scientific reports

OPEN

Mechanism behind reduced resection ability of bent snares during cold snare polypectomy

Ryohei Hirose[1,2,4✉], Takuma Yoshida[1,4], Naohisa Yoshida[1,4✉], Risa Bandou[3], Hiroshi Ikegaya[3], Takaaki Nakaya[2] & Yoshito Itoh[1]

Accidental bending of the snare sheath occasionally occurs during cold snare polypectomy (CSP). We aimed to demonstrate whether snare bending reduces resection ability and, if it does, what causes this reduction. Using currently available CSP snares and prototype snares, we investigated changes in the resection ability of bent snares as well as the stiffness of their sheaths and wire spindles. Furthermore, to evaluate the performance of the bent snares, we measured the completion rate of CSP for 5-mm-diameter pseudo-lesions on the porcine rectal mucosa. Snare bending significantly decreased resection ability and wire spindle stiffness. Compared with bending the snares once, bending the snares five times further decreased the resection ability and wire spindle stiffness. A strong correlation was observed between wire spindle stiffness and resection ability after snare bending (correlation coefficient = 0.82; $P < 0.001$). Additionally, snare bending reduced the completion rate of CSP. Bending a CSP snare causes decreased wire spindle stiffness, thereby reducing its resection ability and potentially lowering the resection completion rate. The resection ability cannot be restored; therefore, snare replacement is recommended.

Keywords Bent snare, Cold snare polypectomy, Resection ability, Stiffness

Cold snare polypectomy (CSP) is widely used to bluntly resect polyps because of its high safety profile[1–7]. However, CSP is associated with a less effective resection ability compared to that of endoscopic mucosal resection (EMR), which utilizes energization for resection. Occasionally, during CSP, the cold snare can become stuck and fails to resect, resulting in the need to switch to EMR[1,5].

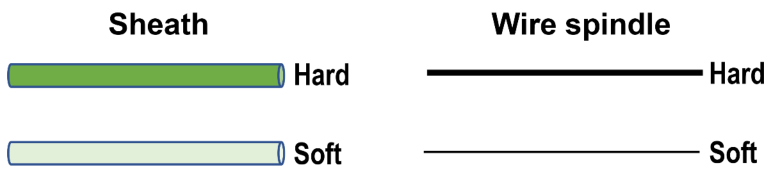
When multiple polyps are resected, the CSP snare must be inserted several times through the instrument channel port. Accidental bending of the snare sheath during insertion occasionally occurs, thus decreasing the snare performance; however, it remains unclear whether snare bending reduces the resection ability. Additionally, there is no consensus regarding whether CSP can be continued with a bent snare or whether the bent snare should be replaced with a new snare.

In this study, using currently available CSP snares and prototype snares, we aimed to demonstrate that snare bending reduces the ability to resect polyps (Fig. 1). We recently revealed a strong correlation between the resection ability and stiffness of the sheath and wire spindle[8]. To elucidate the mechanism underlying the reduced resection ability of bent CSP snares, we investigated whether the changes in the resection ability of the bent snare were related to the stiffness of its sheath and wire spindle.

Results

When the snares were bent during snare insertion, both the sheath and the wire spindle inside the sheath were bent (Fig. 2). Snare bending significantly decreased the wire spindle stiffness. Additionally, compared with bending the snare once, bending the snare five times further decreased the wire spindle stiffness (Fig. 3A). Specifically, regarding the Exacto cold snare, Captivator cold snare, Micro-Tech cold snare, SnareMaster Plus snare, and hard/hard and hard/soft prototype snares (numbers 1 and 2, respectively), after bending once and after bending five times, their wire spindle stiffness was significantly lower than that of snares that had not been bent ($P < 0.001$ for all). Moreover, regarding the soft/hard and soft/soft prototype snares (numbers 3 and 4,

[1]Department of Molecular Gastroenterology and Hepatology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, 465 Kajii-cho, Kawaramachi-Hirokoji, Kamigyo-ku, Kyoto 602-8566, Japan. [2]Department of Infectious Diseases, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan. [3]Department of Forensic Medicine, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan. [4]Ryohei Hirose, Takuma Yoshida, and Naohisa Yoshida contributed equally to this work. ✉email: ryo-hiro@koto.kpu-m.ac.jp; naohisa@koto.kpu-m.ac.jp



Parts configuration of prototype snares

Snare No.	Wire spindle	Sheath
1	Hard	Hard
2	Hard	Soft
3	Soft	Hard
4	Soft	Soft

Fig. 1. Prototype snares. The four prototype snares with different characteristics of each component were prepared.

respectively), after bending five times, the wire spindle stiffness was significantly lower than that of snares that had not been bent ($P < 0.001$ for all). In contrast, snare bending minimally affected the sheath stiffness (Fig. 3B).

