatively recently.[3] Electromagnetic energy is created in the form of photons. Each photon is produced by excitation of a specific element or compound, and therefore each photon is of a characteristic wavelength. These photons can be manipulated to deliver electromagnetic energy to tissue with the intent of incision, excision, or ablation (gross removal of tissue in layers by vaporization).[4]

Tissue is affected by a variety of mechanisms, the most significant being photothermal effects. Photothermal tissue effects are a result of conversion of photons to thermal energy within tissue. This thermal energy in turn has effects on cellular components, including water, hemoglobin, and melanin. When tissue temperatures are below 60° C, thermal injury may occur without necrosis. When tissue temperature reaches 60-65° C, proteins are denatured and tissue necrosis occurs. When tissue temperature reaches 100° C, the water in the tissue turns to steam, resulting in explosive vaporization. When temperatures reach greater that 150° C, rapid protein breakdown results in a layer of carbonization commonly referred to as char. The char layer should be removed as it develops because it acts as a heat sink, resulting in further thermal damage to peripheral tissues.[4]

Delivery Systems

Dental lasers have emission wavelengths of 500 to 10,600-nm depending on the elements or molecules stimulated. Delivery systems can be divided into reflective surfaces or transmitting fibers. Reflective surfaces take the form of either a hollow wave guide (tube with an internal mirrored finish) or an articulating arm, both of which are used in a noncontact mode. Transmitting fibers are most commonly used in contact mode, where the tip of the fiberoptic cable actually touches the surgical site. Transmitting fibers have diameters ranging from 200 to 1000-µm. The type of excitation medium dictates the delivery system. CO_2 lasers utilize reflective surfaces, whereas diode and various YAG (yttrium-

Table 1

Lasers commonly used in dentistry and oral surgery.[7,11,18,23,25]

Type of laser	Wavelength (nm)	Delivery system	Soft tissue applications	Hard tissue applications	Target tissues	Contact vs. noncontact	Comments
Argon	488 and 514	Optical fiber	Pigmented soft tissue	Caries detection (transillumination), light-curing of dental materials containing camphoroquinone	488 nm: light cured dental materials 514 nm: pigmented tissue	Contact or noncontact	Excellent hemostasis; absorbed most significantly by hemoglobin
CO_2	10,600	Wave guide or mirrored articulating arm	Many (see Table 2)	May provide increased caries resistance by treatment of surface enamel and sealing of exposed dentinal tubules	Water	Noncontact	Lack of penetration prevents inadvertent damage to deeper structures (shallow zones of thermal necrosis); currently not able to be delivered through an endoscope channel
Diode	810-980	Optical fiber	Endoscopically guided biopsy, soft tissue ablation, gingiva	Poorly absorbed by tooth structure	Pigmented tissue	Contact or noncontact	Deeper penetration than CO2 or argon lasers, but not as deep as Nd:YAG; rapid heat increase may occur to peripheral tissue; compact design
Er: YAG	2940	Special air cooled optical fiber	Ablation of soft tissue; water spray should be turned off for better hemostasis	Caries removal and cavity preparation when coupled to water	Water, hydroxy-apatite	Noncontact	Increased water content of carious lesions causes preferential interaction with diseased tissue
Ho:YAG	2120	Optical fiber	Arthroscopy, discectomy; impractical for tissue incisions due to slow pulse rate	Poorly absorbed by tooth structure; acoustical energy allows for use in lithotripsy	Water	Contact	Limited hemostatic abilities due to little affinity for pigmented tissue; used for arthroscopic surgery of the temporomandibular joint in humans
Nd:YAG	1064	Optical fiber	Many, including periodontal debridement	Removal of pigmented carious lesions	Pigmented tissue > water	Contact or noncontact	First laser designed exclusively for human dentistry; penetrates deeply into oral soft tissues (> 3 mm)

Figure 1

Photograph showing various tips used with the CO_2 laser. The focal spot size increases from left to right (0.3, 0.4, 0.8, and 1.4-mm). As the focal spot size increases, the function of the tip changes from a cutting to a ablative mode.

Figure 2

Photograph showing special attachments for the CO_2 laser, including a backstop attachment for soft palate resection (A) and a scanning handpiece for tissue ablation (B).

aluminium-garnet) systems utilize transmitting fibers.[5] There are benefits and disadvantages to each of the delivery systems. Transmitting fibers are generally the least expensive delivery system. A main advantage of this type of delivery system is the ability to deliver the laser deep inside the patient by utilizing an endoscopic channel.[5] However, fibers can become cracked and damaged, reducing the ability to deliver the laser. Articulated arms are hinged, which provide some flexibility of movement, and are capable of good beam coherence with minimal power loss. These arms require care when handling as the internal mirrors may become clouded or misaligned with improper use. Hollow reflective wave guides provide more positional freedom than articulating arms when working in the oral cavity, but wave guides do not transfer power as efficiently as articulating arms. Replacement of wave guides does not require special expertise and can be done by the clinician. The replacement cost is less than that of an articulating arm.[5]

Regardless of the delivery system used, the focal spot describes the precise location where delivery of energy is the greatest, and knowledge of the focal spot distance should be utilized to provide the desired effect. When the handpiece is moved further from the tissue, the laser beam is defocused and becomes divergent. This defocused mode is utilized when the desired effect is superficial hemostasis or light ablation of superficial cell layers. The laser tip used also determines whether an incisional or ablation effect is obtained, with the wider tips being used for ablative functions and the narrow tips being used in an incisional function (Fig. 1).[6]

