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Comparison of Strength of Anastomosis Between Four Different Techniques for Colorectal Surgery

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Abstract. *Background/Aim: Advances in stapling devices have led to their widespread use in colorectal surgery. We compared the strength of four types of anastomoses using bursting pressure. Materials and Methods: We created stapled anastomosis models [double stapling technique (DST), functional end-to-end anastomosis (FEEA) unbuttressed or buttressed, and triangulating anastomosis (TA) with two- or three-row stapling] and a hand-sewn anastomosis model. Bursting pressures of each method were measured. The primary end point was the bursting pressure. The effectiveness of buttressing and three-row stapling were the secondary endpoints. Results: The DST group had significantly lower bursting pressure than TA with three-row stapling, FEEA buttressed, and hand-sewn groups. No significant difference was found between the bursting pressure of the FEEA unbuttressed and FEEA buttressed groups and that of the TA with two-row and three-row stapling groups. Conclusion: DST has the lowest bursting pressure compared to other anastomotic techniques. Buttressing suture and three-row stapling have no effect on the strength of anastomosis.*

Successful anastomosis is an extremely important aspect of gastrointestinal surgery. Stapling devices have been widely used for anastomosis since the 1960s, when Steichen and Ravitch adopted the use of them (1-3). Stapled anastomosis is simple, reduces the duration of surgery, and reduces the stress that surgeons may experience (4). However, the rate of anastomotic leakage, the main complication of colorectal surgery, has not been reduced (5). Furthermore, stapled anastomosis is associated with higher rates of anastomotic leakage (6). For cases of rectal cancer surgery, the rate of anastomotic leakage is between 10% and 15% (7, 8). Anastomotic leakage could lead to severe conditions and poor prognoses, especially in cases of colorectal cancer (9-11). Although a wide variety of anastomotic techniques are available for colorectal anastomoses, it is not known which technique has the least chance of anastomotic leakage. Our retrospective study reported that the use of triangulating anastomosis (TA) for cases of colon cancer reduces anastomotic leakage (12, 13). Factors influencing anastomotic leakage include patient and operation factors (14-17), blood supply at the site of anastomosis, tension, and strength of the anastomosis (18-23). The blood supply and tension can be addressed by adjusting the surgical procedure. However, the strength of the anastomosis depends on the anastomosis technique and stapling device used. Stapling devices include two-row, three-row, and circular staplers. The stapling devices and anastomosis techniques are often selected by surgeons based on their experience and preferences. However, knowing the strengths of the various anastomosis techniques would aid in the selection of anastomosis technique used in the operation. Therefore, in this study, we created anastomosis models for the various techniques using a bovine intestinal tract and compared the bursting pressure by subjecting the models to bursting tests to elucidate the strengths of the various anastomosis techniques. The aim of this study was to evaluate the differences between the strengths of the various anastomotic techniques for colorectal surgery.

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Key Words: Stapled anastomosis, bursting pressure, triangulating anastomosis.

Materials and Methods

The rectums were surgically removed from bovine cadavers of cows to create the anastomosis models. Segments of the intestinal tract utilized in this study had half-circumference measurements between 37 mm and 40 mm. An anastomosis was created for each anastomotic method using two segments, each measuring approximately 20 cm in length. Extension tubes were inserted in the stumps of the two segments, which were ligated using sutures. Then, the free stumps of the two segments were clamped using Lister forceps. The anastomosed colon was submerged in a tank filled with physiological saline (Figure 1a). The tube was connected to a pressure gauge (HANDY MANOMETER PG-100 102GP; Nidec

Copal Electronics, Tokyo, Japan), and air was injected at 10 ml/sec using a 50-ml syringe. The pressure (kPa) at which the initial air leakage started and the air leakage point were recorded (Figure 1b).