Snare bending significantly increased the force required to resect (FRR) a 15-mm-wide human colonic mucosa and decreased the resection ability of commercially available CSP snares. Bending the snare five times significantly increased the FRR and decreased its resection ability compared with those of snares that had been bent only once (Fig. 4). The FRRs of Exacto cold snares increased from 6.5 ± 1.0 N to 20.5 ± 1.8 N and 31.3 ± 1.6 N after bending once and after bending five times, respectively. Furthermore, the FRRs of Captivator cold snares increased from 7.4 ± 1.2 N to 22.1 ± 2.2 N and 30.9 ± 1.7 N, those of Micro-Tech cold snares increased from 12.5 ± 1.2 N to 20.1 ± 1.1 N and 28.2 ± 1.4 N, and those of SnareMaster Plus snares increased from 13.6 ± 1.0 N to 23.6 ± 1.5 N and 33.7 ± 1.4 N after bending once and after bending five times, respectively. The same trend was observed for the four prototype snares, with a more pronounced reduction in resection ability after bending and high stiffness of the wire spindle (numbers 1 and 2) (Fig. 4). The FRRs of the Exacto cold snare, Captivator cold snare, Micro-Tech cold snare, SnareMaster Plus snare, and hard/hard and hard/soft prototype snares (numbers 1 and 2, respectively) after bending once and after bending five times were significantly higher than those of snares that were not bent ($P < 0.001$ for all). Moreover, the FRRs of soft/hard and soft/soft prototype snares (numbers 3 and 4, respectively) after bending five times were significantly higher than those of snares that were not bent ($P < 0.001$ for all).

Decreased wire spindle stiffness resulting from snare bending reduced resection ability, and a strong correlation was observed between wire spindle stiffness and resection ability after snare bending (correlation coefficient = 0.82; $P < 0.001$) (Fig. 5A). In contrast, no correlation was observed between sheath stiffness and resection ability after snare bending (correlation coefficient = 0.46; $P < 0.001$) (Fig. 5B).

Snare bending also reduced the completion rate of CSP for pseudo-lesions on the porcine rectal mucosa (Fig. 6 and Supplementary Table S1). The resection completion rates of Exacto cold snares decreased from 100% ± 0.0–80.0% ± 20.0% and 66.7% ± 11.5% after bending once and after bending five times, respectively. The resection completion rates of Captivator cold snares decreased from 100% ± 0.0–86.7% ± 11.5% and 73.3% ± 11.5%, those of Micro-Tech cold snares decreased from 93.3% ± 11.5–80.0% ± 20.0% and 73.3% ± 11.5%, and those of SnareMaster Plus snares decreased from 93.3% ± 11.5–80.0% ± 0.0% and 73.3% ± 11.5% after bending once and after bending five times, respectively. Bending the snare five times significantly decreased the resection completion rates of Exacto cold snares and Captivator cold snares ($P = 0.008$ and $P = 0.016$, respectively).

Discussion

When multiple polyps are resected during endoscopic treatment, the CSP snare must be inserted numerous times, thus increasing the risk of accidental bending of the snare sheath, which decreases snare performance. We investigated the changes in the stiffness of bent snare sheaths and wire spindles and their effects on resection ability.

Snare resection ability decreased with an increasing number of bends; bending only once significantly reduced the resection ability of the currently available CSP snares. Therefore, continuation of CSP with a bent snare is not recommended because it may cause an increased incidence of stuck lesions and a reduced resection completion rate. Our evaluation of CSP for pseudo-lesions on the porcine rectal mucosa showed that reduced resection ability may reduce the resection completion rate and increase the incidence of stuck lesions. Sheath stiffness remained almost unchanged after bending; however, the wire spindle stiffness decreased with increased bending. Our previous study revealed that the stiffness of the sheath and that of the wire spindle are factors that determine the resection ability of CSP snares[8]. The present study revealed that when a CSP snare is bent during endoscopic treatment, its resection ability is reduced because of the resulting reduction in the stiffness of the wire spindle; this resection ability cannot be restored. Because the wire spindle inside the sheath is the main cause of reduced resection ability, if the snare is accidentally bent, then replacement with a new snare should be