Common Laser Types in Dentistry and Oral Surgery

The first criterion for selecting a surgical laser is choosing a wavelength that is maximally absorbed by the components of the target tissue (Table 1).[7] The CO_2 laser is well absorbed by water, second only to the Erbium (Er) series of lasers. High absorption by water is desirable in oral surgery due to the high water content of the oral soft tissues. With a wavelength of 10,600-nm, the CO_2 laser is in the invisible, infrared, non-ionizing portion of the spectrum. Since the CO_2 laser is delivered in noncontact mode, the operator must become familiar with the lack of tactile sensation associated with this type of laser. The current delivery system somewhat limits the CO_2 laser's hard tissue applications, but some hard tissue research has shown favorable results in areas of caries prevention,[8] treatment of cervical root sensitivity,[9] and apicoectomy[10] due to its ability to seal dentinal tubules. One of the alluring qualities of the CO_2 laser is its lack of penetration beyond the tissue surface layer, which decreases the chance of inadvertent harm to deeper structures.[11] Some lasers are equipped with a rapid pulse mode (often referred to as superpulse) that provides a series of high energy pulses of microsecond duration, allowing the tissues to cool between pulses and minimizing collateral thermal damage. Various tips and handpieces are available to accommodate different uses. Handpiece extensions are available, including an extension with a backstop for soft palate resections (Fig. 2). In veterinary patients, the backstop accessory provides little benefit when performing soft palate resections due to the significant palate elongation of affected veterinary patients, resulting in bunching of tissue on the backstop. A scanning handpiece accessory is available which delivers an effective 3-mm spot size for rapid ablation of larger areas (Fig. 2).

The diode laser is a solid-state semiconductor laser that uses various elements to change electrical energy into light energy. Wavelengths for dental units range from 800 to 980-nm, placing these lasers in the near-infrared, invisible, non-ionizing portion of the spectrum. The laser is delivered through a fiberoptic cable and is usually used in contact mode. The diode wavelengths are very well absorbed by pigmented soft tissue, and this type of laser has been described as an excellent soft tissue surgical laser for use on gingiva and alveolar mucosa.[11] The diode wavelength is poorly absorbed by hard tissue, but because of rapid thermal increases when used in continuous mode, care should be exercised to prevent inadvertent damage to dental hard tissue. The main benefits of the diode laser are the portability of the units, price, and fiberoptic delivery to less accessible areas.[11]

Nd:YAG (Neodymium-doped Yttrium-Aluminium-Garnet) lasers have a solid medium consisting of a crystal of yttrium-aluminum-garnet and neodymium. This laser is delivered fiberoptically, and used most often in contact with tissues. It was the first laser designed specifically for dentistry. It has a wavelength of 1064-nm in the near-infrared, invisible, non-ionizing portion of the spectrum. It is highly absorbed by pigmented soft tissue and water. The laser is absorbed slightly by dental hard tissue, but there is little interaction with sound dental tissue. The Nd:YAG laser has been shown to be effective in periodontal debridement procedures and removal of pigmented carious lesions without removing healthy surrounding enamel and dentin. Ho:YAG (Holium:YAG) lasers are similar in many ways to Nd:YAG lasers, except in wavelength (2120-nm) and its absorption by water. The Ho:YAG laser's absorption by water is 100 times greater than that of Nd:YAG lasers, and it can therefore remove oral soft tissue more rapidly. Er:YAG (Erbium:YAG) lasers have a wavelength of 2940-nm which is the wavelength most readily absorbed by water. This particular wavelength is not easily transmitted, and fiberoptic bundles are costly and fragile.[5] Vaporization of water from within the crystalline structure of hydroxyapatite results in volume expansion and loss of mineral due to explosion. These lasers are utilized most commonly for caries removal and tooth preparation, relying on the increased water content of carious lesions. Healthy enamel surfaces can be treated to provide increased adhesion of restorative material. Er:YAG lasers can ablate soft tissue readily, but hemostatic ability is limited.[11]

Argon lasers have two emission wavelengths, both in the visible spectrum: 488- nm and 514-nm. The 488-nm wavelength is exactly the wavelength needed to activate camphoroquinone, the photoinitiator causing polymerization of resin in light-cured composite materials. Some studies have shown increased strength of laser-cured resin compared to visible light-cured resin.[12] The 514-nm wavelength has its peak absorption in red pigment. Therefore, tissues containing hemoglobin, hemosiderin, and

Figure 3

Oral photograph in a 5-year-old DSH cat with refractory caudal stomatitis.

