doi: 10.17221/1/2016-VETMED

Shape memory compression anastomosis clips in gastrointestinal surgery in dogs

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ABSTRACT: This paper describes clinical experiences with the use of shape memory nickel-titanium (NiTi) clips in gastrointestinal surgery in dogs. Side-to-side small bowel anastomosis was performed in eight dogs where intestinal continuity had to be restored after bowel resection. Billroth's operation I was performed in one case. Compression anastomosis clips with two-way shape memory were used in all surgical procedures. Intestinal and gastrointestinal anastomoses involving shape memory clips were effective in all patients. Anastomotic leaks were not observed, and all clips were expelled 5–7 days after surgery. The outcomes of surgical procedures performed on canine patients with the use of shape memory NiTi clips indicate that sutureless compression anastomosis is a safe, effective and simple method of restoring gastrointestinal continuity, which can be widely applied in veterinary practice.

Keywords: CAC; intestinal anastomosis; NiTi; animals

Bowel resection and anastomosis account for a relatively large number of gastrointestinal surgery procedures in dogs. Resections are performed mainly due to necrosis resulting from foreign body ingestion, mechanical damage caused by biting, cancer or intussusception. Resection always requires tight and effective anastomosis without luminal narrowing. Bowel anastomoses are usually created manually, and mechanical sutures are less frequently used. Mechanical sutures are widely used and highly effective in intestinal and gastrointestinal anastomoses in human medicine, but they are rarely used in veterinary surgery due to their relatively high cost. In veterinary practice, mechanical sutures are created mainly with the use of linear and circular staplers. Other devices, such as the Valtrac biofragmentable anastomosis ring, are also used for sutureless anastomosis (Nowicki et al. 2008). The use of compression anastomotic clips and compression anastomotic rings made of nickel-titanium (NiTi) alloys that can undergo a programmed change in shape has been increasingly documented in the literature in the past decade (Kaidar-Person et al. 2008). Shape memory properties are associated with martensitic transformation, where the structure of the alloy changes during cooling and heating. Martensitic transformations are fully reversible and repeatable (Morawiec et al. 2009). In medical and veterinary literature, numerous papers describe experiments performed on animal models, mainly pigs, with the use of compression anastomotic clips (Tucker et al. 2008; Holak et al. 2014). There are no published clinical studies documenting the use of shape memory NiTi clips in bowel anastomosis in dogs. This paper describes the authors' clinical experiences with two-way shape memory NiTi clips in intestinal and gastrointestinal anastomoses in canine patients.

MATERIAL AND METHODS

Ten side-to-side small bowel anastomoses and one gastrointestinal anastomosis were created in clinical patients that had undergone intestinal resection. Surgery was performed in nine dogs of various breeds and both sexes, aged 1–12 years, with body weights of 15–25 kg. Double jejunal

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anastomosis was created in two animals that had sustained mechanical damage to the bowel due to biting. In six patients, jejunal resections were performed due to necrosis caused by foreign object ingestion, and in one patient – due to intussusception. Billroth's operation I (pylorectomy and gastroduodenostomy) was performed in one patient with gastric mucosal hypertrophy and hypertrophic pyloric stenosis which caused gastroesophageal reflux (Table 1). All surgical procedures were performed in accordance with the standards of the Polish Animal Welfare Council and upon the approval of the Local Ethics Committee for Animal Experimentation (Resolution No. 12/2011).

The compression clips used in intestinal anastomoses and gastroduodenal anastomosis were made of Ti50 Ni48.7 Co1.3 alloy in the form of elliptical double-coil rings with two-way shape memory. Clips measured 25 mm in length and 7 mm in width. Two-way shape memory clips remain in a closed position at room temperature, and when cooled in liquid nitrogen, they open automatically to an angle of approximately 30°. When surgically inserted, clips become locked under exposure to body heat (Figure 1). The compressive strength of NiTi clips was determined at 7–10 N under laboratory conditions.