Four types of stapling anastomosis were utilized: the double stapling technique (DST), functional end-to-end anastomosis (FEEA), and TA, while the hand-sewn technique utilized was the Albert-Lembert (AL) anastomosis. FEEA is performed using two to three stitch reinforcements. We performed FEEA unbuttressed and FEEA buttressed (two types) techniques. TA was performed with two-row or three-row stapling. The specific procedures used for each anastomosis method are described herein. The same researchers performed all anastomoses and bursting tests for seven subjects in each group. Data from five subjects in each group were compiled after excluding the maximum and minimum values (one of each) from the results. We also recorded the anastomosis sites where air leakage occurred. The primary endpoint was the differences in the bursting pressures between the DST, FEEA buttressed, TA with three-row stapling, and hand-sewn groups. The secondary endpoint was the differences in bursting pressures of the FEEA buttressed and FEEA unbuttressed groups. We also compared the air leakage sites and the bursting pressures of TA with two-row stapling and TA with three-row stapling to determine any differences in the bursting pressures at the anastomosis sites.

DST group. The DST anastomosis was performed using the Endo GIA Tan Reload with Tri-Staple Technology camel 60 mm and DST Series EEA 25-3.5 mm (Medtronic, Dublin, Ireland).

TA with two-row stapling group. Anastomosis was performed using the DST Series TA 60-3.5 mm (Medtronic) three times. The first stapling was performed using the inverted (inside-out) intestinal tract. The remaining two staplings were performed after placing the intestinal tract segments in their normal positions.

TA with three-row stapling group. Anastomosis was performed using Endo GIA Tan Reload with Tri-Staple Technology camel 60 mm (Medtronic) three times. Other procedural details were the same as those for two-row stapling.

FEEA unbuttressed group. Side-to-side anastomosis was performed using the Endo GIA Tan Reload with Tri-Staple Technology camel 60 mm (Medtronic) once. Stump closure was performed using the Endo GIA Tan Reload with Tri-Staple Technology camel 60 mm (Medtronic) twice.

FEEA buttressed group. Buttressed FEEA was performed using the Endo GIA Tan Reload with Tri-Staple Technology camel 60 mm (Medtronic) three times. The anti-mesenteric anastomotic apex was buttressed using three 3-0 Polysorb sutures (Medtronic).

Hand-sewn group. AL anastomosis procedures were performed using interrupted 3-0 Polysorb sutures (Medtronic).

Statistical analysis. Data are expressed as a mean±standard deviation (SD). To compare continuous variables, non-paired Student's *t*-test and an analysis of variance assuming equal variances were performed, as appropriate. Tukey's HSD *post-hoc* test was used to compare the individual means. All *p*-values were considered statistically significant when the associated probability was less than 0.05.

Results

The half circumference of the intestinal tract segments was 39.2±0.8 mm (mean±SD).

No significant differences were found between the half circumference measurements of the bovine intestinal tract segments used for the anastomosis techniques (p=0.542).

Bursting pressures were highest for TA with three-row stapling, followed by FEEA buttressed, FEEA unbuttressed, hand-sewn, TA with two-row stapling, and DST (p=0.001) (Figure 2). The air leakage points are shown in Table I.

Comparison of the FEEA buttressed, TA with three-row stapling, and AL groups. The DST group had significantly lower bursting pressure than the FEEA buttressed group (p=0.001), TA with three-row stapling group (p=0.007), and hand-sewn group (p=0.049). However, no differences were found in the bursting pressures of the TA with three-row stapling group, FEEA buttressed group, and hand-sewn group (Table II).

Comparison of the FEEA unbuttressed group and FEEA buttressed group. No significant differences were found between the pressure tolerances of the FEEA unbuttressed group and FEEA buttressed group (p=0.147). However, in four of the five cases treated with unbuttressed FEEA, air leakage was seen in the anti-mesenteric anastomotic apex, but only one case treated with FEEA buttressed showed air leakage at the same site (Figure 3).

Comparison of the TA with two-row stapling group and TA with three-row stapling group. No significant differences were found between the groups treated using TA with two-row stapling and TA with three-row stapling (p=0.128) (Figure 4).

Discussion

This study showed that the DST group had significantly lower bursting pressure than the TA with three-line stapling group, FEEA buttressed group, and hand-sewn group. The bursting pressures between FEEA unbuttressed and FEEA buttressed and those between TA with two-line stapling and TA with three-line stapling showed no significant differences.