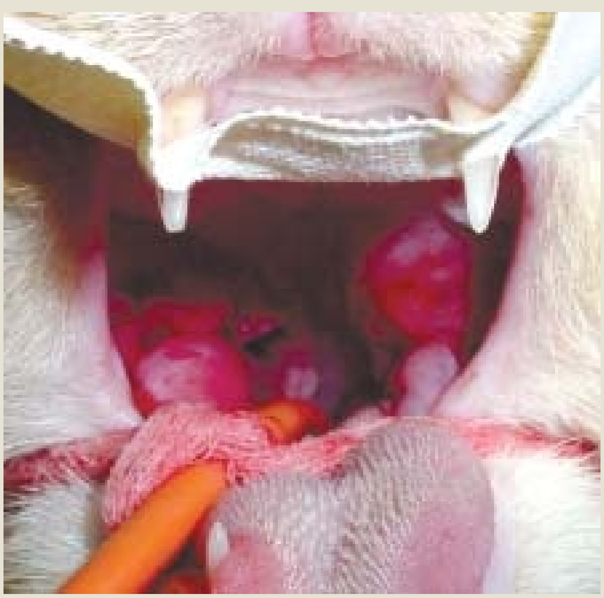
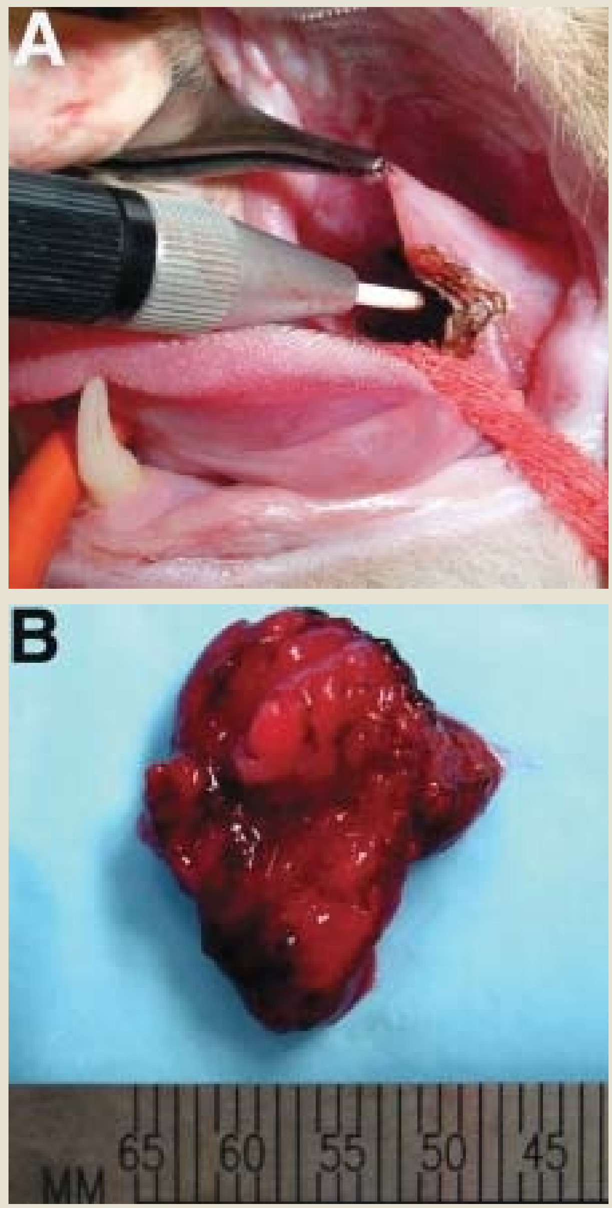


Figure 4

Oral photograph showing the CO_2 laser used in cutting mode (A) to excise proliferative tissue at the left palatoglossal fold in a 5-year-old DSH cat with refractory caudal stomatitis. The resected tissue is submitted for histopathological evaluation (B).



melanin readily interact with this laser, and its hemostatic capabilities are very good. The laser is typically used in contact mode, and it has been used for treatment of highly vascular lesions such as hemangioma in humans. Both wavelengths are not well absorbed by dental hard tissue or by water. The argon laser has been advocated for use in caries detection by transillumination of the affected tooth,[13] and tooth whitening[14].

Case Report

A five-year-old, male/castrated domestic shorthair cat presented for refractory caudal stomatitis (inflammation of the mucosa lateral to the palatoglossal folds[15]) which had not resolved after extraction of all premolar and molar teeth. These teeth were extracted by the referring veterinarian 3-months prior to referral. The cat was negative for serum ELISA tests of feline leukemia and feline immunodeficiency viruses, but it had previously tested strongly positive (1:64,000) for *Bartonella felis* via western blot. Treatment of the stomatitis with azithromycin[a] (10.0 mg/kg QD X 30-days) resulted in no improvement. Clinical signs included ptyalism, decreased appetite, and decreased water intake. Physical examination was unremarkable except for mild dehydration and oral disease. Oral examination revealed inflammation confined to the area lateral to and including the palatoglossal folds bilaterally. These areas were ulcerated and bleeding spontaneously and also had a proliferative component with excess tissue extending into the oropharynx (Fig. 3). All teeth were missing except for the maxillary and mandibular canine teeth. The gingiva and alveolar mucosa adjacent to the canine teeth appeared to be healthy with no clinical evidence of inflammation. A complete blood count and chemistry screen were performed and determined to be within normal limits.

The cat was placed under general anesthesia for a more thorough oral examination. Premedication included a combination of atropine[b] (0.02 mg/kg), midazolam[c] (0.25 mg/kg), hydromorphone[d] (0.1 mg/kg) and ketamine[e] (4.0 mg/kg) administered intramuscularly. A 22-gauge intravenous catheter was placed in the right cephalic vein, and induction was accomplished via slow intravenous bolus of propofol[f] (5.25 mg/kg) until adequate sedation was achieved to allow for placement of an endotracheal tube. Anesthesia was maintained using 0.5-2 % isoflurane[g] and oxygen in a low-flow, semi-closed circuit. An electrocardiograph (ECG) constantly monitored heart rate and rhythm. Heart rate, respiratory rate, and systolic blood pressures were recorded every 5-minutes. Temperature was monitored every 30-minutes, and warm water blankets and warm forced air units were used to maintain body temperature during the procedure. An isotonic balanced electrolyte[h] solution was administered intravenously throughout the procedure at a rate of 10 ml/kg/hr.

Dental radiographs were obtained to assess for the presence of root remnants. No root remnants were seen clinically or radiographically. The patient was placed in sternal recumbency with the upper jaw supported between two adjustable intravenous fluid poles with tape. After ensuring adequate seal of the endotracheal cuff, a moistened gauze was wrapped around the endotracheal tube to prevent the laser from contacting it. The laser was calibrated according to manufacturer's instructions. A smoke evacuator was placed near the patient's mouth. The operator and observers donned 0.1-µ laser surgical masks[i] designed for filtration of small particulate matter. An anti-inflammatory dose of dexamethasone sodium phosphate[j] was administered (0.1 mg/kg IV) preemptively to minimize oropharyngeal swelling. The CO_2 laser[k] was set to 6 watts in continuous mode delivered to a 0.8 mm ceramic tip used in focused (cutting) non-contact mode to resect the proliferative tissue of the caudal oral cavity. A portion of the resected tissue was submitted for histopathological examination, which revealed chronic-active, ulcerative, lymphoplasmacytic stomatitis with severe submucosal edema and inflammation (Fig. 4).