All patients were prepared for intestinal and gastroduodenal anastomoses in accordance with standard surgical anaesthesiological procedures for the species. After resection, the lumen of each of the clipped jejunal loops was separately closed with two layers of 3-0 absorbable monofilament sutures. The anti-mesenteric borders of clipped intestinal sections were joined with two stay sutures. Five-millimetre-long incisions were made across all layers of the intestinal wall to create an enterotomy on the joined sections of the bowel. The clip was cooled by immersion in liquid nitrogen for 15 s and was inserted in the open position, one clip per incision (Figure 2). The clip was locked under exposure to body heat, joining the walls of both bowel sections. In the following stage of the procedure, an incision was made on the side of the intestinal lumen across both walls of the anastomosed bowel section inside a closed clip to enable the passage of digesta. The enterotomy above the closed clip was closed with a single layer of 3-0 absorbable monofilament suture. Abdominal integuments were closed according to the standard procedure.

In Billroth's operation I, the pylorus was resected, and a gastroduodenal anastomosis was created. The surgical protocol was similar to that observed in intestinal anastomosis. The duodenal lumen and pylorus were closed and anastomosed with a NiTi clip in accordance with the previously described procedure.

Fluids, analgesia and antibiotics were administered for seven days after surgery, and the patients' condition and body temperature were monitored. Oral administration of fluids commenced 12 h after the surgery, and 48 h after the procedure it consisted of small portions of semi-fluid food.

Table 1. Description of patients subjected to clinical trial

Patient No.	Age (years)	Sex	Breed	Body weight (kg)	Procedure	Aetiology
1	1	male	mongrel	15	jejunal anastomosis	necrosis caused by foreign object ingestion
2	3.5	male	mongrel	17	jejunal anastomosis	necrosis caused by foreign object ingestion
3	4	male	mongrel	17	double jejunal anastomosis	mechanical damage to the bowel due to biting
4	3	female	Bloodhound	23	double jejunal anastomosis	mechanical damage to the bowel due to biting
5	6	female	German Shepherd	24	jejunal anastomosis	necrosis caused by foreign object ingestion
6	7.5	female	Labrador	22	jejunal anastomosis	necrosis caused by foreign object ingestion
7	10	female	mongrel	21	jejunal anastomosis	intussusception
8	12	male	mongrel	16	pylorectomy and gastroduodenostomy	gastric mucosal hypertrophy and hypertrophic pyloric stenosis
9	9	male	Boxer	25	jejunal anastomosis	necrosis caused by foreign object ingestion

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Figure 1. Nickel-titanium clip with two-way shape memory. Left: locked clip at room temperature. Right: open clip after cooling

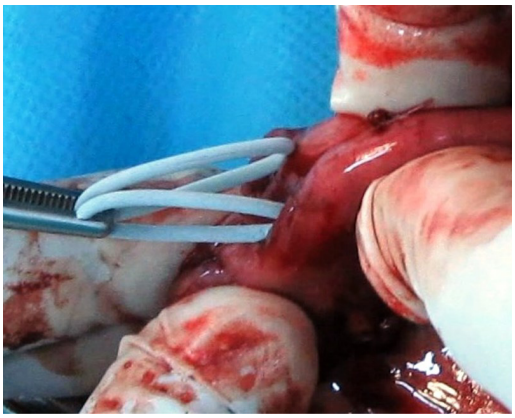

Figure 2. Insertion of an open nickel-titanium clip into an incision in anastomosed bowel segments

RESULTS

Complications were not observed, and all patients successfully recovered after intestinal anastomoses and gastroduodenal anastomosis. Clips were expelled with faeces five days after the procedure by one animal, six days after surgery by six dogs, and seven days after the procedure by three animals. In one dog, clip excretion with faeces was not observed by the owners, but an X-ray examination performed 14 days after the procedure confirmed that it had been expelled. Rectal tenesmus was observed four days after the procedure in one patient. The dog expelled the clip on the next day and the symptoms of tenesmus subsided.

