# Advantages of Handsewn over Stapled Bowel Anastomosis

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**Bowel anastomoses are conventionally performed using a handsewn technique or a stapling device. Each has potential benefits and disadvantages. The most clinically significant complications of the bowel anastomosis are anastomotic leakage and stricture formation. The indices of healing and tissue cohesion were compared dynamically over time in 24 dogs randomized to undergo either a standard two-layer handsewn anastomosis or a stapled anastomosis with the Premium CEEA™ (United States Surgical Corporation, Norwalk, CT). Animals were sacrificed at 1, 4, 7, and 28 days postoperatively. Each anastomosis was evaluated for anastomotic index, burst pressure, collagen content, and histologic appearance. The anastomotic index was similar on postoperative day (POD) 1, 4, and 7; but on day 28 all handsewn anastomoses had larger diameters than the widest CEEA™ anastomosis. Burst pressure was higher in handsewn anastomoses at all intervals. Collagen content tended to be higher on POD 7 in the CEEA™ anastomoses. Histological evaluation showed more complete epithelialization and less inflammation in handsewn anastomoses on POD 28. The higher level of collagen in the CEEA™ anastomoses on POD 7 may be implicated in the tendency toward stricture formation found with this type of anastomosis. This study demonstrates that the greater speed and ease of the stapled anastomosis is offset by the greater strength, reduced tendency to stricture, and more complete healing of the handsewn anastomosis. [Key words: Colorectal surgery; Suture techniques; Surgical anastomosis; Surgical staplers; Dogs]**

Bowel anastomoses are conventionally performed using handsewn or stapling techniques. The basic principles of intestinal suture have been the importance of obtaining a serosa-to-serosa inverting anastomosis as demonstrated by Lembert[1] in 1826 and the demonstration by Halsted[2] in 1887 of the importance of including the tough submucosa in every suture. Probably the most common type of intestinal suture technique is the one described by Connell in 1892 in which an inner row of continuous inverting suture through all layers is strengthened by an outer row of interrupted seromuscular sutures.[3] Surgical stapling devices were first introduced in 1908 by Hultl in a presentation at the Second Congress of the Hungarian Surgical Society.[4] Modern gastrointestinal stapling techniques were introduced in the early 1960s by the Institute for Experimental Apparatus and Instruments in Moscow and modified by Ravitch and associates in the late 1960s.[5,6] Since then there has been a revolution in gastrointestinal surgery. Recently, the technique of using a button instead of sutures or staples has again been introduced.[7–9] The idea is not new: in 1826, Denans[10] conceived of the technique; and in 1892, Murphy[11] practiced it in dogs and patients. The use of the button is not as popular as the other techniques. Staples have become very popular in the USA after Ravitch's experience.

Each technique has its own advantages as well as drawbacks. The use of circular staplers facilitates low anterior resection and rectum-sparing procedures. Although handsewn techniques are readily performed, staplers are frequently less time-consuming. The most important complications are stenosis and leakage. Stenosis at the anastomotic site seems to be more common in stapled anastomoses.[12] Overall there is continued controversy as to the comparative merits of handsewn vs. stapling techniques of anastomosis.[13–23] We could not find any study that described and compared both techniques dynamically over time. We report here the results of such a study.

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## METHODS

In conducting the research described in this protocol, we adhered to the *Guide for Laboratory Animal Facilities and Care*, as promulgated by the Institute of Laboratory Animals Resources, National Academy of Sciences, National Research Council.

### Procedure

We compared handsewn with stapled anastomoses in 24 mongrel, male dogs weighing 15–20 kg. Dogs were randomly assigned to either group. Preoperatively, the animals were fasted 24 hours and received two Fleet® enemas and 500 mg of intravenous cefoxitin. After the induction of anesthesia with 1 mg/kg subcutaneous xylazine and 25 mg/kg intravenous pentobarbital sodium, the animals were intubated and ventilated on the Harvard Respiration Pump® (Harvard Apparatus, Dover, MA). Using sterile technique, the colon was devascularized for 2 cm and transected 10 cm from the peritoneal reflection. A 1-cm sample was taken for collagen evaluation. Handsewn anastomoses were performed using a two-layer inverting closure of inner, running 3-0 catgut and outer, interrupted 3-0 silk. Stapled anastomoses were performed using the largest stapler that the bowel could accommodate with a Premium CEEA™ stapler, 25 mm (n = 2), 28 mm (n = 6), or 31 mm (n = 4) (U.S. Surgical Corporation, Norwalk, CT). For the stapled anastomosis, purse-string sutures using 2-0 monofilament polypropylene were placed circumferentially around the proximal and distal ends of the colon. The stapler was introduced via the rectum, the anastomosis was performed, and the instrument removed for inspection of the tissue doughnuts. The mesocolic defect was closed with 3-0 chromic suture. The abdomen was closed in layers using 0 Prolene® for fascia and 2-0 nylon for skin. The time taken to perform the procedure was recorded. All procedures were performed by surgical research fellows.