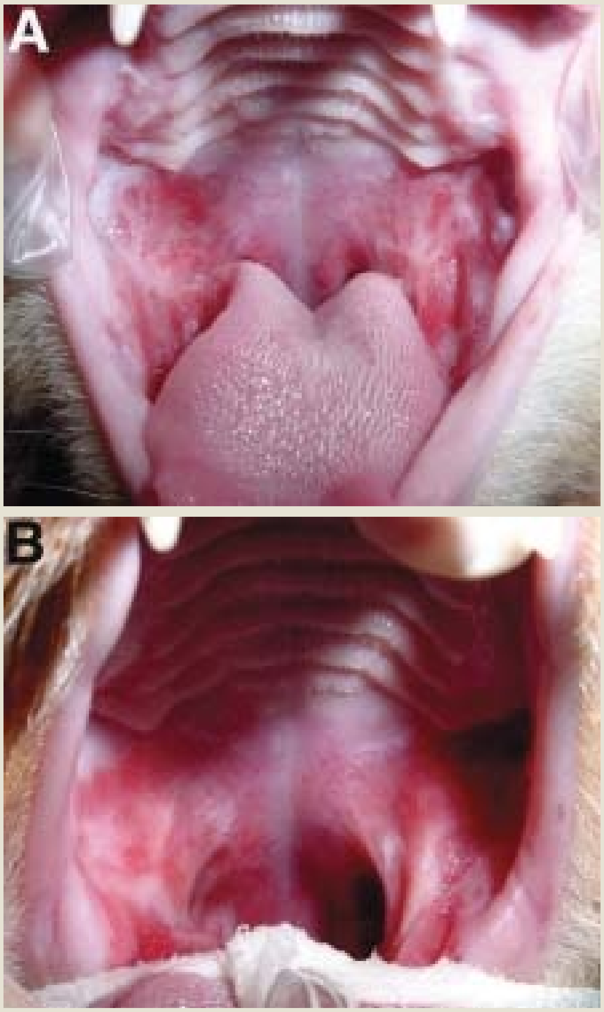
After gross removal of proliferative tissue, the wave guide was changed to accommodate a scanning handpiece[l] capable of efficient ablation of larger areas (Fig. 5). The scanning handpiece was used at a setting of 6 watts in continuous mode. The tissue at the base of the excised portions was ablated layer by layer with creation of a char layer and removal of char with saline-soaked cotton tipped applicators. This process was repeated approximately 20 times until all proliferative tissue was removed and the tissue showed a decreased tendency to bleed spontaneously. The gauze was removed from the throat and the mouth was inspected for signs of bleeding. The treated surfaces were sprayed with 2.0 mg of lidocaine[m] prior to extubation. Hydromorphone[d] (0.05 mg/kg) and acepromazine[n] (0.25 mg/kg) were administered intravenously just prior to extubation. Once the cat was normothermic, a fentanyl transdermal patch[o] (25 µg/hr) was

Figure 5

Oral photograph showing the CO_2 laser used for ablation of inflamed areas of the right caudal oral cavity in a 5-year-old DSH cat with refractory caudal stomatitis. A scanning handpiece attachment is used which rotates a 0.8-mm focal spot to create a 3-mm diameter of ablation.

Figure 6

Oral photographs showing the palatoglossal fold area in a 5-year-old DSH cat with refractory caudal stomatitis 1-month (A) and 2-months (B) following the initial laser treatment.



placed over a shaved portion of skin of the neck. The cat recovered from anesthesia without complication and was discharged the following day with directions for administration of oral clindamycin[p] (6.5 mg/kg BID X 14-days) and chlorhexidine gel[q] (1 inch applied to the tongue BID).

The cat did well at home for three days postoperatively, but it became painful as the fentanyl patch wore off, and appetite and water intake decreased. Oral examination showed that the areas previously treated by laser were markedly inflamed and dark red in color. The cat was hospitalized for application of a new fentanyl patch, intravenous fluid therapy and administration of injectable opiates (buprenorphine 0.01 mg/kg SQ TID-QID, PRN)[r] until the new patch was able to provide transdermal analgesia. The cat was discharged from the hospital on the following day with instructions for a 2-week postoperative examination, or sooner if problems arose. The cat was prescribed liquid prednisone[s] (0.7 mg/kg PO QD) daily until the next examination. Two-weeks later, the cat was presented for examination. Its appetite had been good since the previous visit, and the cat gained a small amount of weight (0.34 kg) since hospitalization. The previously treated areas in the mouth were pink with a new bed of granulation tissue.

The cat returned 1-month after the initial laser treatment for a second application of laser treatment. Oral examination showed a combination of granulation tissue and striations of fibrous tissue spanning the previously treated area with no signs of recurrence of proliferative tissue (Fig. 6). A similar protocol was used to place the cat under general anesthesia. The second laser treatment involved approximately 20 cycles of tissue ablation using the scanning handpiece at a setting of 6 watts in continuous mode as described previously. The cat was discharged from the hospital the same day after postoperative administration of hydromorphone[d] (0.05 mg/kg IM) and placement of a fentanyl transdermal patch. Clindamycin and prednisone were prescribed at the same doses previously administered. Oral examination performed 2-weeks later revealed significant erythema of the treated areas.

After an additional 2-weeks (2-months after the initial laser treatment), the cat presented for a recommended third laser treatment. The oral cavity appeared to be much improved, with an increase in the amount of fibrous tissue and interspersed areas of continued inflammation. The proliferative disease that was previously very significant showed no signs of recurrence (Fig. 6). The third treatment was identical to the second treatment, including multiple ablations but no resection of tissue. Postoperative medications prescribed were identical to those prescribed at the second laser treatment, except that the prednisone dose was decreased to every other day in an attempt to encourage more fibrosis of the treated sites. Three days later, the cat exhibited stertor suggestive of an upper respiratory infection and was admitted to the hospital for evaluation. Thoracic radiographs revealed no overt pathology. Subcutaneous fluids were given to address mild dehydration, and a new fentanyl transdermal patch was placed to provide continued comfort postoperatively. The cat continued to improve and was seen for reexaminations every few weeks to monitor the oral cavity and obtain body weight measurements. The treated areas were much improved with no recurrence of proliferative tissue, and weight gain continued.

