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Effect of a Slow-firing Method on Porcine Small Intestine: Evaluation of Staple Malformation by Two Different Methods

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Background: In addition to improvement in staplers, surgeons have made some ingenious changes in stapling techniques. There are few reports that have examined in detail the effect of one ingenious change, the slow-firing method, on the malformation of staples. In this study, the malformation of staples was examined from the viewpoint of twisting and wrapping of staple legs.
Methods: Fresh porcine small bowel was used for all experiments. The front and rear walls of the small intestine segments were stapled in the longitudinal direction. A powered Echelon Plus stapler with a GST cartridge and an EndGIA tri-stapler with an AMT cartridge were used. After a 1-min pre-compression, firing was done as usual in the normal group. In the slow-firing groups, firing was done over a 1-min period. Malformation of staples was evaluated by the degree of wrapping of the legs to the backspan and the degree of leg twisting.
Results: The slow-firing method significantly improved the twist score in Echelon Plus. In contrast, the twist score increased with the slow-firing method in EndGIA. Some staples in Echelon Plus were category Ⅱ or Ⅲ. In addition, all staples on the outside of the tip of stapler were category Ⅱ or Ⅲ. All staples in EndGIA were category Ⅰ. No significant difference in the wrap category was shown by the firing method in both staplers.

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Conclusion: The slow-firing method contributed to the better formation of staples with Echelon Plus, but the effectiveness was not recognized with EndGIA. B-shaped staples with less twisting and wrapping are important factors to complete a reliable suture. After understanding the characteristics of various staplers and selecting the appropriate staple height, adding techniques, such as pre-compression and slow-firing methods will lead to a reduction in post-operative complications.

Keywords: Powered stapler; staple malformation; slow firing.

1. INTRODUCTION

Stapler improvements have contributed to a reduction in complications, such as leakage and post-operative bleeding. The major stapler improvements are changing the staple array from 2 to 3 rows and powered stapling. In using these staplers, surgeons have also devised more reliable stapling methods (pre-compression and slow-firing methods). The effectiveness of the pre-compression method has been reported [1]; however, reports involving use of the slow-firing method in the gastrointestinal tract are limited [2]. Therefore, we compared the effect of the slow-firing method on staple formation.

2. MATERIALS AND METHODS

Fresh porcine small bowel was used for all experiments. The specimens were obtained from animals that had been sacrificed for use in approved non-gastrointestinal research studies. The specimens were used within 24 h of being sacrificed. Each segment of the intestinal tract was 15 cm in length. The front and rear walls of the small intestine segments were stapled in the longitudinal direction using a linear surgical stapler. The three pieces of intestine were overlapped in the experiments. A powered Echelon Plus stapler with a 60-mm staple cartridge (GST60B; Ethicon, Japan) and Endo GIA tri-staple with EndoGIA60AMT (Medtronic, Japan) were used in the experiments. After a 1-min pre-compression, firing was done as usual in the normal group. In the slow-firing groups, firing was performed over a 1-min period. To observe the staples in the original sequence, we performed the stapling procedure, as shown in Fig. 1. First, we wrapped a plastic bag on the cartridge side of the stapler (a), then we stapled the intestine (b). Each device was clamped on the tissue for 1 min (pre-compression). Five staplings were completed with each stapler and method. After stapling, the intestine in a plastic bag was immersed in sodium hydroxide to dissolve the intestine (c, d).