Previous reports have shown improved pressure tolerance attributable to buttressing with FEEA (24); however, in the present study, no significant difference was found between buttressed and unbuttressed FEEA. There were multiple cases of air leakage at the anti-mesenteric anastomotic apex in the unbuttressed FEEA group; hence, we concluded that the anti-mesenteric anastomotic apex is likely to be the weakest site of FEEA. Nevertheless, this study found that air leakage from the anti-mesenteric anastomotic apex was reduced by the use of buttressing. Therefore, it might be prudent to buttress FEEA.

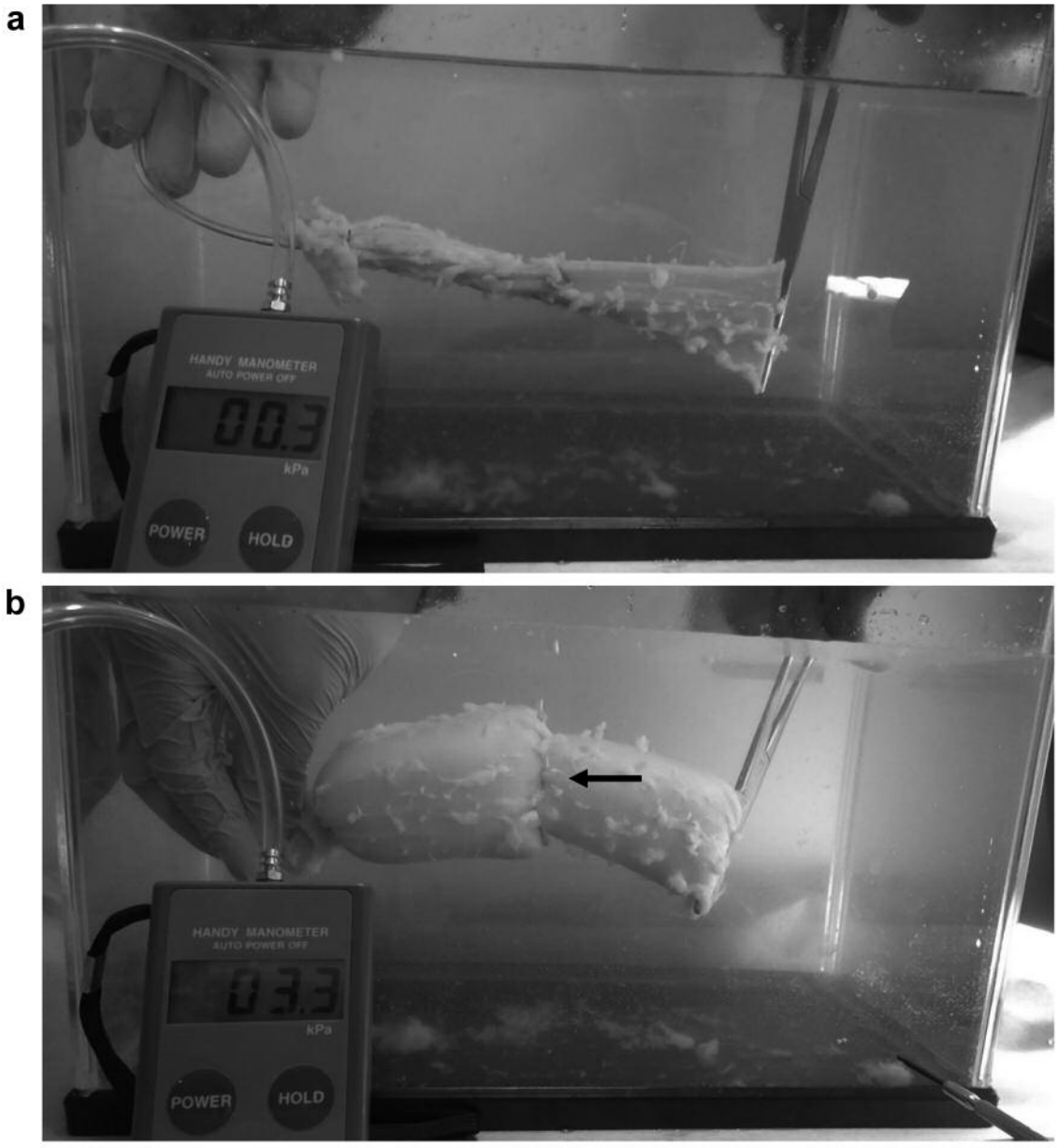

Figure 1. *Bursting test of the anastomosis model created using a bovine intestinal tract. a: Anastomosis models were submerged in a tank filled with physiological saline. b: The initial air leakage started during the anastomosis (arrow).*