However, moderate inflammation was present in the area of the palatoglossal folds 6-months after initiating treatment. At this time, inflammation was present around all four canine teeth and the ventral tongue surface (Fig. 7). The recommendation was made to extract the remaining teeth and perform another laser treatment of the caudal oral cavity. After preoperative blood tests were determined to be within normal limits, the cat was anesthetized using a protocol similar to those used previously. All four canine teeth were extracted in an open technique, and flaps were sutured using 5-0 poliglecaprone 25[t] in a simple interrupted pattern. Ablative laser treatment was performed in the area lateral to each palatoglossal fold using a technique similar to previous visits. The cat recovered well from anesthesia and was discharged the following day with a fentanyl transdermal patch and amoxicillin/clavulanate[u] (16.0 mg/kg PO

Figure 7

Oral photographs showing the caudal oral cavity (A) and sublingual area (B) in a 5-year-old DSH cat with refractory caudal stomatitis 6-months following initial laser treatment. Note the islands of intact epithelium, sublingual inflammation, and gingivitis and gingival recession present around the mandibular canine teeth.

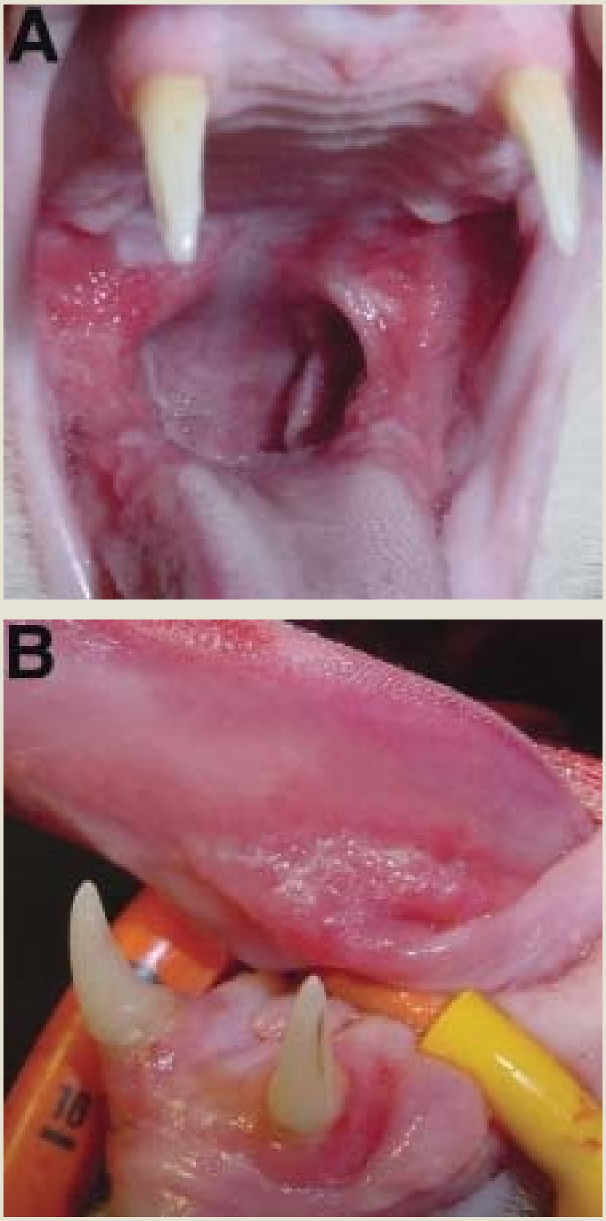


Figure 8

Oral photographs showing resolution of the gingival and sublingual inflammation in a 5-year-old DSH cat with refractory caudal stomatitis 2-months after extraction of the maxillary and mandibular canine teeth and 8-months after the initial laser treatment.

BID X 7-days). Oral prednisone was continued at a dose of 5.0 mg QD, and oral administration of chlorhexidine gel was continued as previously described.

Examination 2-months later (8-months after initial laser treatment) showed resolution of inflammation around extracted canine teeth and the ventral tongue surfaces (Fig. 8). Moderate inflammation was present of the areas lateral to the palatoglossal folds, but no recurrence of the proliferative tissue was seen. Examination 1-year after initiation of laser therapy showed almost complete resolution of all inflammation with no recurrence of proliferative tissue. The oral prednisone dose was decreased to 2.5 mg QD. The cat was monitored with monthly examinations, with the oral prednisone dose tapered slowly. Eighteen-months after initial laser treatment, no signs of inflammation or proliferation were present. The cat had gained an additional 0.2-kg and was eating well at home with no evidence of discomfort. Prednisone was discontinued at 20-months after beginning laser treatment, and no recurrence of inflammation was seen after discontinuation of either prednisone or chlorhexidine gel. Three-years after initial treatment, the cat remains free of inflammation without the need for medication (Fig. 9).

