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RESEARCH ARTICLE

PROMISING VETERINARY ONCOLOGY: "DEVELOPMENT OF AN INNOVATIVE SELF-EXPANDING METALLIC COLONIC STENT SYSTEM FOR MINIMALLY INVASIVE TREATMENT OF CANINE AND FELINE'S COLON CANCER"

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ABSTRACT

Colon cancer, a disease similar to its human counterpart, also affects animals, including pets such as canines and felines. This malignant disease involves the uncontrolled growth of malignant cells in the tissues of the colon, a central section of the large intestine responsible for absorbing nutrients and water from digested food. The causative factors for colon cancer in animals remain complex and include genetic predisposition, dietary influences, inflammation, and possible environmental influences. Characteristic symptoms of colon cancer in animals include changes in bowel habits, hematochezia, weight loss, abdominal discomfort, decreased appetite, and lethargy. When colorectal cancer or related health problems are suspected in pets, timely veterinary intervention is essential. Timely diagnosis and appropriate medical treatment greatly improve the prognosis and management of the disease. This research article presents a new approach in the treatment of colon cancer. A self-expanding metallic colon stent system is presented, which consists of a nitinol alloy wire developed using the braiding technique. The stent has free wire ends to enhance stability and anchoring during expansion. This innovative approach strategically displaces tumors during expansion, improving colonic passage. While this study enhances our understanding of the commonalities of colon cancer in animals and humans, it highlights a breakthrough technique that holds promise for new therapeutic strategies. A critical evaluation performed in-house at laboratory scale to avoid significant risk to patient safety, stent integrity, and long-term durability has demonstrated the compressive strength of a self-expanding metallic colon stent system. This analysis has confirmed the mechanical strength of the system.

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INTRODUCTION

There have been significant advances in the treatment of colonic obstruction, a distressing and potentially life-threatening condition, with the use of self-expandable metallic colonic stents. Colon obstruction, characterized by blocked passage in the colon due to strictures, tumors, or other obstructive lesions, poses a significant challenge to patient well-being. In recent years, self-expandable metallic colonic stents have shown promise in removing these obstructions and restoring normal flow of luminal contents. This article discusses in detail the innovative self-expandable metallic colonic stent system, focusing on its application in veterinary medicine for the treatment of colonic obstruction in canines and felines. This stent is used in many breeds such as Boxers, English Springer, Spaniels, Doberman Pinschers, etc. A self-expandable metallic colonic stent system is designed to be inserted into the colonic lumen to achieve controlled expansion, effectively relieving obstruction.

A particularly noteworthy material used in the construction of these stents is nitinol, a unique nickel-titanium alloy. Nitinol has exceptional properties, including super elasticity and shape memory, allowing the stent to return to its original shape when heated. This transformative property, combined with its malleability at lower temperatures, makes nitinol an ideal candidate for colon stent creation. The introduction of the self-expandable metallic colonic stent system has introduced a breakthrough approach to the treatment of colonic obstruction in veterinary medicine. The system is specifically designed to treat colonic obstruction in canines and felines and offers different stent diameters to accommodate the anatomical differences between these species. With colonic diameters ranging from 2 to 3 cm, the stent offers 20 mm and 30 mm for cats and dogs, respectively. This not only demonstrates the adaptability of self-expandable metallic colon stents in different animal species, but also highlights their potential in treating complex and life-threatening diseases in veterinary medicine. Colonic obstruction in canines and felines can have a variety of causes, including benign and malignant

strictures and tumor-related and intrinsic obstruction. Obstruction of the colon, characterized by obstruction of fecal passage, requires timely intervention to avoid potential complications. High-risk patients, especially those with colorectal carcinoma or other malignancies, benefit significantly from the use of colonic stents to relieve obstructive symptoms. In addition, conditions such as gynecologic malignancies and diverticular disease can lead to extrinsic and intrinsic colonic obstruction, further emphasizing the importance of advanced treatment modalities. In the present research study, the use of a self-expandable metallic colonic stent system was shown to be a transformative strategy for the treatment of colonic obstruction in veterinary medicine. The innovative technology, driven by the unique properties and advances of nitinol, holds promise for improving patient outcomes and minimizing complications associated with colonic obstruction. Furthermore, the importance of crush recovery testing in this context cannot be overstated. Crush recovery testing plays a critical role in evaluating the performance and safety of these stent systems and ensuring that they can withstand the dynamic forces in the colonic environment. This article aims to provide a comprehensive overview of this evolving field, highlighting the current state of research and its potential impact on clinical practice.