### Postoperative Care

The dogs were kept NPO for 3 days postoperatively and were given 1,000 ml of 5 percent dextrose in lactated Ringer's solution with 500 mg cefoxitin by clysis daily. Water was given on the 4th and 5th days and regular, dry dog food was started on the 6th postoperative day. The dogs were sacrificed 1, 4, 7, or 28 days after surgery with intravenous T-60 embutramide (0.7 mg/kg). There were three dogs in each group.

### Radiologic Evaluation

The colon was dissected out and the contents flushed with warm water. To measure luminal diameters, the specimen was suspended in U-shape with funnels at either end and filled with 10 percent barium sulfate under 20-cm pressure (Fig. 1). X-rays in two perpendicular planes were performed on each specimen. The internal diameter of the colon was measured and the anastomotic index calculated. The anastomotic index was defined as two times the colon diameter at the anastomosis (2a) divided by the sum of the colon diameters 3 cm proximal (b) and 3 cm distal (c) to the anastomosis (Fig. 2). In this way, any dis-

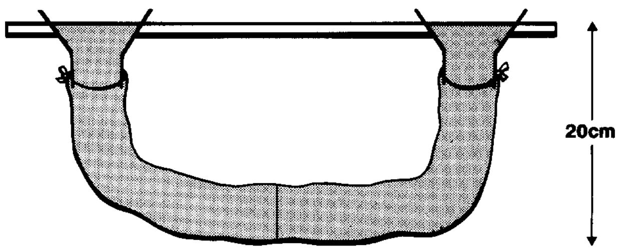


**Figure 1.** X-rays were taken in two perpendicular planes of the suspended colon filled with 10 percent barium sulfate at 20-cm pressure.

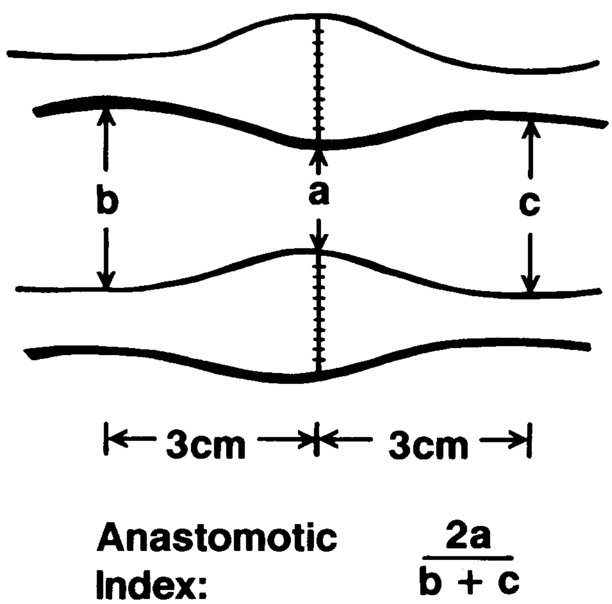


**Figure 2.** Calculation of the anastomotic index (AI).

crepancy in the diameter of the joined segments would be taken into consideration. By these criteria, a perfect cylinder would have an anastomotic index of 1.

### Pressure Testing

The dissected colon was gently flushed with warm water and both ends ligated with umbilical tape. A polypropylene tube inserted into the lumen of the bowel was connected to an eight-channel Sanborn recorder-pressure transducer P23ID (Hewlett-Packard 7788A, McMinnville, OR). The colon was then submerged in warm saline and air injected (50 ml/minute) by an automatic syringe (Harvard Apparatus Infusion/Withdrawal Pump). Burst pressure was taken to be the point at which the bowel was unable to maintain pressure, at which point rupture occurred. This was seen as a precipitous drop in the pressure curve.