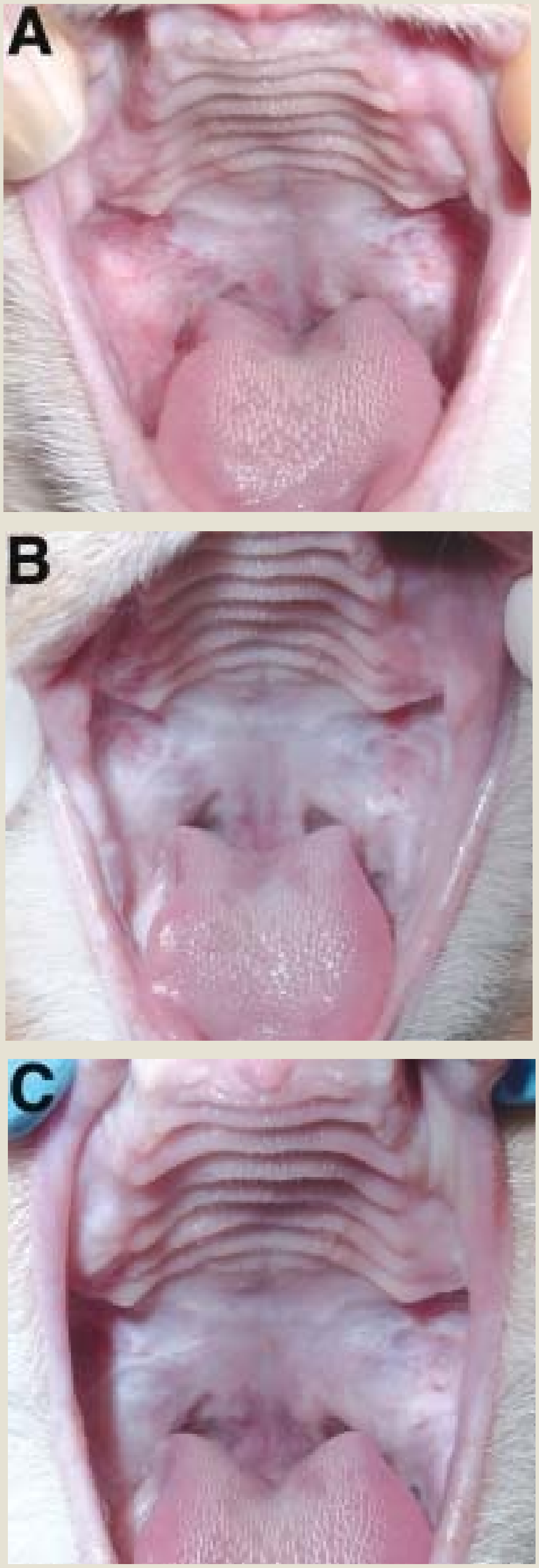
Discussion

Safety is of utmost importance when using medical lasers. Care must be used to avoid contact with eyes and skin of the patient and operators.[16] Appropriate warning signs should be placed on entrances of the operatory. Wavelength-specific eyewear must be worn by all personnel. Patient eye protection can be accomplished with saline soaked sponges or corneal eye shields. Surgical instruments with a matte or ebonized finish can minimize the chances of beam deflection and inadvertent ocular damage. Laser-safe endotracheal tubes should be considered when using deeply penetrating lasers for oral and respiratory surgery. Alcohol-based preparation solutions should be avoided due to their flammability. Laser plume has been shown to be capable of transmitting papillomavirus.[17] Therefore, a smoke evacuator and laser-specific facemasks are mandatory to prevent inhalation.

Previously documented uses of CO_2 lasers in veterinary oral surgery include gingivoplasty and gingivectomy, operculectomy, removal of oral masses, frenotomy, frenectomy and periodontal

Figure 9

Oral photographs showing resolution of the gingival and sublingual inflammation in a 5-year-old DSH cat with refractory caudal stomatitis 12 (A), 18 (B), and 36-months (C) after the initial after the initial laser treatment.



flap surgery;[18,19,20] treatment of eosinophilic ulcers;[30] treatment of stomatitis;[18,22-25] elongated soft palate resection;[26-28] partial maxillectomy, mandibulectomy and glossectomy;[29] and ranula marsupialization.[6] Table 2 contains an overview of previously documented uses and settings of CO_2 laser for common oral surgery procedures. Promising results were reported after Nd:YAG laser treatment of clinically visible and palpable resorption at the cervical portion of teeth in cats, however, lack of dental radiography at follow-up visits in this study precluded determination of radiographic progression of tooth resorption.[30] Effects of treatment on pulp vitality were not determined histologically in this study due to client reluctance.

Lasers, like electrocautery, cause thermal injury and therefore may result in pulpitis, when in contact with dental tissue, and delayed healing of soft tissue. Potential nerve injury and irreversible tissue damage in the pulp were reported with the use of Nd:YAG laser on feline teeth.[31,32] Thermal injury has also been shown to increase the likelihood of dehiscence of oral mucosa that will be sutured over a defect.[33] This deserves particular consideration if dehiscence of the surgical site results in serious consequences, such as postoperative development of an oronasal fistula. For this reason, the authors discourage the use of laser for creation of large mucosal flaps or for maxillectomy procedures, as other surgical techniques are faster and safer in accomplishing the treatment goals.

Treatment of feline stomatitis with CO_2 laser has been documented previously,[18, 22-25] but no case reports or case series are described in the veterinary literature. In the case report described here, the goals of laser treatment were: (1) removal of proliferative tissue to resolve self-induced trauma and entrapment of food and debris in tissue pockets; (2) stimulation of fibrosis to make the tissue less prone to continued inflammation and proliferation; and (3) reduction of opportunistic bacteria in abnormal tissue.

The proliferative component of the disease affecting this patient was well controlled with the use of laser in excisional and ablation modes. No recurrence of tissue proliferation occurred after initial removal. Mucosal proliferation was severe on initial presentation, mimicking a neoplastic process and warranting histopathological examination. *Bartonella* has been suggested to play a role in the development of feline stomatitis, and an increased incidence of stomatitis has been documented in *Bartonella* seropositive cats.[34,35] The highly positive *Bartonella* western blot test of the patient in this case report may suggest that the non-neoplastic proliferative oral lesion in this cat may have been associated with *Bartonella* infection. Proliferative vascular lesions of the oral cavity are seen in humans affected by bacillary angiomatosis, which is caused by *B. henselae* and/or *B. quintana*.[36] Tissue proliferation in humans can be so severe that it may mimic a neoplastic process.[37] Treatment of the patient in the current case report with azithromycin resulted in no improvement of clinical signs. However, evaluation of the western blot 3-years after presentation revealed a four-fold decrease in *Bartonella* titer. It is speculative whether or not resection of the proliferative oral tissue removed a possible focal environment for the microorganism.