MATERIALS AND METHOD

Development of the Braided Net: The "self-expanding metallic colon stent system" was developed using the braiding technique, as shown in Figure.01. A stainless steel mandrel (*M.M.Technocraft, India*) with a length of 300 mm was used to braid a 200-micron nitinol wire (*Fort Wayne, China*) with a 72-beam braiding machine (*B&B Machine, Ahmadabad, India*). This braided mesh forms an integral structural support for maintaining openness within the colonic lumen. The nitinol wire is braided in a zigzag pattern that gives the devices the desired shape. The braiding process begins by winding the nitinol wire onto spools or carriers, which are then inserted into a special braiding machine programmed with a specific pattern. Computer-controlled needles precisely execute the braiding pattern. In this study, uncovered types of self-expanding metallic colonic stent systems with diameters of 22 mm, 25 mm, and 26 mm and lengths of 60 mm.

(A) Carriers are affixed to a braiding machine

(B) The fibers are transformed into yarn, which serves as a medium for the subsequent braiding process.

Figure. 01. 72 Carrier Braiding Machine

Thermo-fixation Process: The thermo fixation process also known as a heat-setting process for nitinol wire is a crucial step in shaping the wire into the desired shape and achieving the desired properties. Nitinol is a shape memory alloy composed of nickel and titanium, and due to its unique properties, it is able to return to a predetermined shape when a certain temperature change occurs. The heat-setting process involves several steps that are essential for achieving the desired shape and properties of the wire.

Wrapping the Mandrel: The process began by carefully wrapping the nitinol wire around a mandrel that served as a template for the desired shape of the wire. This step ensures that the wire takes the desired shape during the subsequent curing process.

Precise Temperature Application: The wrapped nitinol wire is then carefully placed in a controlled heating environment, usually an oven. The temperature to which the wire is heated is critical because it determines the shape and properties that the wire will take. The temperature is usually in the range of 450 to 550 °C.

Indicative Color Change: An interesting phenomenon was observed during the heat-setting process is the alteration of the nitinol wire color. Initially, it appears a silver hue, but as it underwent the heat treatment, it transitioned to blue hue, (refer to Figure.02). This color change was an indicator of the phase transformation occurred in the material.

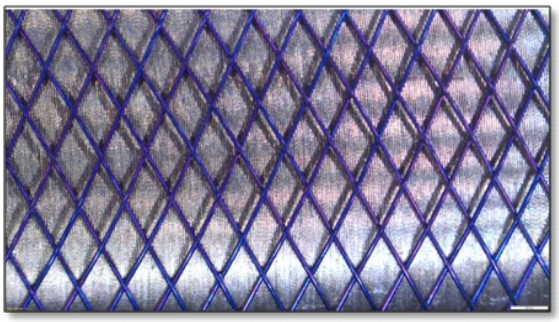


Figure 02. Transition of Nitinol Wire Color: Silver to Blue

Quenching in Water: After the wire has been exposed to the specified temperature and duration, a rapid quenching process in water followed. In this critical step wire is rapidly cooled, thereby effectively "locking" the desired shape and properties into the nitinol alloy's structure.

Shape Setting: Subsequent to the quenching process, the wire was carefully removed from the mandrel. The heat-setting process, including the heating, holding, and quenching steps, had successfully given the desired shape and properties to the wire. The wire was now cured to the desired shape and ready to exhibit shape memory behavior in response to temperature changes. The resulting material is shown in Figure.03.

Figure 03. A Self-Expandable Metallic Colonic Stent With a Free Wire End

Manual Cutting: Cutting the braid was a manual process in which a braided wire mesh was precisely cut with a sharp cutting tool. In this procedure, the wires were brought together and their alignment was ensured before they were precisely cut at the desired locations. The length of the specimen was accurately measured before cutting. After precise cutting, all loose ends were carefully trimmed to achieve a clean and finished result.