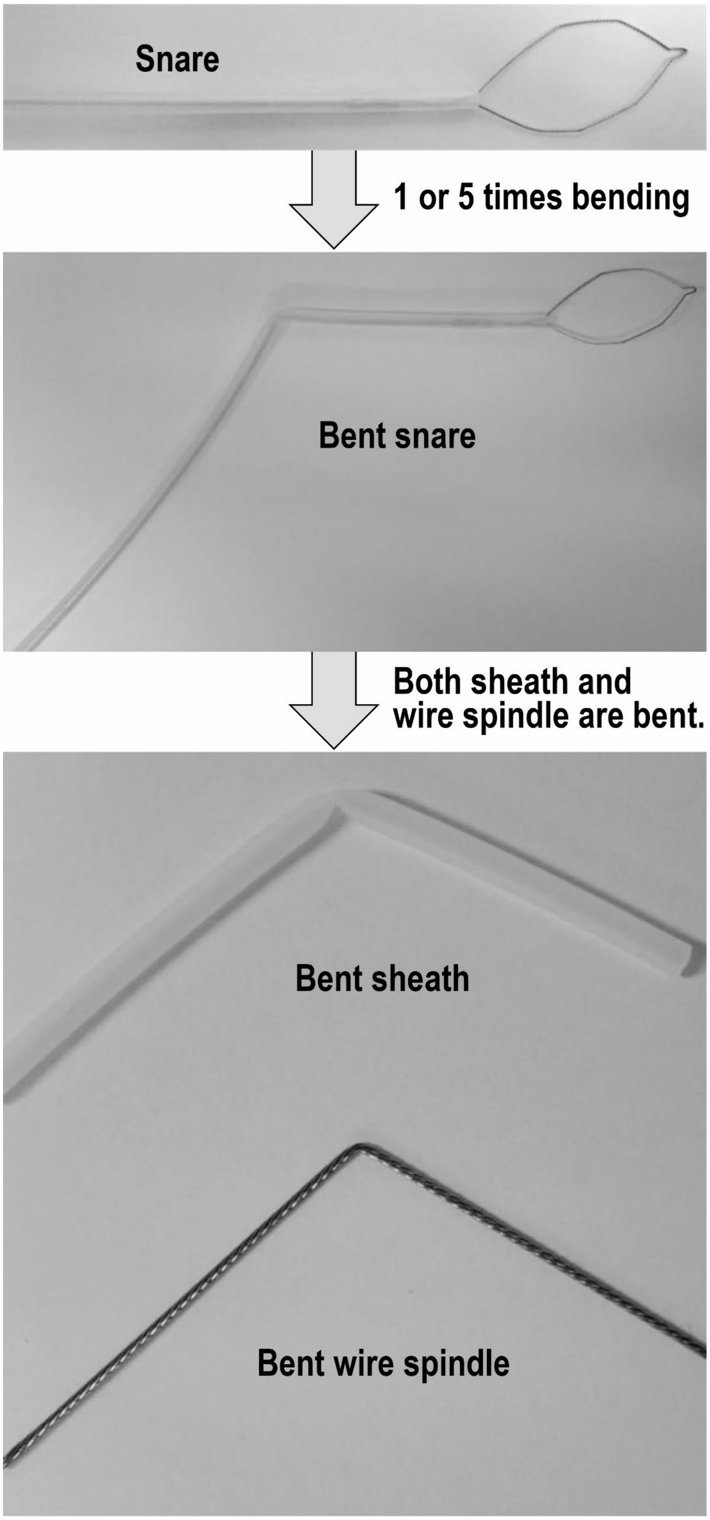


Fig. 2. Bent snare. The sheath portion of the snare is sometimes accidentally bent when the snare is inserted through the instrument channel port. When the sheath portion of a snare is bent, the sheath and wire spindle inside the sheath are bent simultaneously.

considered before continuing CSP. Modifying the bent sheath with methods such as reinforcement with tape will not restore the resection ability.

During the analysis of prototype snares, the reduction in resection ability caused by snare bending was more pronounced in snares with wire spindles with high stiffness and high resection ability (numbers 1 and 2); this was also true for the current CSP snares. In contrast, the reductions in wire spindle stiffness and resection ability