### Hydroxyproline Evaluation

Tissue at the anastomotic site was excised, cut into 1- × 2-cm pieces, and stored at −70°C until all samples were collected. All sutures and staples were removed from the tissue before hydroxyproline determination. The colorimetric method of Woessner[24] was used to determine hydroxyproline content. The method uses the hydrolysis of the tissue protein by concentrated hydrochloric acid to release free amino acids. Since hydroxyproline is found almost exclusively in collagen, comprising approximately one-third of the amino acids in this protein, a measure of hydroxyproline permits an estimate of collagen. Estimated collagen content is reported as gram-percent.

### Microscopic Examination

Samples from each anastomosis were fixed in 10 percent formalin for at least 5 days. Representative sections of each anastomosis were taken and prepared for microscopic examination with hematoxylin and eosin staining. The sections were evaluated by a pathologist blinded to the protocol.

### Statistical Methods

Results are expressed as the mean ± SEM. Differences in means were evaluated for significance with Student's paired *t*-test. Differences were considered significant if $P < 0.05$.

## RESULTS

There was no intraoperative or postoperative mortality or morbidity in the 24 dogs entered in the study. No technical difficulties occurred with either of the anastomotic techniques. Significant ($P < 0.05$) time differences for completion of the anastomoses were found. The time for completion of the two-layer anastomosis was longer (47 ± 4 minutes) than that to perform a stapled anastomosis (25 ± 3 minutes). At autopsy, no macroscopic differences were found between the groups. The adjacent organs usually were slightly adherent to the anastomotic site.

### Anastomotic Index

In the early postoperative period, 1, 4, and 7 days after surgery, the anastomotic index was greater in anastomoses performed with the stapler, but this was not statistically significant (Fig. 3). By the 28th day after surgery, all handsewn anastomoses (0.85 ± 0.04) had a greater diameter than the largest stapled anastomosis (0.56 ± 0.04), $P < 0.05$.

### Burst Pressure

At 1, 4, and 7 days after surgery, all "bursts" occurred in the anastomosis. At 28 days after surgery, in two of three colons with the handsewn anastomosis, the rupture was extra-anastomotic, whereas all the CEEA™ anastomosis "bursts" occurred at the anastomoses. At all intervals the burst pressures were higher for handsewn than for stapled anastomoses (Fig. 4). These differences were statistically significant on the 4th postoperative day (POD) and 28th POD.