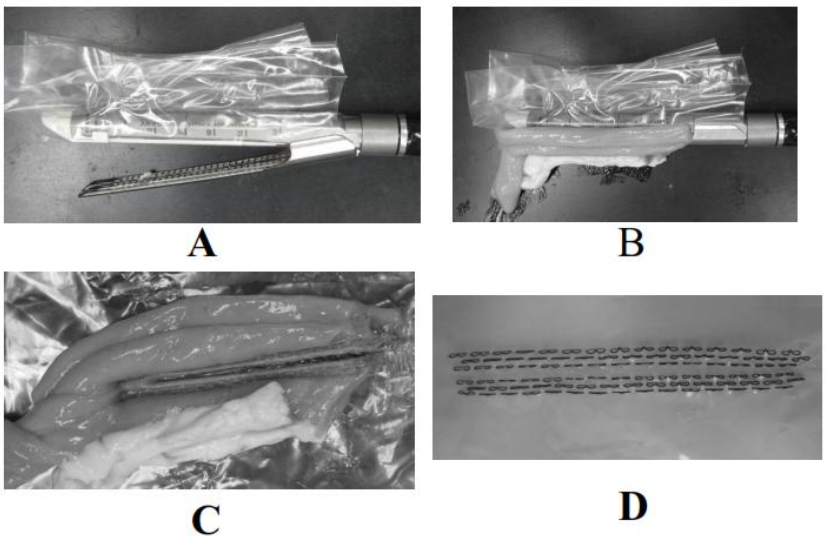

Fig. 1. Stapling procedure
A. A plastic bag is wrapped on the cartridge side of the stapler
B. After gasping the small intestine
C. Stapled small intestine with a plastic bag,
D. All staples attached to a plastic bag

Observations were carried out in a state in which all of the staples were attached to a plastic bag. Staple malformation was evaluated by the degree of leg wrapping to the backspan and the degree of leg twisting [3-5].

The degree of leg twisting was categorized as follows: 0, well-formed staples; 1, the degree of twist was so small that the hook portion was in contact with the linear portion; 2, the distance of the hook portion from the linear portion was less than twice the diameter of the staple; and 3, the degree of malformation is larger than score 2.

The degree of leg wrapping to the backspan was categorized as follows: Ⅰ, staple legs touch and form a “B” shape or are below the top of the staple crown; Ⅱ the staple leg is parallel to the backspan; and Ⅲ, the staple does not wrap toward the backspan.

2.1 Statistical Analysis

Comparisons of staple malformation were performed using Fisher’s exact test. An alpha of 0.05 was considered to be significant.

3. RESULTS

The slow-firing method significantly improved the twist score with Echelon Plus. The twist score = 0 increased from 13.8% to 27.6% and score = 3 decreased from 32.2% to 15.9%. The twist score increased with the slow-firing method in EndGIA. When verified from the wrap category, some staples in the Echelon Plus were category Ⅱ or Ⅲ. In addition, all staples on the outside of the stapler tip were category Ⅱ or Ⅲ. In EndGIA, all staples were category Ⅰ. No significant difference in the wrap category was demonstrated by the firing method using both staplers.

4. DISCUSSION

The evolution and improvement of stapling devices have been significant. Surgeons have also exerted some effort with these devices to improve suturing. The first improvement is the selection of a cartridge suitable for tissue thickness. This selection depends largely on the type of organ and the experience of the surgeon without actually measuring the thickness of the tissue. Next, tissue compression before firing by the stapler is termed pre-compression. Some studies have been conducted and the effectiveness of pre-compression has been confirmed. Another technique is the slow-firing method. Matsumoto [6] reported the effectiveness of the slow-firing method to prevent postoperative pancreatic fistula during laparoscopic distal pancreatectomy. Matsuzawa [7] investigated in detail that pre-compression and firing times affect the formation of serosal lacerations and staples in gastric dissection using the powered stapling method [7]. In this experiment, better formation of staples was obtained even with 1 min of pre-compression and 1 min of slow firing. Therefore, we set the pre-compression and slow firing times to 1 min.

Two types of evaluation were applied with respect to staple malformation in this study. The staple extruded from the cartridge represented the staple twist in the minor axis direction during the process of completing the clinch. The occurrence of a twist was affected by the tissue movement as the staple penetrated the tissue. If the tissue compressed by the stapler was extruded outward, the leg twisted outward. With a twisted staple, the vector compressed by the backspan and legs was not perpendicular to the suture surface, thus the staple may not effectively adhere to the tissue.

The powered Echelon uses “Gripping Surface Technology” [8,9], while EndoGIA uses “Intelligent Compression Technology” [10]. The former is characterized by a firm grasp of the tissue between the anvil and cartridge, and the latter is designed to release the tissue laterally. In fact, we experienced more tissue being released from the stapler. Due to this property, Echelon plus appeared to have a small twist, but the result was the opposite. The reason why the twist was small in EndGIA may be that the release of tissue was already completed in the process of stapling and the movement of the tissue was small. In contrast, the staple twist was larger toward the inside of the stapler compared to each column in Echelon Plus. One factor was that the knife running in the center of the stapler may be involved in displacement of the tissue.