Table 2

Recommended settings of CO_2 laser for oral procedures.*

Procedure	Watts (W) and cutting mode	Tip size	Comments
Gingivoplasty and gingivectomy	8-10 W superpulse[18]	0.25-0.4 mm cutting	Less efficient than scalpel blade, radiosurgery loop, or 12-fluted bur
	4-8 W continuous for shaping after blade gingivectomy[18]	0.8-1.4 mm ablating	
	4 W pulse[52]	0.3-0.4 mm ablating	Used for gingival contouring prior to crown preparation; potential for periodontal tissue damage
Soft palate resection	5-8 W continuous[29]	0.8 mm cutting	Consider intraoperative dexamethasone (0.1 mg/kg IV); suturing not recommended
	10-15 W continuous[25]		
Operculectomy	10 W continuous[18]	0.3 mm ablating	Consider lower power settings (4-6 W) and importance of retaining a collar of gingival connective tissue around the unerupted tooth
Feline stomatitis	2-6 W continuous[23]	0.8-1.4 mm ablating	Scanning handpiece provides most efficient delivery of laser for ablating large areas
	4-6 W continuous with scanning handpiece (current case report)	0.8 mm for cutting proliferative tissue, scanning hand-piece for ablation	
	10 W continuous or superpulse with scanning handpiece[25]	Scanning handpiece	
Oral biopsy	5-10 W continuous[18]	0.3 mm cutting	Thermal damage may prevent evaluation of histological tissue margins
Ranula marsupialization	6-10 W continuous[6]	0.4-0.8 mm cutting	Removal of salivary gland-duct complex may be necessary despite extensive resection of sublingual mucosa
Frenectomy and frenectomy	3-5 W continuous or 20 W pulse[18]	0.3 mm cutting or 1.4 mm ablation	A fine cutting tip is best for releasing a tight labial frenulum
Partial glossectomy	6-8 W continuous[29]	0.4 mm cutting or 0.8 mm cutting	Will not completely prevent bleeding; use higher settings (10-12 W) to improve hemostasis; larger vessels require ligation
Tonsillectomy	10-12 W[25]	0.8 mm cutting	Sutures not necessary

* The above wattage, tip size, and cutting modes are CO_2 laser specific.[k]

The second goal of laser treatment is stimulation of fibrosis. The lased areas in the patient reported here were allowed to heal by second intention to allow for as much fibrosis as possible. Corticosteroids were administered perioperatively to this patient to decrease swelling and inflammation. However, corticosteroids can decrease scar tissue formation at sites of second intention healing, so there are some questions as to whether they should be used when the goal of the procedure is stimulation of fibrosis. Laser type and setting also affect the degree of fibrosis. Pulsed dye lasers have shown long-term efficacy in treatment and removal of hypertrophic scars.[38] Concomitant use of intralesional corticosteroids after laser scar revision in people showed no further decreased sclerosis than those patients who received pulsed dye laser treatment only, suggesting that the type of laser used may affect the degree of post-treatment sclerosis more than steroid administration.[39]

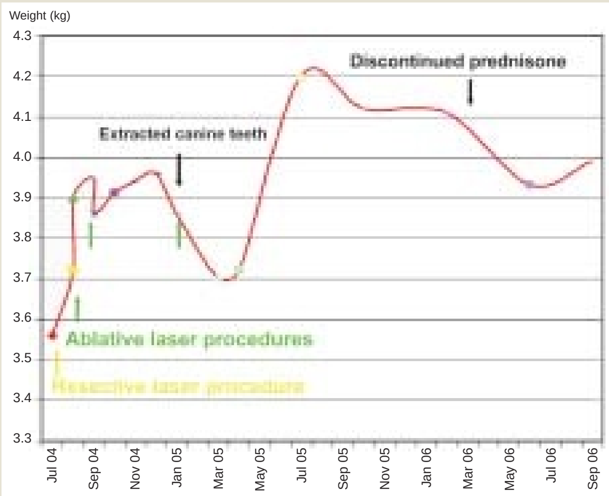
The bactericidal effects of laser light have been well documented *in vitro* and *ex vivo*, but few *in vivo* studies have been performed. An *in vitro* study of bovine teeth showed that the 980-nm diode laser can eliminate bacteria that have migrated deep into the dentin.[40] An *in vitro* study examined the effectiveness of four different lasers (diode, Nd:YAG, Er:YAG, and Er-Cr:YSGG) on sections of freshly extracted human premolar teeth. The samples were steam sterilized and subsequently inoculated with a suspension of either *Escherichia coli* or *Enterococcus faecalis*. After the incubation, the dentinal samples underwent "indirect" laser irradiation through the dentin from the bacteria-free side and were then subjected to quantitative microbiologic evaluation. Microbiology indicated that all laser systems were capable of significant reductions of *E. coli*, but only the diode and the Er:YAG lasers were capable of significant eradication of *E. faecalis*.[41] These studies demonstrate the ability of lasers to disinfect even the deeper layers of dentin which may prove to be a useful tool in canal sterilization during root canal therapy.

