

Research Article

A PROSPECTIVE COMPARATIVE EVALUATION OF THE SAFETY AND EFFECTIVENESS OF EXTRA-CORPOREAL KNOT TYING SUTURE, METALLIC ENDOCLIPS, AND LOOP LIGATURE FOR CLOSURE OF THE APPENDICULAR STUMP IN LAPAROSCOPIC APPENDECTOMY

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ABSTRACT

Background: Acute appendicitis is the most common cause of intra-abdominal surgical emergency, and laparoscopic appendectomy has become the preferred approach. Several techniques are used to secure the appendiceal stump, but no consensus exists on the optimal method.

Objective: To compare the safety and effectiveness of hand-made extra-corporeal knot tying suture, metallic endoclips, and standard endoloop ligature for appendicular stump closure in laparoscopic appendectomy.

Methods: This prospective randomised clinical study included 105 patients undergoing laparoscopic appendectomy, divided equally into three groups of 35 each: Group A (extra-corporeal knot tying), Group B (metallic endoclips), and Group C (standard endoloop ligature). Operative time, stump-closure time, hospital stay, intra-operative and post-operative complications, post-operative pain (Visual Analogue Scale), and cost were compared. Statistical analysis was performed using

SPSS 23.0, with the chi-square test, Fisher's exact test, and Kruskal-Wallis test as appropriate; $p < 0.05$ was considered significant.

Results: The majority of patients were male (63.8%) and aged 21-30 years (38.09%). The mean operative time was 57 ± 3.81 , 49 ± 4.41 , and 56 ± 3.8 minutes in Groups A, B, and C respectively ($p = 0.26$). Mean stump-closure time was 3.71 ± 0.42 , 2.73 ± 0.35 , and 3.20 ± 0.38 minutes ($p = 0.71$), and mean hospital stay was 4.45 ± 1.31 , 3.97 ± 1.29 , and 3.97 ± 1.29 days ($p = 0.8$), with no significant differences among groups. Intra-operative, technique-related, and post-operative complication rates were also comparable across groups. Mean cost was significantly different among the three techniques ($\text{₹}689 \pm 230$, $\text{₹}475 \pm 153$, and $\text{₹}1300 \pm 437$ in Groups A, B, and C respectively; $p = 0.0126$), with metallic endoclips being the least expensive and standard endoloop the most expensive.

Conclusion: Extra-corporeal knot tying, metallic endoclips, and standard endoloop ligature are all safe, feasible, and effective

techniques for appendicular stump closure in laparoscopic appendectomy, with comparable complication rates. Metallic endoclips offer a shorter operative time and lower cost, making them a favourable option, particularly for surgeons in training, while extra-corporeal knot tying remains a reliable and economical alternative that requires no additional instrumentation.

Keywords: Laparoscopic appendectomy; appendicular stump closure; extra-corporeal knot; metallic endoclips; endoloop ligature.

INTRODUCTION

Acute inflammation of the appendix is the leading cause of intra-abdominal surgical emergencies,[1] and appendectomy remains the most frequently performed procedure across surgical departments worldwide.[2,3] It commonly serves as the introductory operation for surgical trainees. Laparoscopic appendectomy, first described by Semm in 1983,[4] has evolved over three decades into a well-established approach that offers reduced pain, faster recovery, and quicker resumption of daily activities,[5-8] and is particularly favoured when the diagnosis is uncertain and in female or obese patients.[3,9]

Although advances in diagnosis, surgical expertise, and antibiotic therapy have reduced mortality from acute appendicitis to below 0.001%, morbidity remains at 5-8%, largely due to delayed diagnosis and intervention.[9] Adequate closure of the appendiceal stump is essential to prevent complications such as stump leakage, intra-abdominal infection, and faecal fistula. Several techniques are used to secure the stump during laparoscopic appendectomy, including extra-corporeal and intra-corporeal knotting, endoloops,

endostaplers, and metallic endoclips, but despite numerous studies, no consensus exists on the preferred technique.[10-13] Cristalli et al. were the first to describe the use of metallic endoclips for securing the appendiceal base in 1991,[13] and apart from one systematic review suggesting that stapling reduces infection compared with loop ligatures, no study has directly compared extra-corporeal knot tying, metallic endoclips, and standard endoloop ligature in the same cohort.[14]