Slow firing was significantly effective on the staple twist in Echelon Plus. The staple with a twist score = 0 also increased from 13.8% to 27.6%; however, the twist score in normal firing was significantly lower with EndGIA. The basis for this finding may be related to the Adaptive Firing Technology installed in EndGIA. This technology measures the firing force and adjusts the stapler speed based on tissue variability measurements, allowing for consistent staple lines.

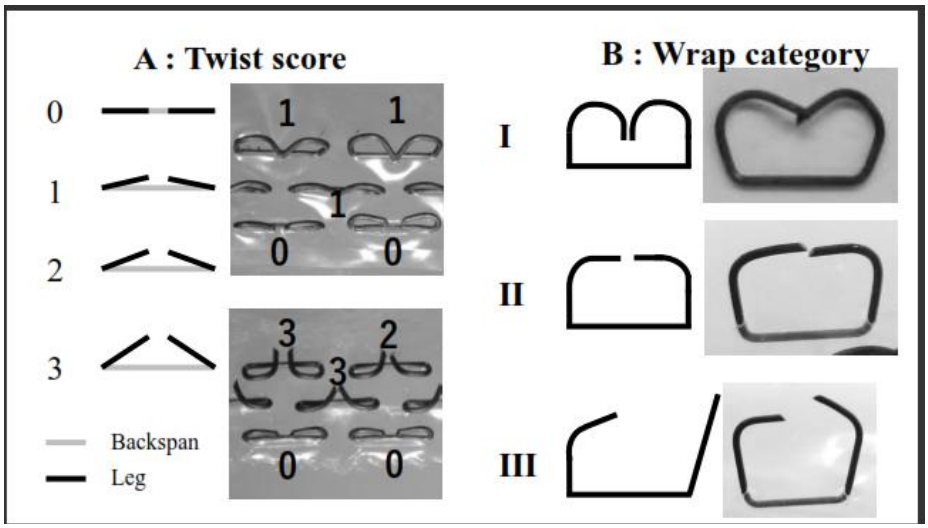

Fig. 2. Malformation of staples and example of the score
A. Twist score, B. Wrap category

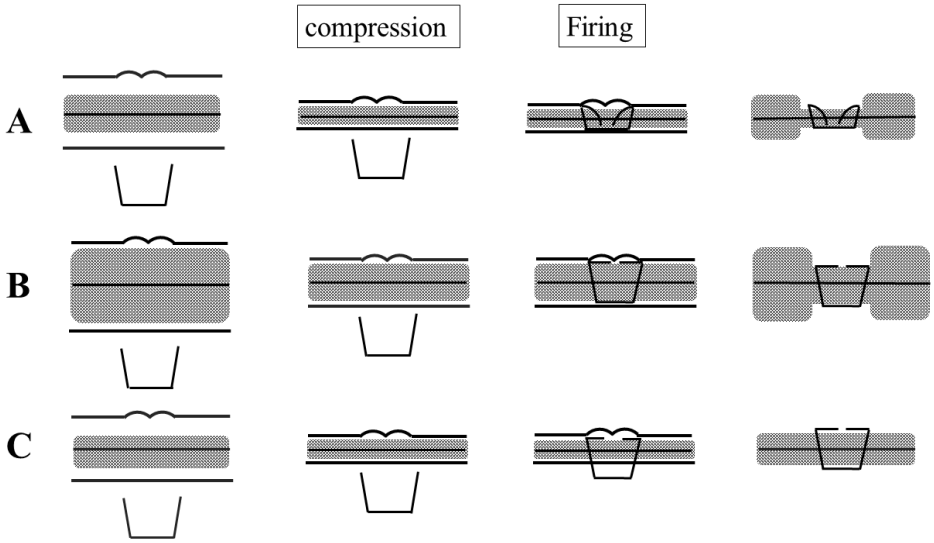

Fig. 3. Schema of stapling procedure in categories Ⅰ and II
A. Category Ⅰ, B. Category IIa, C. Category IIb