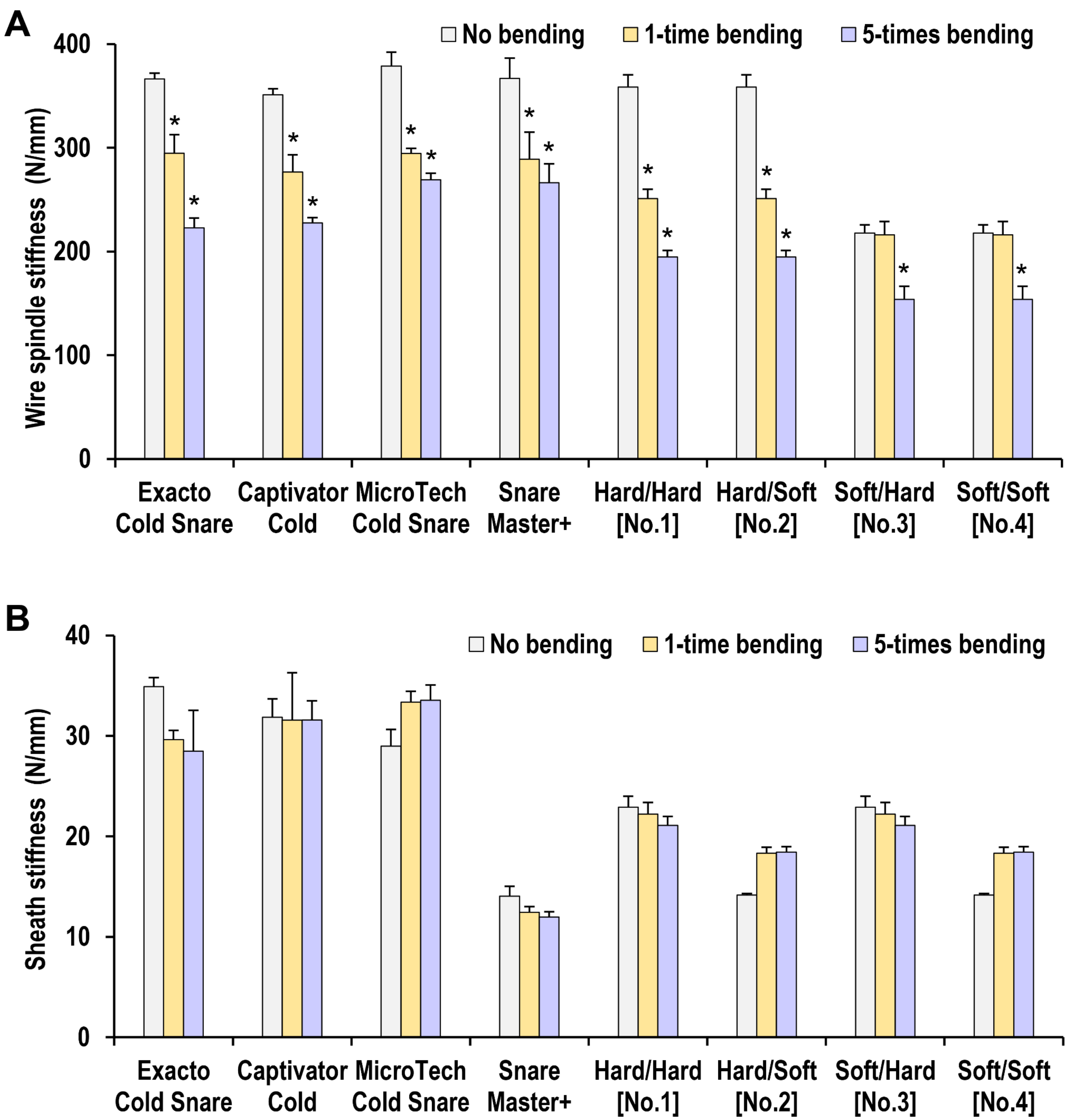


Fig. 3. Measurement of wire spindle stiffness of the snares bent one time or five times (**A**) and measurement of sheath stiffness of the snares bent one time or five times (**B**). Data are expressed as the mean ± standard error of at least five independent experiments. The prototype snare is denoted as follows: wire spindle (soft or hard) / sheath (soft or hard). *$P < 0.001$ (versus no bending).

caused by bending the snare one time were minor for prototype snares with wire spindles with low stiffness (numbers 3 and 4). However, these prototype snares had low resection ability before bending because their wire spindle stiffness was low; therefore, they were not very practical.

Although bending may also reduce the wire spindle stiffness of EMR snares, the reduction in blunt resection ability does not interfere with the procedures or outcomes of EMR, which involves resecting polyps using a current and a snare. Thus, snare bending is a serious concern inherent to CSP, but not to conventional EMR.

This study had some limitations. The resection ability and friction measurement models were generated using colons obtained from forensic autopsy specimens within 12 h of death; therefore, the colons may not have represented the same conditions as those of living individuals. Despite this, these colon models provide the best current results because these measurements cannot be performed in vivo.

