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Continuous barbed versus interrupted extraction-site fascial closure in minimally invasive colorectal surgery: closure time and suture cost

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Keywords

Barbed suture; Fascial closure; Minimally invasive colorectal surgery; Specimen extraction site; Operative time; Cost

Abstract

Purpose

Fascial closure of the umbilical extraction site is the final step of minimally invasive colorectal resection. Two 2026 cohort studies reported that continuous barbed closure of this incision reduces incisional hernia, but neither quantified its cost in operative time or materials. We compared closure time and suture cost between continuous knotless barbed and simple interrupted closure.

Methods

We retrospectively studied 219 consecutive patients undergoing elective minimally invasive colorectal cancer resection at a single centre (January 2024 to July 2025). The knotless barbed suture was introduced in January 2025 and used for the next 27 eligible patients; others underwent interrupted closure with conventional 0 polydioxanone. Each was matched 1:1 (Mahalanobis distance) to a contemporaneous interrupted closure. The primary endpoint was fascial closure time.

Results

Twenty-seven pairs were formed, with balanced follow-up (12.0 vs 12.2 months, $p = 0.355$). Median closure time was 5 min 15 s versus 10 min 25 s (median difference −5 min 17 s, 95% CI −7 min 26 s to −3 min 55 s; $p < 0.001$); interquartile width fell from 5 min 36 s to 1 min 58 s. Barbed closure used one suture pack in all 27 patients versus two packs in 18 of 22 interrupted

closures with retrievable records (mean cost ¥6,168 vs ¥7,924; US$39 vs US$50). Incisional hernia occurred in 2 versus 1 patients.

Conclusion

Continuous knotless barbed closure halved fascial closure time, made it more reproducible, and reduced suture cost. With three hernia events in 54 patients this cohort cannot compare safety, and no equivalence is claimed.

Introduction

Minimally invasive colorectal resection requires a short mini-laparotomy, usually a transumbilical incision of about 5 cm, through which the specimen is delivered. Closing the fascia at this extraction site is the last technical step of the operation, and it is performed in a deep, narrow field at the point when the operating team is most fatigued. Despite being a near-universal step, the optimal closure technique for this specific incision is not defined. Guidelines for abdominal wall closure derive almost entirely from full-length midline laparotomy, where the mechanical demands, the achievable suture-to-wound length ratio and the exposure all differ substantially from those of a 5-cm umbilical incision [1, 2]. Meta-analyses comparing continuous with interrupted closure of midline incisions have found no consistent difference in incisional hernia or wound infection, with continuous closure being the faster of the two [3, 4]; whether this transfers to a 5-cm extraction site is unknown.

Knotless barbed sutures distribute tension along the whole suture line without requiring manual tension maintenance or knot tying, which is precisely what is difficult in a small, deep incision. Across abdominal surgery generally, meta-analyses report that barbed closure reduces surgical site infection and shortens hospital stay without increasing fascial complications [5, 6]. Three cohort studies published in 2026 have now reported that continuous barbed closure of this

particular incision reduces incisional hernia compared with interrupted non-barbed closure: a propensity score-matched series [7], a consecutive single-surgeon series [8], and a computed tomography-based matched analysis in which the 12-month extraction-site hernia rate was 10.1% versus 32.9% [9]. What has not been quantified is the procedural cost of the two techniques: how much operative time each consumes, how reproducible that time is between cases, and what each strategy costs in suture material. These are the variables a surgical unit actually uses when deciding whether to adopt a more expensive device.

We therefore compared continuous knotless barbed closure with simple interrupted closure of the extraction site in a consecutive single-centre cohort, taking fascial closure time as the primary endpoint and suture cost per patient as a secondary endpoint. Surgical site infection and incisional hernia were recorded and are reported descriptively, together with the precision limits this cohort can achieve.