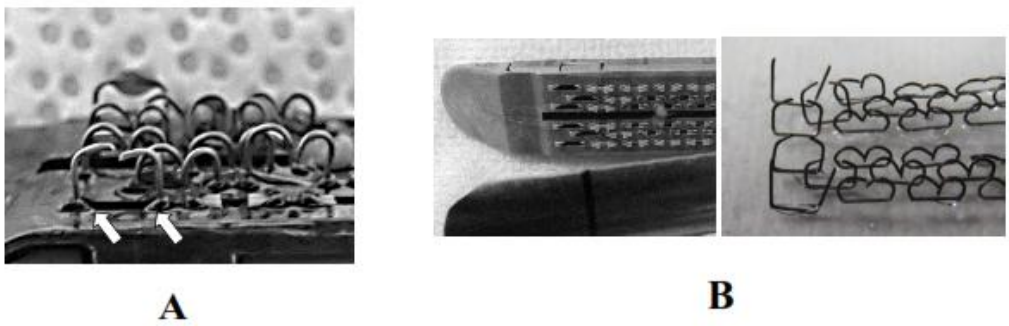

Fig. 4. A. The staple pusher is not raised sufficiently (arrow),
B. The staple pusher with 6 staples on the tip is not raised sufficiently. The 6 staples on the tip are category III

Table 1. Twist score in each group

Twist score	Echelon normal	Echelon slow firing	EndoGIA normal	EndoGIA slow firing
0	121(13.8%)	243(27.6%)	458(50.9%)	489(54.3%)
1	197(22.4%)	237(26.9%)	371(41.2%)	297(33%)
2	279(31.7%)	260(29.5%)	69(7.7%)	112(12.4%)
3	283(32.2%)	140(15.9%)	2(0.2%)	2(0.2%)
P value Normal vs slow firing	<0.01		<0.01	

Table 2. Wrap category in each group

Wrap category	Echelon normal	Echelon slow firing	EndoGIA normal	EndoGIA slow firing
I	861(97.8%)	859(97.6%)	900(100%)	900(100%)
II	6(0.7%)	5(0.6%)	0(0%)	0(0%)
III	13(1.5%)	16(1.8%)	0(0%)	0(0%)
P value Normal vs slow firing	ns		ns	

Next, the degree of folding back (wrap) of the leg to the backspan was evaluated. In general, category Ⅰ is the best, and there are many reports that the shape of the staple is elevated to category Ⅱ in this study; however, we believe that there are two types of staple shape formation processes in category Ⅱ. In one type, the staple shape is formed when the tissue at the time of compression is thick, as shown in Fig. 3B. The staple extruded by the staple pusher from the cartridge penetrated the tissue and reached the anvil pocket, but the leg is not enough to fold back, so the leg becomes parallel to the backspan (category Ⅱa). When the pressure of the tissue by the stapler is released and the thickness of the tissue is restored, the tissue is compressed by the staple. In the other type (category Ⅱ), in which the staple is not sufficiently lifted from cartridge and the length of the leg is relatively short, as in Fig. 3C, there is a possibility that the tissue is not in close contact, even if the pressure on the tissue is released (category Ⅱb). The shapes of the staples formed in Fig. 3B and C are the same, but there is a large difference in the degree of tissue adhesion by the staples.

In this experiment, all staples located on the outermost side of the cutting edge of Echelon Plus were category Ⅱ or Ⅲ. As shown in Fig. 4A, the staple pusher that lifted the staple was not raised sufficiently. In the staples located on the outermost side of the cutting edge, 10 of 20 legs were category Ⅲ in normal firing, but 15 of 20 were category Ⅲ in slow firing. To explore this phenomenon, we performed firing with a manual stapler with GST cartridge. This phenomenon was more pronounced with a manual stapler. Furthermore, in slow firing, the staple pusher does not reach the tip. For that reason, the staple pusher with six staples on the tip could not be lifted sufficiently and the staples became category Ⅲ (Fig. 4B). When all staples are involved in suturing, such as a functional end-to-end anastomosis, sufficient attention should be paid to these phenomena [11].

The length of backspan and staple legs is 3-4 mm. In clinical practice, it is difficult to assess the shape of the formed staples. In addition to staples, blood flow, infection, and patient factors affect complications, such as leakage. There is no doubt that formation of staples will contribute to the complication. It is necessary to fully understand the characteristics of the stapler and staples, and aim for more reliable suture by combining techniques, such as pre-compression and slow firing.

5. CONCLUSION

In this study slow firing reduced the staple twist in Echelon Plus. EndGIA could not confirm the effectiveness of slow firing because of the influence of the installed Adaptive Firing technology. It should be noted that slow firing may result in insufficient wrapping of the leg in Echelon Plus. It is important not to be confused by computer graphics created by the manufacturer, but to fully understand the

characteristics of the stapler. In addition, it is important to select a more secure stapler and cartridge, and to select a firing method.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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