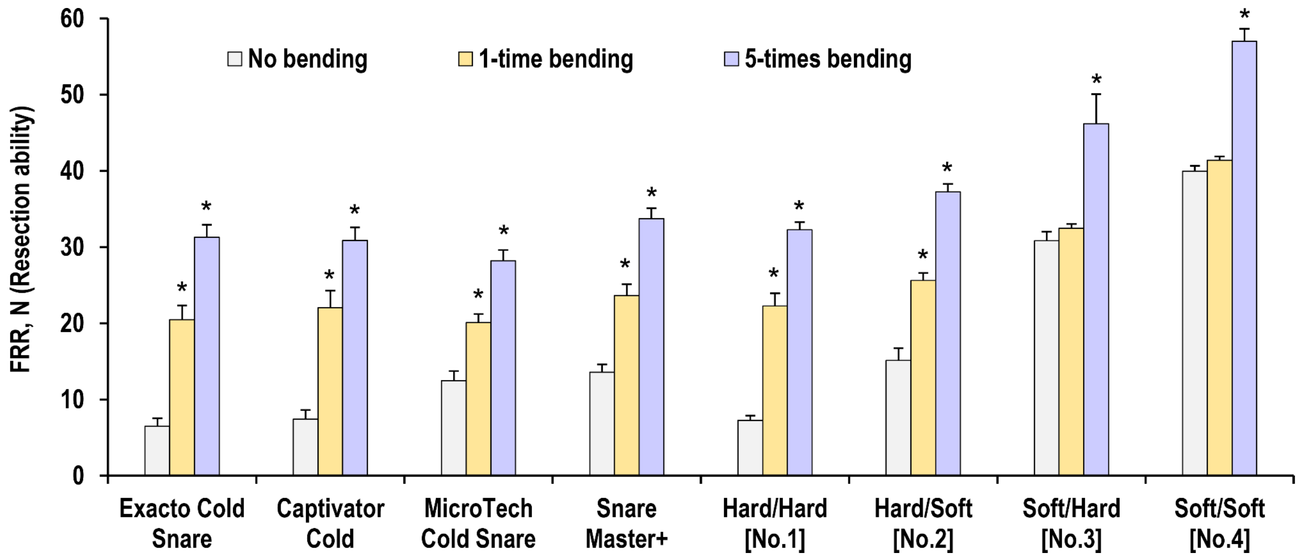


Fig. 4. Measurement of force required for resection (FRR) of the snares bent one time or five times. Data are expressed as the mean ± standard error of at least five independent experiments. The prototype snare is denoted as follows: wire spindle (soft or hard) / sheath (soft or hard). *$P < 0.001$ (versus no bending).

In conclusion, when a CSP snare is bent, its resection ability is reduced because of the reduced stiffness of the wire spindle, and this ability cannot be restored. This reduced resection ability may lower the resection completion rate of CSP and increase the incidence of stuck lesions. Therefore, endoscopists should avoid bending CSP snares during treatment. Replacement of the snare is recommended if bending occurs.

Methods

Preparation of snares

We prepared currently available CSP snares, including the Exacto cold snare (US Endoscopy, Mentor, OH, USA), Captivator cold single-use snare (Boston Scientific, Marlborough, MA, USA), Micro-Tech cold snare (Micro-Tech, Nanjing, China), and SnareMaster Plus snare (Olympus, Tokyo, Japan). Prototype snares were also prepared, including hard and soft versions of both the sheath and wire spindle. Four prototype snares were developed by combining these features (Fig. 1). The soft and hard sheaths were made of Teflon and high-density polyethylene, respectively, whereas the wire spindles were made of stainless steel.

Each target snare was bent approximately 120 degrees at a point 10 cm from the sheath tip. The same procedure was repeated when bending the snare multiple times. The bent snares were manually returned to their original shape (i.e., straight) before the start of each evaluation.

Evaluation of the resection ability

The FRR to resect a 15-mm-wide human colonic mucosa was measured as an indicator of resection ability using a previously constructed model[8,9]. A length of 15 mm corresponds to a circumference of a polyp with a diameter of 4.8 mm, and this assessment reproduced the CSP situation for diminutive colon polyps with a diameter of approximately 4–5 mm. Colon specimens collected after forensic autopsies at the Department of Forensic Medicine at the Kyoto Prefectural University of Medicine were cut open and flattened, and only the mucosal layer was detached. The detached mucosal layer was stretched and excised as 15-mm-wide strips that were resected using a target snare. The force required to push the snare handle during resection was measured using a force gauge (ZTA-500 N; IMADA, Aichi, Japan), and the maximum force was defined as the FRR. The FRR reflected the resection ability of the snare. If the FRR was low, then the resection ability was considered high. Data are expressed as means ± standard errors. Calculations were performed after at least five independent experiments.