Materials and methods

Patients

This retrospective cohort study included 220 consecutive patients who underwent elective minimally invasive colorectal resection at Osaka Metropolitan University Hospital between January 2024 and July 2025. One patient, operated for sigmoid diverticular disease with stricture rather than for cancer, was excluded, leaving 219 patients with colorectal cancer. The study was approved by the institutional review board (approval number 4383) and conducted in accordance with the Declaration of Helsinki. The requirement for written informed consent was waived because of the retrospective design; an opt-out notice was posted on the institutional website.

Procedures

All procedures were performed by four board-certified surgeons. The specimen was delivered through a transumbilical mini-laparotomy standardised to 5 cm unless the tumour was exceptionally bulky, in which case the incision was extended and this was recorded.

The knotless barbed suture (STRATAFIX Symmetric PDS Plus, catalogue number SXPP1B407; Ethicon, Johnson & Johnson) was introduced at our institution in January 2025 and was used for the next 28 consecutive eligible patients, of whom 27 met the inclusion criteria. All other patients underwent simple interrupted closure with conventional 0 polydioxanone (0-PDS Plus, catalogue number PDPB740D). Both sutures are absorbable polydioxanone products from the same manufacturer, so the comparison is between two closure strategies rather than between vendors. Unit prices are given in Table 3. Interrupted closure remained in concurrent use throughout the period in which the barbed suture was available, so the two techniques were not separated in time. The technique was chosen by the operating surgeon rather than by patient characteristics: surgeons who had adopted the barbed suture used it as their default closure, and it accounted for 27 of the 73 closures performed during the period in which the barbed group was operated.

For both techniques the suture pitch was 5 mm, the tissue bite was 5 mm from the fascial edge, and a suture-to-wound length ratio of at least 4:1 was maintained, following the small-bites principle [10, 11].

Endpoints and definitions

The primary endpoint was fascial closure time, measured from the first fascial bite to completion of the closure. Secondary endpoints were suture cost per patient, surgical site infection, incisional hernia, postoperative complications and length of stay.

Surgical site infection was defined by the CDC/NHSN criteria [12]. Incisional hernia was defined, in accordance with the European Hernia Society, as any abdominal wall defect at the scar detectable clinically or on imaging; in this study a fascial defect of 10 mm or more on computed tomography was recorded as positive irrespective of symptoms [1]. Follow-up was calculated from the date of surgery to the date of the last computed tomography. Postoperative complications were graded by the Clavien–Dindo classification [13] and are reported at both the grade ≥2 and grade ≥3 thresholds, since neither was pre-specified for this analysis.

Suture cost

Cost was calculated from the institutional purchase price per pack: ¥74,021 per box of 12 packs for the barbed suture (¥6,168.4 per pack) and ¥52,300 per box of 12 packs for the conventional suture (¥4,358.3 per pack). Amounts are also given in US dollars, converted at ¥158.13 to US$1, the rate on 24 September 2026. Cost per patient was the unit price multiplied by the number of packs opened. The number of packs was retrievable from the operative record for all 27 barbed cases and for 22 of the 192 interrupted cases; operative notes were no longer held for the remaining interrupted cases, so availability of the record, and not any clinical feature, determined which cases could be costed. The cost analysis is restricted to these 49 patients. Only suture material was counted; operating theatre time was not monetised.

Statistical analysis

Each barbed case was matched 1:1, without replacement, to a patient who underwent interrupted closure **during the period in which the barbed suture was in use** (12 February to 22 July 2025, 46 eligible patients). Restricting the control pool to this period was pre-planned for the present analysis in order to balance follow-up duration: interrupted closure was used throughout the whole study period, and most interrupted cases preceded the introduction of the barbed

suture. Using the whole pool left the control group with more than five months of additional follow-up (12.0 vs 17.7 months, $p < 0.001$), which would bias a time-dependent endpoint such as incisional hernia. As a sensitivity analysis the control window was instead anchored to the date the device first became available (15 January 2025, the date of the excluded non-cancer case), which enlarged the pool to 58 patients; this yielded the same 27 pairs' worth of events and a closure-time difference of −5 min 07 s (95% CI −6 min 58 s to −3 min 47 s, $p < 0.001$), with slightly poorer covariate balance.