The extra-corporeal knot-tying technique uses a Roeder's knot fashioned from Vicryl-0 suture and is cost-effective but time-consuming.[15-17] Metallic endoclips provide a simple, quick alternative that is favourable during the learning curve of laparoscopic surgery, though their safety may be compromised in a wide or oedematous appendiceal base.[15,16,18] The standard endoloop, a pre-formed ligature housed in a plastic introducer, is safe and reliable but adds to the cost of the procedure.[11,12] Given the absence of a direct comparison among these three techniques, this study was designed to evaluate their relative safety and effectiveness, with infection and other complications as the primary focus, and cost, operative time, and duration of hospitalisation as secondary considerations.

AIM

To compare the effectiveness and safety of hand-made extra-corporeal knot tying suture, metallic endoclips, and loop ligature (standard endoloop) for appendiceal stump closure in laparoscopic appendectomy.

OBJECTIVES

To compare the three techniques of appendicular stump closure in terms of:

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1. Safety, in terms of the probability of leakage and slippage of the ligature, clips, or knot.
2. Ease of application.
3. Time taken to close the appendiceal stump.
4. Duration of surgery.
5. Intra-operative and post-operative complications.
6. Duration of hospital stay.

MATERIALS AND METHODS

Study design: This was a prospective randomised clinical study conducted at our institution in patients undergoing laparoscopic appendectomy for acute or chronic appendicitis on an elective or emergency basis.

Study groups: Patients were randomised into three equal groups of 35 each: - Group A: Hand-made extra-corporeal knot tying. - Group B: Metallic endoclips. - Group C: Standard endoloop ligature.

Sample size: A total of 105 patients were required, based on a population size of 110 (derived from institutional data for the preceding year), a hypothesised outcome frequency of 3%, a design effect of 1, and a precision of $\pm 5\%$, giving a minimum calculated sample size of 96 at a 95% confidence level and 80% power. After a 12% adjustment for anticipated loss to follow-up, the final sample size was set at 108, with patients recruited by convenience sampling.

Inclusion criteria: Patients with a clinico-radiological diagnosis of acute appendicitis undergoing laparoscopic appendectomy, of either sex.

Exclusion criteria: Patients unfit for general anaesthesia, pregnant women,

complicated appendicitis, haemodynamically unstable patients, and patients at high risk for intervention.

All patients underwent a standard pre-operative work-up comprising a detailed history and systematic clinical examination.

Surgical technique: General anaesthesia was administered, and the patient was positioned supine with the left arm tucked. After antibiotic prophylaxis, a Foley catheter was inserted and deep venous thrombosis prophylaxis was given. Pneumoperitoneum was established at the umbilicus using either a closed (Veress needle) or open (Hasson) technique, and a 10 mm port was placed for the laparoscope. The patient was positioned in Trendelenburg and left lateral decubitus, and two additional 5 mm ports were placed. After inspection of the peritoneal cavity and mobilisation of the caecum and terminal ileum, the appendix was identified, dissected, and mobilised, and the mesoappendix was divided and secured. The appendiceal stump was then closed using one of the three techniques described below, the specimen was retrieved through the 10 mm port, the field was irrigated, and the port sites were closed with absorbable sutures.