Measurement of the wire spindle stiffness and sheath stiffness

The stiffness of the wire spindles and that of the sheaths were assessed using a force tester (MCT-2150; A&D Systems, Tokyo, Japan) following previously established methods[8–10]. The 5-cm wire spindles were subjected to a tensile test by attaching a jig to the wire tip. The load required to stretch a 1-mm wire in the elastic region was calculated based on the data obtained (MSAT-Lite, A&D). This value was used as an index of wire spindle stiffness. To obtain the load value used as an index of sheath stiffness, a titanium rod was passed through the sheath lumen to prevent deflection of the sheath, and a 5-cm sheath was set so that it could be pushed only with an attached jig. A compression test was performed, and the load required to compress a 1-mm sheath in the elastic region was calculated based on the data obtained.

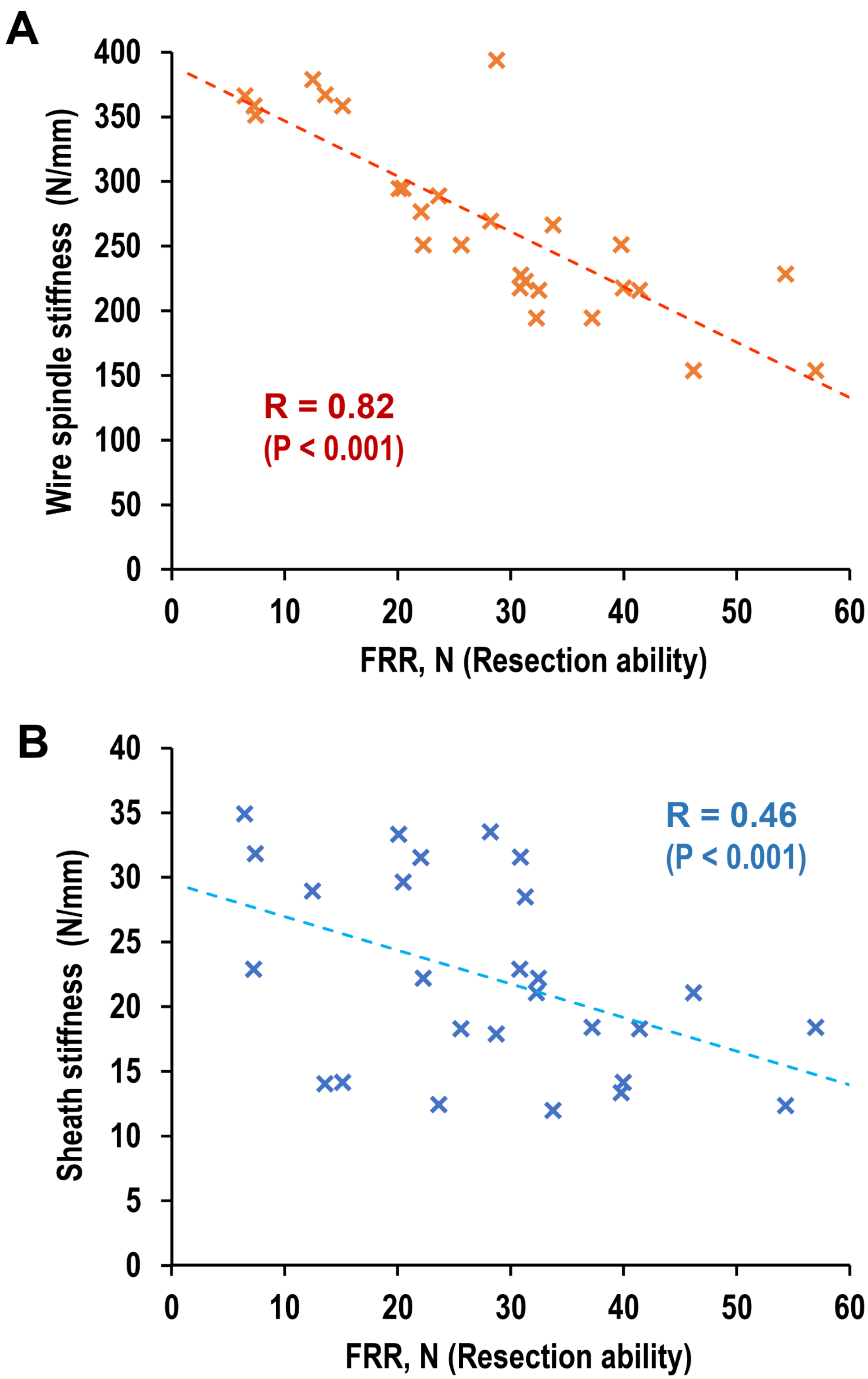


Fig. 5. Correlation analysis of the force required for resection (FRR) and wire spindle stiffness (**A**) and correlation analysis of the FRR and sheath stiffness (**B**). Pearson's correlation coefficient was used to evaluate the correlations.