Matching used the Mahalanobis distance across sex, age, body mass index, ASA physical status, diabetes, steroid use and clinical stage. Nearest-neighbour matching on the logit of the propensity score estimated from the same covariates was also examined but left a standardised mean difference of 0.301 for body mass index, and calipers between 0.05 and 0.50 standard deviations did not bind; the Mahalanobis distance achieved better balance and was therefore used. Balance was assessed by standardised mean differences, with values below 0.1 taken to indicate adequate balance [14].

Continuous variables are given as median (interquartile range) and were compared with the Mann–Whitney U test; for closure time the Hodges–Lehmann median difference and its 95% confidence interval are also reported. Categorical variables are given as n (%) and were compared with Fisher's exact test, with absolute risk differences and 95% confidence intervals calculated by the Newcombe hybrid-score method [15]. Analyses were performed in R 4.4.1 with the Matching (4.10.15) and tableone (0.13.2) packages; the random seed for tie-breaking during matching was 20260922. A two-sided p value below 0.05 was considered significant.

Results

Cohort and matching

Of 219 patients, 27 underwent continuous barbed closure and 192 interrupted closure. Forty-six patients underwent interrupted closure during the period spanned by the barbed group, and all 27 barbed cases were matched within this pool. After matching, diabetes and steroid use were identical between groups (standardised mean difference 0.000) and sex was closely balanced (0.076); the largest remaining imbalances were clinical stage (0.160), ASA physical status (0.134) and body mass index (0.109) (Table 1). Median follow-up was 12.0 months (IQR 8.4–12.9) after barbed closure and 12.2 months (IQR 11.8–12.9) after interrupted closure (p = 0.355). Across the whole cohort, eight patients had no postoperative computed tomography at our institution because they were followed up elsewhere; four of these were in the matched barbed group.

Table 1. Baseline characteristics before and after matching

	Unmatched				**Matched**			
	Barbed (n=27)	Interrupted (n=192)	p	SMD	Barbed (n=27)	Interrupted (n=27)	p	SMD
Female sex	11/27 (40.7%)	70/192 (36.5%)	0.675	0.088	11/27 (40.7%)	10/27 (37.0%)	1.000	0.076
Age (years)	69.0 (61.5–80.5)	74.0 (64.0–79.0)	0.394	0.199	69.0 (61.5–80.5)	71.0 (63.5–77.5)	0.729	0.082
BMI (kg/m²)	21.2 (19.1–24.1)	22.4 (20.1–24.8)	0.192	0.222	21.2 (19.1–24.1)	22.6 (20.7–24.8)	0.416	0.109
ASA physical status	2.0 (2.0–3.0)	2.0 (2.0–3.0)	0.404	0.165	2.0 (2.0–3.0)	2.0 (2.0–2.5)	0.580	0.134
Diabetes mellitus	5/27 (18.5%)	33/192 (17.2%)	0.791	0.035	5/27 (18.5%)	5/27 (18.5%)	1.000	0.000
Steroid use	0/27 (0.0%)	4/192 (2.1%)	1.000	0.206	0/27 (0.0%)	0/27 (0.0%)	1.000	0.000
Clinical stage	3.0 (1.0–3.0)	2.0 (1.0–3.0)	0.380	0.180	3.0 (1.0–3.0)	2.0 (1.0–3.0)	0.575	0.160

Continuous variables are median (interquartile range). SMD, standardised mean difference.

Fascial closure time

Median fascial closure time was 5 min 15 s (IQR 4 min 14 s – 6 min 12 s) with continuous barbed closure and 10 min 25 s (IQR 8 min 19 s – 13 min 54 s) with interrupted closure (Hodges–Lehmann median difference −5 min 17 s, 95% CI −7 min 26 s to −3 min 55 s; $p < 0.001$) (Table 2, Fig. 1a). The interquartile width of closure time narrowed from 5 min 36 s with interrupted closure to 1 min 58 s with barbed closure.