Pre-Cleaning Process: Pre-cleaning, an essential process for the braided nitinol stents, involved the removal of foreign bodies. The procedure began with the application of isopropyl alcohol (*Sigma, Aldrich, U.S.A*) or ethanol to the surface of the stent. The stent was then thoroughly rinsed with a water spray. Compressed air was then applied to the stent to accelerate the drying process to ensure that it was ready for further processing.

Procedure for Inserting the Stent: The procedure begins with insertion of the stent into the braided tubing (*Majik Medical, India*), as shown in Figure.04. The tubing is then connected to the handle. Once the stent is securely positioned in the tubing, the tubing is carefully advanced toward the proximal end of the catheter. This deliberate movement ensures that the stent is precisely loaded into the tube, ready for insertion. In the handle, the roller is rotated counterclockwise to facilitate partial insertion of the stent into the catheter, as shown in Figure.05. The stent can be gently withdrawn as needed. This procedure exposes the loading process of the stent and improves visibility and control throughout the procedure. Upon completion of full loading, as shown in Figure.06, this step completes the loading process and ensures that the braided stent is fully prepared for deployment. At this point, the stent is optimally positioned in the catheter and has reached its intended location in the colon.

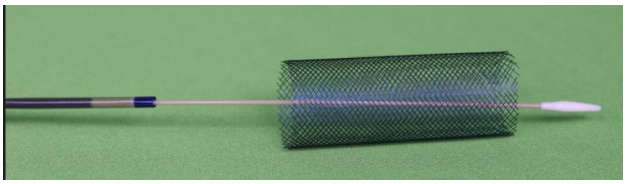


Figure 04. Initial Positioning of the Stent

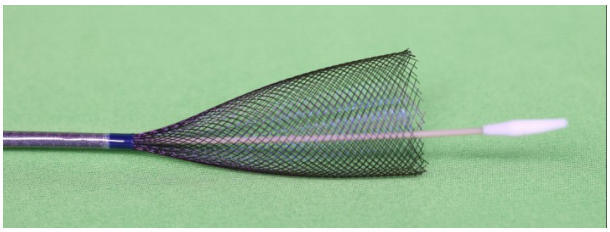


Figure 05. Stent Partially Inserted

Figure 06. Stent Fully Inserted

Facilitation or Access for Implantation of the Colonic Stent through a Delivery Mechanism: The implantation procedure for the "self-expanding metallic colon stent system" ensures precise placement and deployment of the braided stent at the intended site. The stent is inserted through the rectum via a delivery system shown in Figure.07, using a 10Fr delivery system. To achieve accurate delivery, the "over the wire (OTW) technique" is used. This process involves a series of procedural steps:

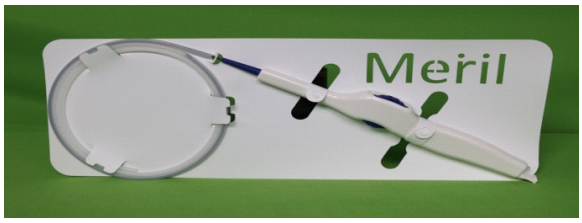


Figure 07. The Complete Setup of the Insertion System

First, a guide wire is inserted into the desired target site, which serves as both a pathway and a reference point for subsequent insertion of the braided stent system. Guide wire insertion is guided by fluoroscopy, a real-time imaging technique using X-rays. This technique allows precise visualization of the guide wire's movement and positioning in the colon. Once the guide wire is accurately positioned, it is carefully guided and positioned to the desired location using fluoroscopy to ensure accurate placement in the colon. The braided stent system is then inserted over the precisely positioned guide wire. The design of the braided stent allows for self-expansion after insertion. Further advancement involves maneuvering a sheath containing the braided stent over the guide wire. The sheath is carefully moved until the braided stent reaches the intended target site in the colon. In summary, this delivery procedure ensures precise placement of the self-expanding metallic colon stent system by using a guide wire, fluoroscopic guide, and self-expanding metallic colon stent system. The end result is precise placement of the stent at the indicated site in the colon, which is facilitated by the over-the-wire technique using a 10-Fr delivery system.