The bactericidal effect of lasers in treatment of periodontitis has also been studied. An *in vitro* study evaluated inhibitory effects of a superpulsed CO_2 laser at low energy density on periodontopathogenic bacteria and lipopolysaccharide (LPS) levels. The irradiation at low energy densities of 7.5 and 12.5 J/cm^2 killed more than 99.9 % of *Porphyromonas gingivalis*, and more than 99.0 % of *Actinobacillus actinomycetemcomitans*. LPS biological activity was significantly decreased by laser irradiation.[42] An *ex vivo* histological study compared root surfaces of periodontally diseased human premolar teeth treated with either curettage or Er:YAG laser. The root surfaces of the laser treated teeth exhibited more complete removal of bacterial flora.[43] However, a recent scanning electron microscopy study has shown that roughness of the root surface created by Er:YAG laser is greater than with hand instrumentation.[44] Diode laser has also been shown to provide bactericidal action in an *in vivo* rat wound model utilizing bioluminescent strains of *E. coli*.[45]

Although the use of laser has shown improved and more rapid return to postoperative function when compared to procedures performed with a scalpel blade,[46,47] a multimodal approach to postoperative pain management is imperative in cats with stomatitis that undergo aggressive removal of diseased tissue. Clients should be made aware that successful laser treatment requires aggressive tissue ablation and therefore good postoperative pain control. Local or regional anesthesia, preferably with longer lasting anesthetics such as 0.5 % bupivacaine, should be utilized in addition to systemic pain medication. The use of opiates (by means of transdermal patches and injectable or oral routes of administration) is essential in the surgical treatment of cats with stomatitis. Commonly used opiates for postoperative pain in cats include buprenorphine, hydromorphone and fentanyl transdermal patches. Buprenorphine has been shown to be absorbed readily through the oral mucosa in cats, but some anesthesiologists feel its use alone or with full agonists is questionable since it is a partial mu agonist.[48] To the authors' knowledge, the interaction between buprenorphine and fentanyl in patch formulation has not been

Figure 10

Chart showing the patient's weight monitored over time as an indicator of appetite. The initial resective and ablative laser treatment (yellow arrow) is noted along with subsequent ablative laser treatments (green arrows).



investigated in cats or dogs. Studies in mice confirm clinical experience that in the analgesic dose range a switch between buprenorphine and fentanyl is possible without loss of analgesic efficacy and without a refractory period between the termination of buprenorphine analgesia and the onset of action of the new mu-opioid treatment.[49] Absorption of fentanyl via transdermal patches has been studied in cats and appears to provide safe and effective analgesia.[50] Administration of medications, maintenance of hydration, and sustaining nutrition requirements during the postoperative period may warrant placement of an esophagostomy feeding tube, since aggressive treatment and second intention healing may result in a prolonged recuperative period. Postoperative feeding tubes are particularly important in cats with concurrent stomatitis and metabolic disturbances such as diabetes.

All inflammatory lesions of the patient in this case report eventually subsided. It is difficult to determine what role the laser treatment played in resolution of inflammation, especially after extraction of the remaining canine teeth performed at the fourth and last ablative laser treatment. Plaque retentive tooth surfaces may play a role in perpetuation of stomatitis even if the teeth are located relatively distant from the actual site of inflammation (*e.g.,* caudal stomatitis), and this may also imply that full-mouth extraction eventually provides a higher success rate than extraction of only premolar and molar teeth. Studies are necessary to determine if laser treatment provides a true benefit for the stomatitis patient. Determining the effectiveness of laser treatment is difficult due to the often required multimodal treatment approach. Patients are rarely treated by laser alone. Another difficulty in assessing effectiveness is the potential for the disease to wax and wane even without treatment. Patient weight is a helpful guideline during treatment which may serve as an indicator of comfort in the absence of overt signs of pain (Fig. 10).

Extraction has been documented to provide a beneficial effect in the majority of patients.[51] Empirical evidence of the cases treated by the authors of this article suggests that laser treatment is not a stand-alone modality and does not appear to be a replacement for near full-mouth or full-mouth extraction. However, laser treatment may be used as an adjunct in cats with refractory stomatitis that do not respond to extractions and post-extraction medical therapy.

Laser represents an exciting technology which provides an alternative to other surgical techniques for treatment of certain oral and dental diseases. The ablative capabilities of the laser, which allows for layer-by-layer removal of tissue, cannot be compared to any other surgical tool. Controlled studies are necessary to determine the effectiveness of CO_2 laser as it is currently used, and for development of future uses in dentistry and oral surgery.

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[a] Zithromax, Pfizer, New York, NY
[b] Atropine sulfate, Phoenix Pharmaceuticals, Inc., Belmont, CA
[c] Midazolam, Bedford Laboratories, Bedford, OH
[d] Dilaudid, Knoll Pharmaceuticals, Mt Olive, NJ
[e] Ketaset, Fort Dodge Animal Health, Fort Dodge, IA
[f] PropoFlo, Abbott Laboratories, Chicago, IL
[g] IsoFlo, Abbott Laboratories, Chicago, IL
[h] Normosol-R, Abbott Laboratories, Chicago, IL
[i] ViroSafe Surgical Mask, Buffalo Filter, Buffalo, NY
[j] Dexamethasone sodium phosphate, American Regent Laboratories, Shirley, NY
[k] NovaPulse CO_2 laser, Lumenis, Santa Clara, CA
[l] NovaScan spatial scanning handpiece, Lumenis, Santa Clara, CA
[m] Lidocaine HCl, 2%, Hospira, Lake Forest, IL
[n] PromAce, Fort Dodge Animal Health, Fort Dodge, IA
[o] Fentanyl transdermal patch, Sandoz, Broomfield, CO
[p] ClinTabs, Virbac, Fort Worth, TX
[q] CET chlorhexidine oral gel, Virbac, Fort Worth, TX
[r] Buprinorphine, Bedford Laboratories, Bedford, OH
[s] Prednisone suspension, Roxane Laboratories, Columbus, OH
[t] Monocryl, Ethicon, Somerville, NJ
[u] Clavamox, Pfizer, New York, NY

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