Table 2. Operative and postoperative outcomes (matched cohort, 27 per group)

	Barbed	**Interrupted**	**Difference (95% CI)**	**p**
Open approach	1/27 (3.7%)	4/27 (14.8%)	−11.1 pp (−29.0 to +6.0)	0.351
Operating time (min)	263.0 (220.5–355.5)	246.0 (184.5–412.5)	17.0	0.500
Blood loss (g)	3.0 (2.0–15.0)	30.0 (3.0–45.0)	−27.0	0.062
Stoma creation	2/27 (7.4%)	1/27 (3.7%)	+3.7 pp (−11.8 to +20.0)	1.000
Incision extension	2/27 (7.4%)	3/27 (11.1%)	−3.7 pp (−21.5 to +13.8)	1.000
Fascial closure time	**5:15 (4:14–6:12)**	**10:25 (8:19–13:54)**	**−5:17 (−7:26 to −3:55)**	**<0.001**
Postoperative stay (days)	11.0 (10.0–13.0)	12.0 (10.5–14.0)	−1.0	0.181
Surgical site infection	1/27 (3.7%)	0/27 (0.0%)	+3.7 pp (−9.1 to +18.3)	1.000
Incisional hernia	2/27 (7.4%)	1/27 (3.7%)	+3.7 pp (−11.8 to +20.0)	1.000
Complications (CD ≥2)	3/27 (11.1%)	0/27 (0.0%)	+11.1 pp (−3.3 to +28.1)	0.236
Complications (CD ≥3)	1/27 (3.7%)	0/27 (0.0%)	+3.7 pp (−9.1 to +18.3)	1.000
Follow-up (months)	12.0 (8.4–12.9)	12.2 (11.8–12.9)	−0.3	0.355

Closure time is min:s. pp, percentage points; CD, Clavien–Dindo.

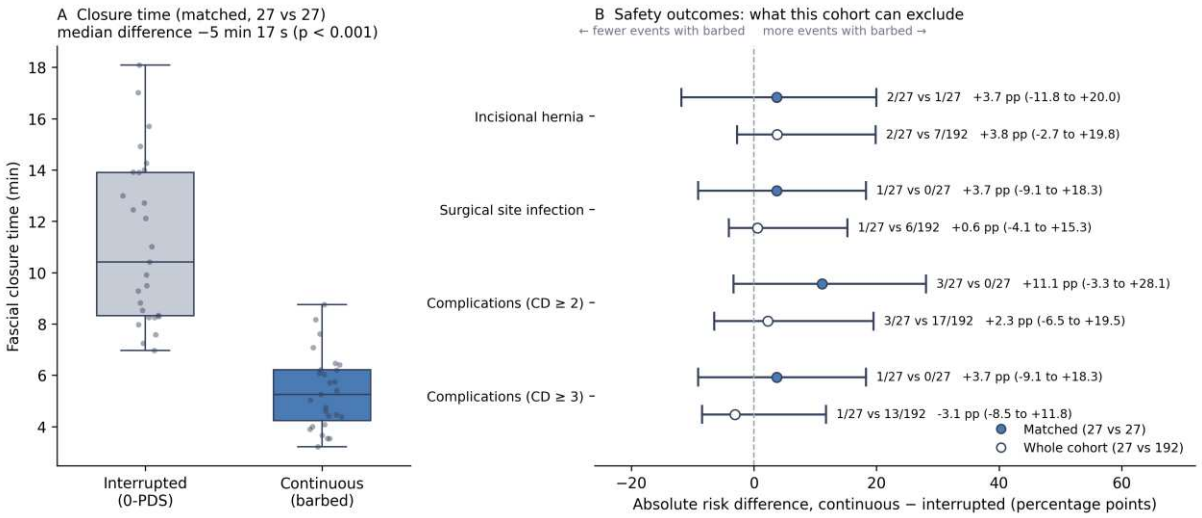


Figure 1. Fascial closure time and the precision limits of the safety comparison.