Regarding the comparison between three-row stapling and two-line stapling, it has been reported that the bursting pressure of Endo GIA blue (Medtronic) was significantly higher (25). In the present study, however, no difference ws found in bursting pressure. The study by Kawasaki *et al*. (25) only compared pressure along the staple line; however, in the present study, we investigated the pressure tolerance at the anastomosis site and did not make a direct comparison between three-line stapling and two-line stapling. This may indicate that when the anastomosis is created, differences in the pressure tolerances of the anastomosis sites disappear.

TA is associated with less anastomotic leakage (12, 13, 17). However, the results of the present study showed no differences in the bursting pressure of TA, FEEA buttressed, and hand-sewn anastomoses. In the present study, DST was found to have the lowest bursting pressure of all the techniques investigated. This might be one reason for the higher incidence of anastomotic leakage with DST during

Table I. *Comparison of half circumference of bovine colon and bursting pressure across all anastomotic methods and air leakage points.*

Anastomotic method	DST (N=5)	FEEA unbuttressed (N=5)	FEEA buttressed (N=5)	TA with two-row stapling (N=5)	TA with three-row stapling (N=5)	Hand-sewn (N=5)	*p*-Value[b]
Half circumference (mm)[a]	38.8±0.8	39.0±1.2	39.4±0.5	38.8±1.1	39.4±0.5	39.6±0.5	0.542
Bursting pressure (kPa)[a]	2.6±1.1	6.3±1.1	7.4±1.0	5.8±1.4	8.5±3.2	6.2±1.6	0.001
Air leakage point							
Anterior wall	3			3	1		
Posterior wall	1			1	2		
Cross point of stapler lines	1			1	2		
Anti-mesenteric anastomotic apex		4	1				
Anti-mesenteric anastomotic staple line			1				
Staple line for closure of entry site		1	3				

[a]Mean±SD; [b]To compare continuous variables, an analysis of variance was performed. DST: Double stapling technique; FEEA: functional end to end anastomosis; TA: triangulating anastomosis.

Table II. *Comparison between bursting pressures of four anastomotic methods.*

Anastomotic method[a]	DST (N=5)	FEEA buttressed (N=5)	TA with three-row stapling (N=5)	Hand-sewn (N=5)
DST (N=5)		0.007	0.001	0.049
FEEA buttressed (N=5)	0.007		0.802	0.777
TA with three-row stapling (N=5)	0.001	0.802		0.284
Hand-sewn (N=5)	0.049	0.777	0.284	

[a]To compare the individual means, Tukey's HSD *post-hoc* test was performed. DST: Double stapling technique; FEEA: functional end-to-end anastomosis; TA: triangulating anastomosis.

rectal cancer surgery. A previous retrospective study reported that as anastomotic leakage decreased after DST buttressing using two to four sutures to reinforce the cross-point of the stapler, the lack of buttressing was a factor related to anastomotic leakage (26). However, in the present study, one model showed air leakage at the cross-point of the stapler after DST; in contrast, air leakage was identified at the staple line created by the circular stapler in the remaining four models. A circular stapler produces a two-line stapling pattern in a circle. In the present study, we were unable to clarify whether the cause of leakage was a structural weakness in the circular stapler line or the two-row stapling pattern. Because DST had the lowest pressure tolerance, another technique should be recommended if possible. However, in cases of rectal cancer, it is often difficult to avoid DST because of procedural issues, which may explain the higher anastomotic leakage rate of rectal cancer as compared to colon cancer. FEEA buttressed and TA with three-line stapling, which are types of suturing methods used for colonic anastomosis, showed no differences in pressure tolerances as compared to the hand-sewn method. Therefore, for colonic anastomosis, stapling offers the advantages of ease and simplicity; however, it exhibited no advantages related to strength. The limitations of our study need to be considered before our findings can be applied clinically. First, the intestinal tract of cows used during this study was