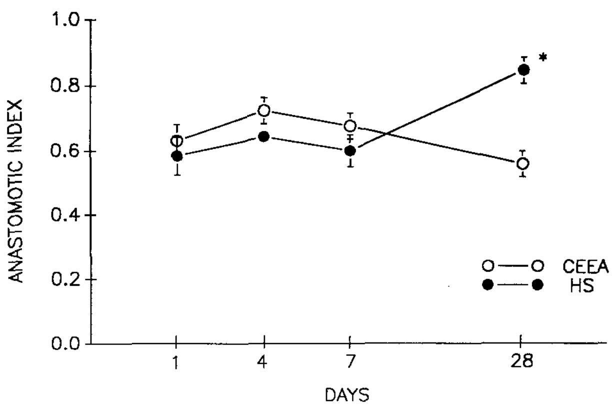


**Figure 3.** Results of the anastomotic index. * $P < 0.05$.

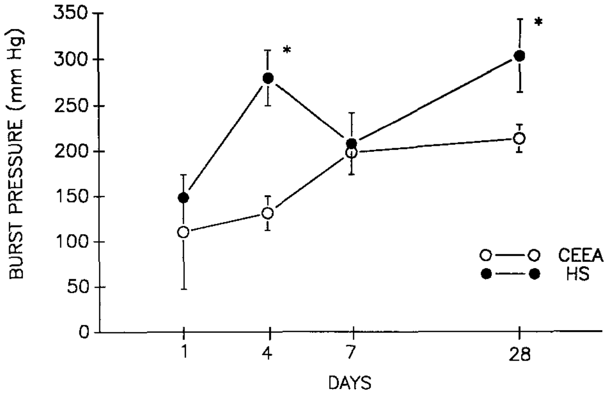


**Figure 4.** Results of the burst pressure. * $P < 0.05$.

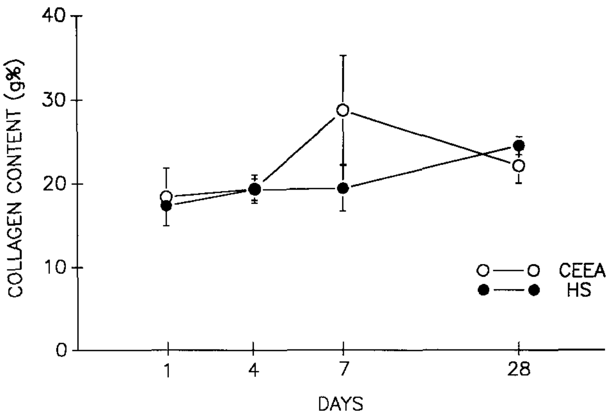


**Figure 5.** Results of the collagen level.

## Collagen Content

The level of collagen was similar in both types of anastomosis at 1, 4, and 28 days after surgery (Fig. 5). On day 7, collagen content was much higher in stapled anastomoses (28.9 ± 6.5 gram-percent) than in handsewn anastomoses (19.5 ± 2.7 gram-percent), but this difference was not statistically significant ($P = 0.1$). On day 28, the collagen content in the anastomosis was similar to collagen levels in the colon before anastomosis. The mean level of collagen in the samples of adjacent normal bowel taken during surgery was 24.6 gram-percent.

## Microscopic Appearance

There were no major differences in the histologic appearance of sections from the anastomotic site taken 1, 4, and 7 days after surgery, all of which showed areas of necrosis and major inflammation. On POD 28, the handsewn anastomoses showed more complete epithelialization, less inflammation, and better tissue alignment than the stapled anastomoses (Figs. 6 and 7).

## DISCUSSION

The aim of the bowel anastomosis is to reconstitute continuity of the colon, allowing for unimpeded passage of colonic content with neither leakage nor obstruction. The width of the anastomosis should be as equal to the original organ lumen as possible. Stenosis at the anastomotic site may be considered anatomically or clinically. The definition of anastomotic stenosis is not exact and may account for the wide range of incidence of clinical stenoses reported (0–22 percent) after colocolostomy or coloproctostomy.[12,14,18,22,23] The first stenosis after EEA™ circular stapling was described by Brain *et al.*[25] Luchtefeld *et al.*[12] pro-

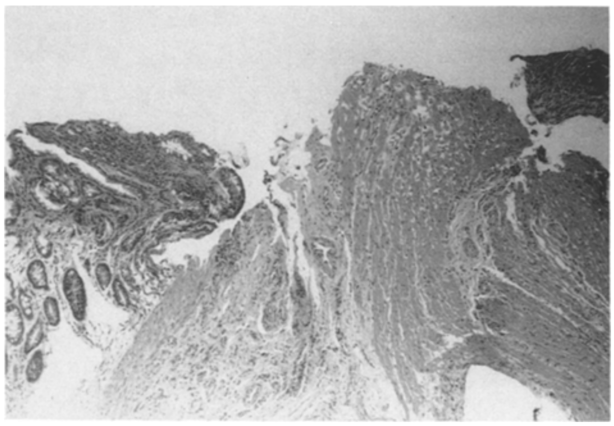

**Figure 6.** Typical microscopic section of the staple site showing malalignment of tissue layers and incomplete mucosal epithelialization.

**Figure 7.** Microscopic section of the handsewn site showing complete reepithelialization, suture granulomas, and good tissue alignment.

posed the following practical definition of a clinically significant stenosis: "Any chronic narrowing or obstruction to flow of intestinal contents resulting in clinical signs or symptoms of obstruction, either partial or complete." Stenosis is diagnosed most commonly between 1 and 6 months after surgery. The tendency of stapled anastomoses to stricture has been observed clinically. In 1981, Smith[18] reported a 9.8 percent incidence of stenosis after a stapled anastomosis. These data were based on a questionnaire sent to members of The American Society of Colon and Rectal Surgeons. Other authors have reported a similar incidence of stenosis after a stapled anastomosis.[14, 18, 22, 23] Although dilatation of stenotic areas with a balloon catheter is usually successful in managing these strictures, on rare occasions the use of lasers or formal surgical revision is required.

The most important finding of our study was the tendency of stapled anastomoses to stricture, in comparison with handsewn anastomoses, when examined 1 month after surgery. This was evident in smaller luminal diameters, as reflected by lower anastomotic indices in the stapled anastomoses. Although the handsewn anastomoses tended to have smaller luminal diameters in the early postoperative period, this was dramatically reversed by POD 28, where, as stated, all handsewn anastomoses were larger than the largest stapled anastomosis. Transient, early luminal narrowing in the handsewn anastomoses may be explained by the greater inversion of tissue in the two-layered handsewn technique and by edema. Kozol *et al.*[26] found that edema 28 hours after surgery was greater in handsewn than in stapled anastomoses. This is also evident by simple light-microscopic examination of histologic sections.[27] We found no difference in edema at later periods when examined microscopically.