(a) Fascial closure time in the propensity score-matched cohort (27 patients per group). Boxes show the median and interquartile range, whiskers extend to 1.5 × IQR, and individual patients are overlaid as jittered points. Median closure time was 10 min 25 s (IQR 8 min 19 s – 13 min 54 s) with interrupted closure and 5 min 15 s (IQR 4 min 14 s – 6 min 12 s) with continuous barbed closure. The Hodges–Lehmann estimate of the median difference was −5 min 17 s (95% CI −7 min 26 s to −3 min 55 s; Mann–Whitney U test, $p < 0.001$). The interquartile width fell from 5 min 36 s to 1 min 58 s.

(b) Absolute risk differences (continuous barbed minus interrupted) for the safety outcomes, with 95% confidence intervals calculated by the Newcombe hybrid-score method. Positive values indicate more events after barbed closure. Filled circles are the matched cohort (27 versus 27) and open circles the whole cohort (27 versus 192); both are shown because, at these event counts, the matched estimates depend heavily on which 27 controls are selected. Matched versus whole-cohort estimates were: incisional hernia +3.7 (95% CI −11.8 to +20.0) versus +3.8 (−2.7 to +19.8) percentage points; surgical site infection +3.7 (−9.1 to +18.3) versus +0.6 (−4.1 to +15.3); postoperative complications of Clavien–Dindo grade ≥ 2, +11.1 (−3.3 to +28.1) versus

+2.3 (−6.5 to +19.5); and grade ≥ 3, +3.7 (−9.1 to +18.3) versus −3.1 (−8.5 to +11.8). Both complication thresholds are shown because neither was pre-specified. The width of these intervals defines what this cohort can and cannot exclude: an absolute increase in incisional hernia of up to approximately 20 percentage points remains compatible with the data. The panel is presented to delimit, rather than to assert, the safety comparison.

Controls were drawn from patients who underwent interrupted closure during the period spanned by the barbed group (February to July 2025). Incisional hernia was defined as a fascial defect of 10 mm or more on computed tomography, irrespective of symptoms, in accordance with the European Hernia Society definition.

In the whole unmatched cohort the corresponding medians were 5 min 15 s and 11 min 55 s (median difference −6 min 31 s, 95% CI −7 min 45 s to −5 min 22 s; $p < 0.001$).

Operating time, blood loss and length of stay did not differ between the matched groups (Table 2).

Suture cost

Barbed closure required a single suture pack in all 27 patients. Among the 22 interrupted closures with a retrievable operative record, 18 required two packs and 4 required one. Mean suture cost per patient was ¥6,168.4 (SD 0; US$39.01) with barbed closure and ¥7,924.2 (SD 1,720.5; US$50.11) with interrupted closure, a difference of ¥1,755.8 (US$11.10) in favour of the barbed strategy ($p < 0.001$ for the distribution of pack counts; Table 3). Records of suture usage were retrievable only for operations whose operative note was still held, which is why the interrupted denominator is 22. A single pack of conventional suture is cheaper than a barbed suture, but the interrupted technique usually required a second pack even within the standardised 5-cm incision.

Table 3. Suture material cost

	Continuous barbed	Interrupted	p
Unit price per pack, JPY (USD)	6,168.4 (39.01)	4,358.3 (27.56)	—
Patients with pack data retrievable	27/27	22/192	—
Packs used: 1 / 2	27 / 0	4 / 18	<0.001
Suture cost per patient, mean (SD), JPY	6,168.4 (0.0)	7,924.2 (1,720.5)	<0.001
Suture cost per patient, mean, USD	39.01	50.11	—
Mean difference	¥1,755.8 (US$11.10) lower		—

Unit prices are institutional purchase prices (¥74,021 and ¥52,300 per box of 12 packs). US dollar amounts are converted at ¥158.13 to US$1, the rate on 24 September 2026.

Postoperative outcomes

Postoperative complications of Clavien–Dindo grade ≥2 occurred in 3 of 27 patients after barbed closure and in none of the 27 after interrupted closure (risk difference +11.1 percentage points, 95% CI −3.3 to +28.1). The three events were a chronic subdural haematoma, chylous ascites and an intra-abdominal abscess; none involved the abdominal wall or the fascial closure itself. At the grade ≥3 threshold there was one event versus none (+3.7 percentage points, 95% CI −9.1 to +18.3).