Implant Insertion Procedure: The implant delivery procedure serves the purpose of precisely delivering the stent to the specific location in the colon where it is needed. This system usually consists of a catheter, a guide wire, and a pusher (also known as a roller). The "self-expanding metallic colon stent system" uses an exceptionally effective roller mechanism to achieve accurate placement. This system consists of a 10Fr introducer catheter (*Majik Medical, India*), a tantalum marker on the tube (*Heraeus Group, Germany*) and a 0.025” Over the Wire (OTW) guide wire. These components work together to ensure precise and controlled positioning of the braided stent. During the procedure, the polyetheretherketone tube (PEEK) (*Zeus Industrial Products, Inc, United States*) allows for controlled and consistent thrust, delivering the braided stent to the exact intended location for effective treatment. The PEEK tube is designed to securely hold the braided stent throughout the delivery process, preventing premature deployment. For visualization and accurate placement, the system is equipped with a radiopaque platinum marker ring on the braided tube. These markers are strategically positioned to provide clear and reliable radiographic guidance. This allows healthcare professionals to closely monitor the placement of the stent in the colon. The markers greatly enhance the visibility of the stent during fluoroscopy, ensuring precise alignment and placement. The guide wire is made of stainless steel and is critical for minimally invasive treatments. The "self-expanding metallic colon stent system" uses a 0.025” Over the Wire (OTW) compatible guide wire. This guide wire acts as a reliable pathway that guides the delivery catheter and stent through the target vessels with ease and precision. Its compatibility with the OTW system simplifies the procedure and ensures a smooth and controlled delivery process.

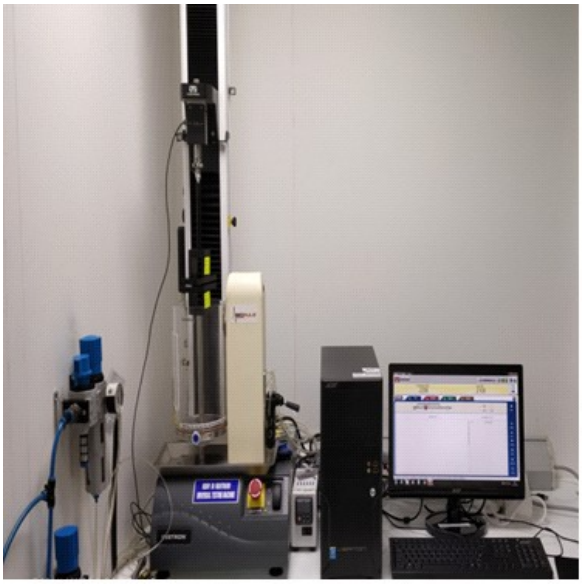
RESULTS AND DISCUSSION

Assessment of Crush Resistance: The study aims to assess the crush resistance property of a Self-Expandable Metallic Colonic Stent. Crush resistance refers to the ability of the stent to withstand external pressure or compression without collapsing.

Test Setup: The researchers used a Universal Testing Machine *(Istron, Egypt)* shown in the Figure.08 designed to test the crush resistance of the aforementioned stent system. This machine was likely designed to simulate the conditions that the stent might be subjected to when implanted in the body.

Test Parameters: The machine was programmed with specific parameters for the testing process:

Test Speed: The stent sample was 50% compressed at a constant speed of 5.00 millimeters per minute (mm/min). This controlled speed ensures consistent and reproducible testing conditions.