CSP for pseudo-lesions on the porcine rectal mucosa

To evaluate the performance of bent snares, CSP was performed for pseudo-lesions using porcine rectums. Rectums were harvested from 6-month-old domestic hybrid female pigs, frozen immediately, and thawed at room temperature 6 h prior to each experiment[11]. A pseudo-lesion with a 5-mm diameter was created on the rectal mucosa, and CSP using currently available snares was performed. Two endoscopists (two experts with

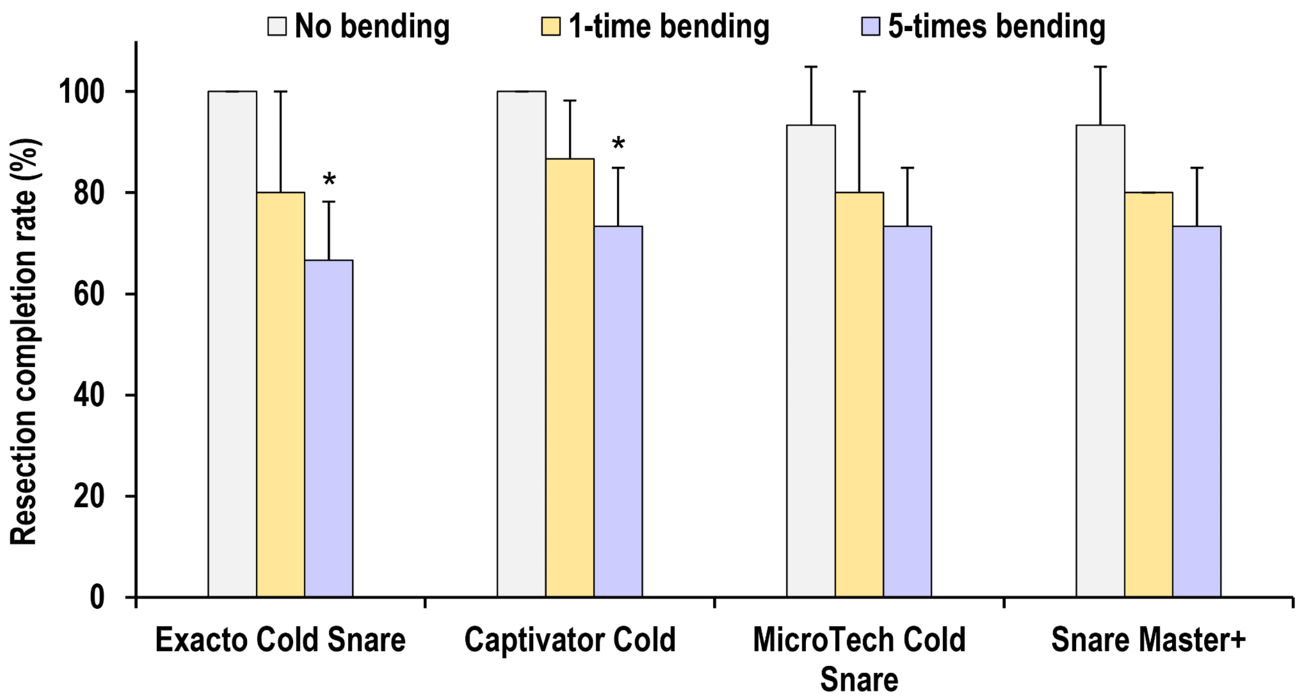


Fig. 6. Resection completion rate of cold snare polypectomy using snares bent one time or five times. To evaluate the performance of the bent snares, cold snare polypectomy was performed for a 5-mm-diameter pseudo-lesion using a porcine rectum, and the resection completion rate was calculated. The resection completion rate was defined as the percentage of pseudo-lesions that could be resected with a snare without becoming stuck. Pathological evaluations were not included because pseudo-lesions were targeted. Data are expressed as means ± standard errors. **P* < 0.05 (versus no bending). See also Supplementary Table S1 for detailed data.

experience performing ≥ 5,000 colonoscopies) conducted all CSPs and were not informed prior to CSP about the type of snare and whether it was bent. CSP was performed five times, and the resection completion rate was calculated. The resection completion rate was defined as the percentage of pseudo-lesions that could be resected with a snare without becoming stuck. Pathological evaluations were not included because pseudo-lesions were targeted. This analysis was conducted thrice. Data are expressed as means ± standard deviations.