Surgical site infection occurred in 1 of 27 patients after barbed closure and none after interrupted closure (+3.7 percentage points, 95% CI −9.1 to +18.3). Incisional hernia was detected in 2 versus 1 patients (+3.7 percentage points, 95% CI −11.8 to +20.0) (Fig. 1b). With three hernia events across 54 patients these comparisons are presented descriptively only.

Discussion

In this consecutive cohort, continuous knotless barbed closure of the extraction site took about half the time of simple interrupted closure, and the closure step was markedly more reproducible:

the interquartile range of closure time fell from just over five minutes to just over two. Interrupted closure depends on the operator's knot-tying tension, spacing and comfort in a deep field, and the spread of closure times reflects that dependence; the self-anchoring mechanism removes it. For a step performed at the end of every minimally invasive colorectal resection, a predictable two-minute closure has practical value for theatre scheduling independent of the absolute time saved.

Barbed closure was also cheaper. This is counter-intuitive, since a single barbed suture costs more than a single conventional one, and it is the reason the comparison is worth making explicitly: the interrupted technique required a second pack in 18 of 22 cases, which more than offset the unit price difference. The saving of about ¥1,756 (US$11) per patient counts only suture material. Operating theatre time was not monetised, and including it would widen the difference further; we did not attempt a formal cost-effectiveness analysis because theatre cost per minute varies substantially between institutions and depends heavily on which components of overhead are counted [16].

The 5-mm tissue bite and 5-mm suture pitch used here follow the small-bites principle validated for midline laparotomy [10, 11], applied through a knotless mechanism to a standardised 5-cm umbilical incision. Achieving and maintaining a suture-to-wound length ratio of 4:1 or greater in a short, deep incision is awkward with interrupted sutures, because each knot must be tied at depth under maintained tension. The barbed mechanism anchors along the suture line, so apposition is maintained without an assistant holding tension and without knots; the intraperitoneal view in Online Resource 1 illustrates the resulting closure.

Whether this mechanical advantage translates into fewer hernias is not a question this cohort can answer. Three hernia events occurred across 54 matched patients. The absolute risk difference

was +3.7 percentage points with a confidence interval spanning −11.8 to +20.0, so an increase of up to roughly 20 percentage points remains compatible with the data; detecting the observed difference with 80% power would require approximately 597 patients per group, and this study had about 9% power to do so. We therefore make no claim of equivalence.

The wide variation in published hernia rates reinforces this caution. Reported incidences in the interrupted arms of recent Japanese series of the same incision are 18.3% [8], 32.9% [9] and 33.3% [7], against 3.6% in the present cohort, and rates after midline laparotomy rise from 12.3% at one year to 23.2% at three years [17]. This eight-fold spread is unlikely to reflect suture technique alone. It is driven principally by case definition and detection: the minimum fascial defect considered diagnostic, whether asymptomatic radiological defects are counted, whether computed tomography is performed systematically or only when symptoms arise, and the duration of follow-up. Until these definitions are harmonised, cross-study comparison of hernia incidence at this site is of limited value, and a single-centre cohort of this size cannot contribute meaningfully to the question.

This bears directly on how our own hernia counts should be read. If the true incidence at this site is of the order of 10 to 30%, as the three dedicated series suggest [7-9], most hernias in both arms of our cohort went undetected, and the three events we recorded reflect who happened to undergo imaging, and how closely the abdominal wall was examined on it, more than the closure technique. Detection was also unequal: four of the 27 matched barbed patients had no postoperative imaging at our institution, against none of the 27 interrupted patients, so the barbed arm had fewer opportunities for a hernia to be found. We therefore draw no inference from two events versus one in either direction. It is not evidence that barbed closure increases incisional hernia, and it offers no independent support for the protective effect reported elsewhere.