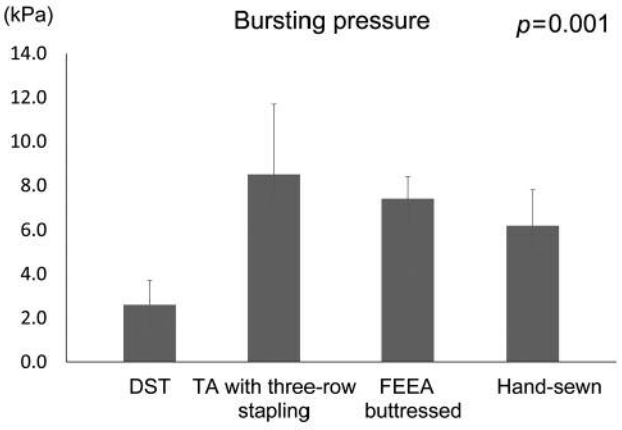

Figure 2. *Comparisons between the bursting pressures of four anastomotic methods.*

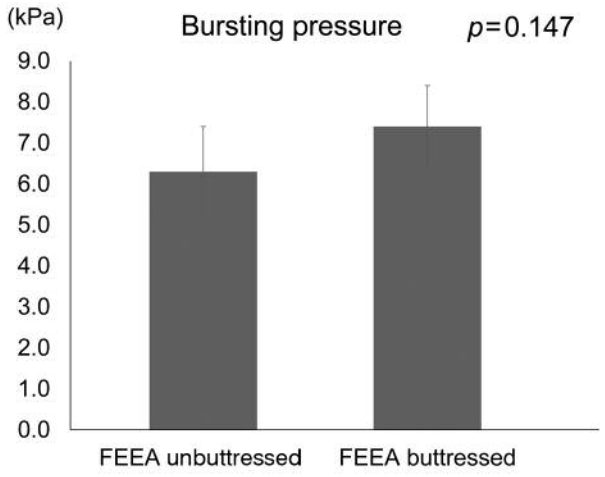

Figure 3. *Comparisons between the bursting pressure of FEEA unbuttressed and FEEA buttressed.*

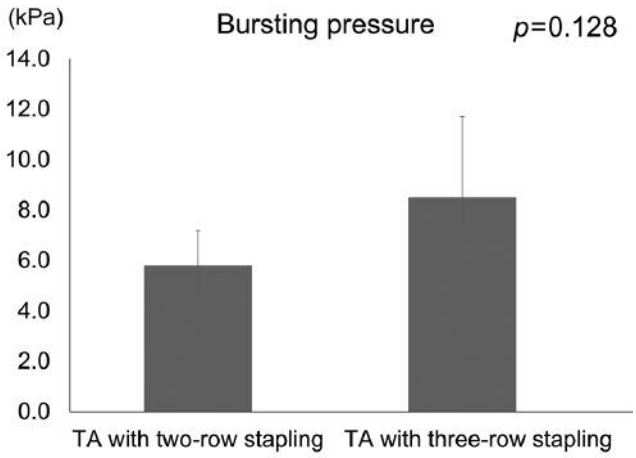

Figure 4. *Comparisons between the bursting pressure of TA with that of two-row stapling and TA with three-row stapling.*

thinner than that of humans. Second, anastomotic leakage occurs because of several different reasons. The strength of the anastomosis must be investigated to determine if it contributes to the reduction of anastomotic leakage.

In conclusion, the DST had a lower bursting pressure than other techniques for colorectal surgery. To reduce anastomotic leakage during rectal cancer surgery involving the DST as the main anastomosis technique, it is important to develop novel stapling devices or stapled anastomosis methods.

Conflicts of Interest

The Authors have no conflicts of interest to declare regarding this study.

Authors' Contributions

Kenta Tomori, MD: First Author, drafted the work and revised it critically for important intellectual content; Ken Eto, MD, PhD: corresponding author, made substantial contributions to the conception and design of the work; Koichiro Haruki, MD, PhD, Hiroshi Sugano, MD, PhD, Tomotaka Kumamoto, MD, Yuta Imaizumi, MD, Naoki Takada, MD, Yuya Shimoyama, MD: made substantial contributions to the analysis and interpretation of the data; Katsuhiko Yanaga, MD, PhD: final approval of the version to be published.

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