DISCUSSION

In intestinal and gastrointestinal anastomoses, the walls of the joined sections of the digestive tract are compressed locally under constant compressive force. Blood supply is cut off at the compressed site, which leads to local necrosis. A scar is formed in the direct vicinity of the compressed site, which guarantees permanent adhesion (Lampe et al. 2008; Holak et al. 2014). Valtrac biofragmentable rings and NiTi compression clips and rings operate on the same principle. Those systems were developed to guarantee tight and minimally invasive tissue anastomoses that reduce inflammations (Tucker et al. 2008). In procedures that rely on compression anastomosis clips, the implant is quickly expelled with faeces. In the present clinical study, the time of clip excretion was 5–7 days after surgery, which is significantly shorter than in the Valtrac biofragmentable anastomosis ring system where the implant used in dogs was expelled 15 days after the procedure on average (Maney et al. 1998; Nowicki et al. 2008). In cases described in the literature, compression intestinal anastomoses in animals were performed experimentally (Nudelman et al. 2000; Kopelman et al. 2007).

We have previously used compression anastomosis clips with two-way shape memory in several experiments. The applied clips had optimal shape and size, and they were easily expelled from the digestive tract. In previous experiments performed on pigs, the anastomotic opening had an estimated diameter of 20 mm, which supported free passage of digesta (Holak et al. 2014). The size of the clip can be adjusted to create an anastomotic opening with the desired diameter to accommodate the needs of patients of various sizes and to eliminate the risk of luminal narrowing which may be encountered in hand-sewn anastomoses. In the authors' opinion, the insertion of the clip is a fairly simple procedure. The clip was freely inserted into the intestine through a 5-millimetre-long incision in the antimesenteric borders of clipped bowel sections, and the clip's longitudinal axis was aligned in parallel with the longitudinal axis of the intestine. A small incision minimises the risk of bacterial contamination in the abdominal cavity. Hand-sewn anastomoses are laborious and time-consuming, whereas compression clips significantly shorten operative time (Kusnierz et al. 2014). In a previous experiment performed on pigs, average operative time per anastomosis created with a compression clip was approximately 20 min shorter in comparison with hand-sewn anastomosis. Moreover, a shorter operation time reduces exposure time to anaesthetic drugs (Lampe et al. 2008; Holak et al. 2014).

In the authors' opinion, NiTi shape memory clips create tight anastomoses. The clips used in this study had a programmed compressive strength of 7–10 N, which prevented leakage of digesta and guaranteed

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the tightness of the anastomosis (Holak et al. 2014; Kusnierz et al. 2014). In gastroduodenal anastomosis, where the stomach wall is thicker than the wall of the bowel, a compressive strength of 7–10 N was also sufficient to create a tight connection. This is an important consideration since leakage is the most common cause of postoperative complications after intestinal and gastrointestinal anastomoses in animals (Ullman et al. 1991; Ralphs et al. 2003). The applied clips had two-way shape memory, which significantly facilitated clip insertion. The clips were opened and locked automatically, and unlike clips with one-way shape memory, their application did not require additional tools (Tucker et al. 2008).

Studies performed on human subjects have revealed that compression clips also shorten hospitalisation time, speed up bowel movement, catheter removal and food intake in comparison with patients with stapled anastomoses (Nudelman et al. 2005). Nickel-titanium clips are also significantly less expensive than biofragmentable or stapled anastomosis systems, which is an unquestionable advantage in veterinary medicine. Compression anastomosis clips are versatile and can be used in both conventional and laparoscopic surgery (Nudelman et al. 2004).

In conclusion, we propose that shape memory compression clips provide veterinary surgeons with a simple, effective and low-cost technique which could be a viable alternative to standard hand-sewn and stapled intestinal and gastrointestinal anastomoses.

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Received: 2016–01–04
Accepted after corrections: 2016–08–04

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