Where our data do add is upstream of that question. The three 2026 studies [7-9] have already addressed the hernia endpoint in larger cohorts, and all three favour continuous barbed closure. What they did not quantify is what adopting the technique costs in theatre time and materials — the information a unit needs in order to act on their conclusion. The present study supplies that; the two lines of evidence are complementary rather than competing.

Our surgical site infection rate was low in both groups, consistent with the view that adherence to prophylaxis and aseptic technique, rather than the choice of fascial suture, is the principal determinant of wound infection at this site [18].

Limitations

First, this is a retrospective, single-centre analysis without randomisation or blinding. Second, treatment assignment was not randomised. The closure technique was determined by the operating surgeon rather than by protocol: surgeons who had adopted the barbed suture used it as their default, and it accounted for 27 of the 73 closures performed during the period spanned by the barbed group. Selection therefore operated largely at the level of the surgeon rather than of the individual case, which makes cherry-picking of favourable cases unlikely. Restricting the control pool to the same period removes calendar-time confounding and balances follow-up duration, but cannot address confounding by surgeon. Third, after matching, standardised mean differences exceeded 0.1 for clinical stage (0.160), ASA physical status (0.134) and body mass index (0.109); balance was not complete. Fourth, the study is substantially underpowered for the safety outcomes and no claim of equivalence is made. Fifth, the number of suture packs was retrievable for only 22 of the 192 interrupted cases, because operative notes were no longer held for the remainder; the cost comparison therefore rests on a subset, although this subset was determined by record availability and not by any clinical feature of the case. Sixth, incisional

hernia was assessed on computed tomography performed for oncological surveillance rather than on a protocol schedule dedicated to the abdominal wall, and our 3.6% rate in the interrupted arm is far below the 18.3-33.3% reported by series that examined this incision specifically [7-9]; our ascertainment is therefore likely to be insensitive, and the absolute rates in this study should not be compared across studies. Median follow-up was about 12 months, and hernias arising later are not captured. Four of the 27 matched barbed patients (15%) had no postoperative imaging at our institution, which limits hernia ascertainment in that arm in particular. Seventh, all procedures were performed at a single institution by four surgeons using a standardised protocol, and the closure times reported here may not generalise to units with different staffing or technique.

Conclusion

Continuous knotless barbed closure of the extraction site after minimally invasive colorectal resection halved fascial closure time, made closure time more reproducible between cases, and reduced suture material cost by about ¥1,756 (US$11) per patient. Safety outcomes were recorded but this cohort is too small to compare them; the hernia question has been addressed in larger matched series, and the present data are best read as the procedural and economic case for a technique whose mechanical merits are established elsewhere.

Statements and Declarations

Ethics approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. This retrospective study was approved by the Institutional Review Board of Osaka Metropolitan University Hospital (approval number 4383).

Consent to participate

The requirement for written informed consent was waived by the Institutional Review Board because of the retrospective design of the study. Information about the study was posted on the institutional website and patients were given the opportunity to opt out.

Consent to publish

Not applicable. No individually identifiable patient data are presented. Supplementary Video 1 contains no identifiable patient information.

Data availability

The dataset analysed during the current study is provided as Supplementary Information. The analysis scripts that reproduce every table and figure are available from the corresponding author on reasonable request.

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Competing interests

The authors declare that they have no competing interests. In particular, no author has received honoraria, research funding or consultancy fees from Ethicon or Johnson & Johnson, the manufacturer of both sutures compared in this study.

Authors' contributions

Conceptualization and study design: N.N., H.K., K.M. Data curation: N.N. Formal analysis: H.K., N.N. Methodology: T.F., I.O., Y.F., Y.S., K.K. Investigation and resources: Y.M., M.Y., T.Tamura, M.S., T.Toyokawa Writing — original draft: N.N., H.K. Writing — review and

editing: all authors Supervision: K.M. Project administration: T.F., H.K. All authors read and approved the final manuscript.

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Ethical considerations

Medical records were accessed for research purposes between 1 August 2025 and 30 September 2026. All data were fully anonymised before analysis and the authors had no access to information that could identify individual participants during or after data collection.

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