Ethical considerations
The study protocol, including the sample collection procedures, was reviewed and approved by the Institutional Review Board of the Kyoto Prefectural University of Medicine (ERB-C-2573). In addition, all methods were carried out in accordance with relevant guidelines and regulations, and are reported in accordance with ARRIVE guidelines.

Statistical analysis
Data were analyzed using GraphPad Prism 7 (GraphPad Inc., La Jolla, CA, USA). Pearson's correlation coefficient was used to evaluate the correlation between the FRR and the stiffnesses of the wire spindles and sheaths. Continuous variables were assessed using Student's t-test. Statistical significance was set at $P < 0.05$ (two-sided).

Data availability
All data included in this study are available from the corresponding author on request.

Received: 18 September 2024; Accepted: 4 December 2024
Published online: 28 December 2024

References
1. Ishibashi, F., Suzuki, S., Nagai, M., Mochida, K. & Morishita, T. Colorectal cold snare polypectomy: current standard technique and future perspectives. *Dig. Endosc Off J. Jpn Gastroenterological Endosc Soc.* **35**, 278–286. https://doi.org/10.1111/den.14420 (2022).
2. Horiuchi, A. et al. Prospective, randomized comparison of 2 methods of cold snare polypectomy for small colorectal polyps. *Gastrointest. Endosc.* **82**, 686–692. https://doi.org/10.1016/j.gie.2015.02.012 (2015).
3. Horiuchi, A., Ikuse, T. & Tanaka, N. Cold snare polypectomy: indications, devices, techniques, outcomes and future. *Dig. Endosc.* **31**, 372–377. https://doi.org/10.1111/den.13314 (2019).
4. Uraoka, T. et al. Guidelines for colorectal cold polypectomy (supplement to guidelines for colorectal endoscopic submucosal Dissection/Endoscopic mucosal resection). *Dig. Endosc.* **34**, 668–675. https://doi.org/10.1111/den.14250 (2022).

5. Uraoka, T., Ramberan, H., Matsuda, T., Fujii, T. & Yahagi, N. Cold polypectomy techniques for diminutive polyps in the colorectum. *Dig. Endosc.* **26 Suppl 2**, 98–103. https://doi.org/10.1111/den.12252 (2014).
6. Horiuchi, A. et al. Removal of small colorectal polyps in anticoagulated patients: a prospective randomized comparison of cold snare and conventional polypectomy. *Gastrointest. Endosc.* **79**, 417–423. https://doi.org/10.1016/j.gie.2013.08.040 (2014).
7. Saito, Y. et al. Colonoscopy screening and surveillance guidelines. *Dig. Endosc.* **33**, 486–519. https://doi.org/10.1111/den.13972 (2021).
8. Hirose, R. et al. Factors determining the resection ability of snares in cold snare polypectomy: construction of an ex vivo model for accurately evaluating resection ability. *Dig. Endosc.* **36**, 573–581. https://doi.org/10.1111/den.14676 (2024).
9. Hirose, R. et al. High-performance dedicated snares with tip attachments can overcome current disadvantages in cold snare polypectomy. *Adv. Mater. Technol.* 2401055 in press. (2024). https://doi.org/10.1002/admt.202401055
10. Schummer, W. Different mechanical properties in Seldinger guide wires. *J. Anaesthesiol. Clin. Pharmacol.* **31**, 505–510. https://doi.org/10.4103/0970-9185.169076 (2015).
11. Hirose, R. et al. An innovative next-generation endoscopic submucosal injection material with a 2-step injection system (with video). *Gastrointest. Endosc.* 93, 503–513.e5 (2021). https://doi.org/10.1016/j.gie.2020.06.031

Acknowledgements

The authors thank Top Corporation for the production of prototype snares. We also thank Editage (www.editage.com) for English language editing and all members of Molecular Gastroenterology and Hepatology, Kyoto Prefectural University of Medicine, for assistance with the study.

Author contributions

RH, TY, and NY contributed equally.Study concept and design: RH. Acquisition of data: RH, TY, NY, and RB. Data analysis and interpretation: RH, TY, and NY. Drafting of the manuscript: RH, TY, and NY. Critical revision of the manuscript for intellectual content: RH. Statistical analysis: RH. Secured funding: RH. Administrative/technical/material support: RH, RB, HI, TN, and YI. Study supervision: RH.

Funding

This work was supported by "The Translational Research program; Strategic PRomotion for practical application of INnovative medical Technology (TR-SPRINT)."

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-82365-z.

Correspondence and requests for materials should be addressed to R.H. or N.Y.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

© The Author(s) 2024