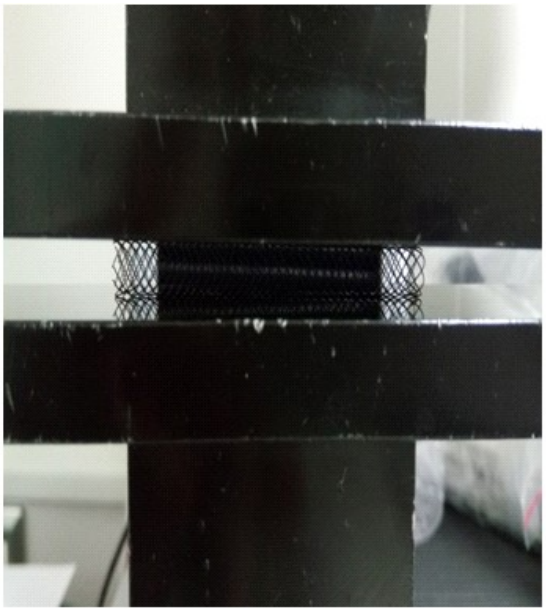


Figure 08. Universal Testing Machine

Testing Procedure

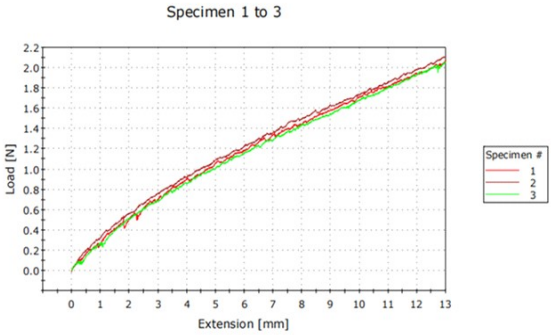
Initial State: The test sample was in its original state with no extension, meaning it was not stretched or compressed at all. At this point, the pressure applied to the test sample was recorded as 0.0 Newtons (N). This initial measurement serves as a baseline for the rest of the test.

Extension Range: The test sample was then gradually extended from 0 mm to 13 mm (an exact half of the actual diameter of stent sample i.e. 26mm). This means the test sample was stretched longitudinally within this range.

Compressive Force Measurement: When the test sample was stretched in the range of 0-13 mm, the machine measured the compressive force applied to the stent. Compressive force is the force pushing inward on the test sample due to the stretching process. The measured values of compressive force obtained from data acquisition system ranged from 0.0 N to 2.2 N as the stent was incrementally extended.

Maximum and Minimum Forces: During the testing, a maximum compressive force observed was 2.11 N, indicating the highest force the stent experienced during the test. On the other hand, the minimum compressive force was 2.05 N, which is the lowest force applied to the stent.

The overall results findings of crush resistancy measured for self-expanding metallic colonic stent are shown in Table.01 along with the graphical representation in Graph.01.



Graph 01. A Graphical Overview of the Crush Resistance Property in Self-Expandable Metallic Colonic Stents

Table 01. Results of Crush Resistancy for 'Self-Expandable Metallic Colonic Stent'

	Sr No.	Maximum Compressive Force(N)	Deflation @ Crush Force (gf)	Deflation @Crush Force (mm)
1	01	2.07	211.5	12.99
2	02	2.11	215.2	12.99
3	03	2.05	209.6	12.97
Minimum		2.05	209.6	12.97
Mean		2.08	212.1	12.98
Maximum		2.11	215.2	12.99
Standard Deviation		0.02	2.8	0.010

CONCLUSION

In this research paper, a breakthrough self-expanding metallic colonic stent system is presented as a novel approach to treat colorectal cancer in Canines and Felines. The innovation of the system lies in the use of reinforced free wire ends, which not only increase the overall stability of the system but also optimize its expansion dynamics. This unique feature facilitates tumor displacement, promoting improved intestinal passage. Beyond its immediate application, this study contributes to a more comprehensive understanding of the common features of colon cancer in different species. By successfully adapting a technique that has demonstrated transformative potential in humans to the veterinary context, the research underscores the interconnectedness of medical advances across species. Crucially, laboratory-scale tests have confirmed the mechanical strength of the stent system, underscoring its suitability as a therapeutic agent. However, given the preliminary nature of the development, there is a need for further rigorous evaluation. One of the next publications will demonstrate the feasibility of this stent in a GLP study. In conclusion, the introduction of this stent system represents a significant advance in veterinary medicine. It not only solves an urgent medical problem in animals, but also embodies the spirit of innovation and adaptation to human medical practice. Therefore, this stent system holds great promise for improving the quality of life of animals struggling with the challenges of colorectal cancer.

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