The mechanism whereby the stapling technique may lead to an increase in stricture formation has not yet been fully elucidated. One of the most important factors in the healing of an intestinal anastomosis is the blood supply. Lehur and Khosrovaninejad,[28] however, found no difference in the tissue blood flow in the stapled anastomosis. Mechanical injury induced by the stapling device might lead to stricture formation, but Buchmann *et al.*[29] reported that the crush injury imparted to the colon by the EEA™ stapler device alone does not result in increased fibrosis of the anastomosis when compared with knife cutting. One simple explanation for anastomotic stricture is the use of too small a stapler.[12, 14] In this study, we used the largest stapler the bowel could accommodate, predominantly the 28-mm and 31-mm staplers, in order to both minimize the concern of inadequate stapler size and to most closely approximate the native colon diameter in each animal. Leakage at the anastomotic site or concurrent pelvic infection, although not unique or necessarily more common in stapled anastomoses, is associated with future stricture formation. We saw no evidence of either leakage or intraperitoneal infection in any of the operated dogs. Animal experimentation has suggested that mucosal healing in anastomoses occurs through a combination of both primary and secondary intention.[12, 13] The potential for increased scar formation in the stapled anastomosis can be seen in the degree of inflammation present 1 month after operation, as seen in the histologic sections taken from the anastomotic site. Mucosal defects and areas of necrosis seen in our study in the stapled anastomosis may be implicated in stenosis and stricture formation.

The process of collagen synthesis and maturation plays a major role in the scar process. Lysis of collagen at the site of injury begins 3 hours after anastomosis[30] and predominates during the first 4 days of healing.[31] By POD 7, collagen synthesis has overtaken lysis.[32] Normal levels of collagen are reached in the anastomosis after 2 weeks. We observed this expected initial decrease in collagen content for both anastomotic techniques on POD 1 and 4, with collagen levels present on day 28 equivalent to the levels in normal adjacent bowel samples taken during surgery. The markedly higher levels of collagen in stapled anastomoses found on POD 7 in our study may be involved in later stricture formation. Similar findings of higher collagen levels 1 week postoperatively were reported by Templeton and McKelvey.[33] Overabundant collagen or an overactive inflammatory response may lead to the tendency toward future stricture formation.

Although limiting the inflammatory response in order to minimize stenotic complications is desirable, the anastomosis must maintain sufficient strength to prevent the more dramatic clinical complication of leakage. Burst pressure data, although not a direct measure of the likelihood of anastomotic leakage, do reflect the relative strength of the anastomosis and its ability to withstand potentially disruptive intraluminal pressures. Burst pressure was significantly higher in handsewn anastomoses on POD 4 and 28. High burst pressure on POD 4 suggests that in the early postoperative period, when collagen breakdown occurs, the sutures were mechanically holding the bowel more securely than staples did. In our study, all CEEA™ anastomoses on POD 28 burst at the anastomosis. In contrast, two of three handsewn anastomotic specimens burst at sites other than the anastomosis. Cronin *et al.*[34] reported that by the 10th day rupture no longer takes place at the anastomosis but in the intact intestine.[34] Whereas in our study, all handsewn anastomoses had higher burst pressures than the matched stapled anastomoses, other authors have disagreed. Templeton and McKelvey[33] reported that burst pressure was higher in stapled anastomoses in dogs on postoperative day 7. Graffner *et al.*[13] found no difference in burst pressures between these two types of anastomosis. These differences may reflect the different techniques of measurement employed. We feel that our method is simple, accurate, and readily duplicated.

In the favor of the stapling device was the shorter time required to perform the anastomosis. All procedures were performed by surgical research fellows, and the operative time for anastomosis was similar to what is reported from clinical series.[13,17] The convenience and efficiency of the stapler in low anterior resections, especially in patients with a narrow pelvis, has also been cited. Although operative time and the reported ease or difficulty of one or the other technique is highly operator dependent, the time saving potential of stapling devices must be acknowledged.

Our data showed that the handsewn technique results in a larger luminal diameter of the anastomosis by POD 28, better healing histologically, and a higher burst pressure at all time intervals. These advantages of the handsewn over the stapled bowel anastomosis support the clinical use of the handsewn technique. Stapled anastomoses may lead to stricture formation by an early increase in collagen synthesis as part of an exaggerated inflammatory response. There is still a need to search for a better device to combine the speed and ease of the stapling technique with the better healing and lower stricture incidence of handsewn anastomoses.

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