Group A - Extra-corporeal knot tying: The appendiceal base was secured with Vicryl-0 using two knots placed 5 mm apart, fashioned as a Roeder's knot (a half-hitch followed by three full turns and a locking half-hitch) and tightened snugly around the base with a knot pusher.[16,17]

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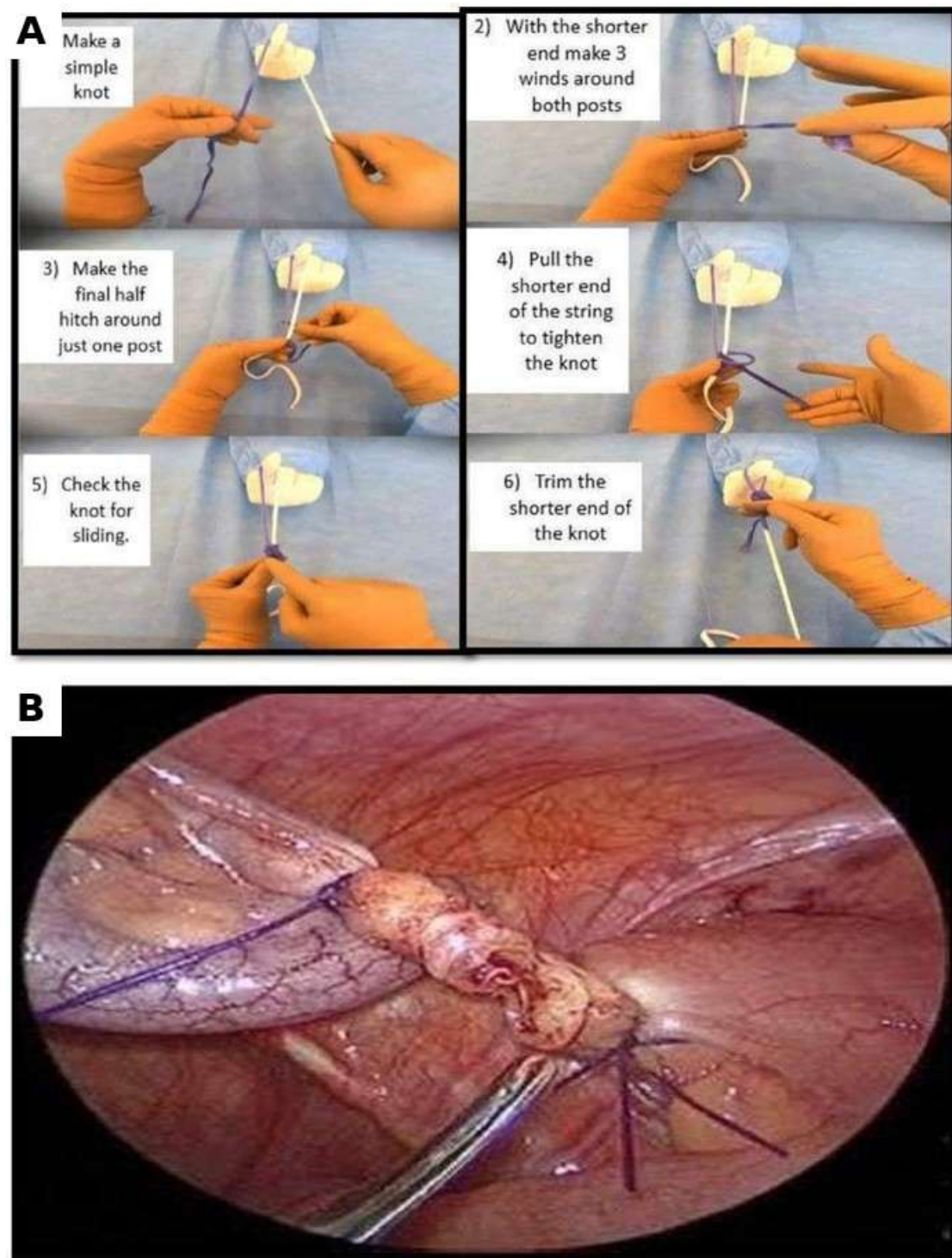


Figure 1. Extra-corporeal (Roeder's) knot tying technique. (A) Step-wise formation of the knot outside the abdomen. (B) Intra-operative view of the completed knot secured around the appendiceal base.

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Group B - Metallic endoclips: Three metallic endoclips (titanium clip cartridge, medium-large or large size) were placed near the appendiceal base, two positioned close together and opposing each other, and the third 5 mm away; the appendix was then divided between the two proximal clips.[10,15]

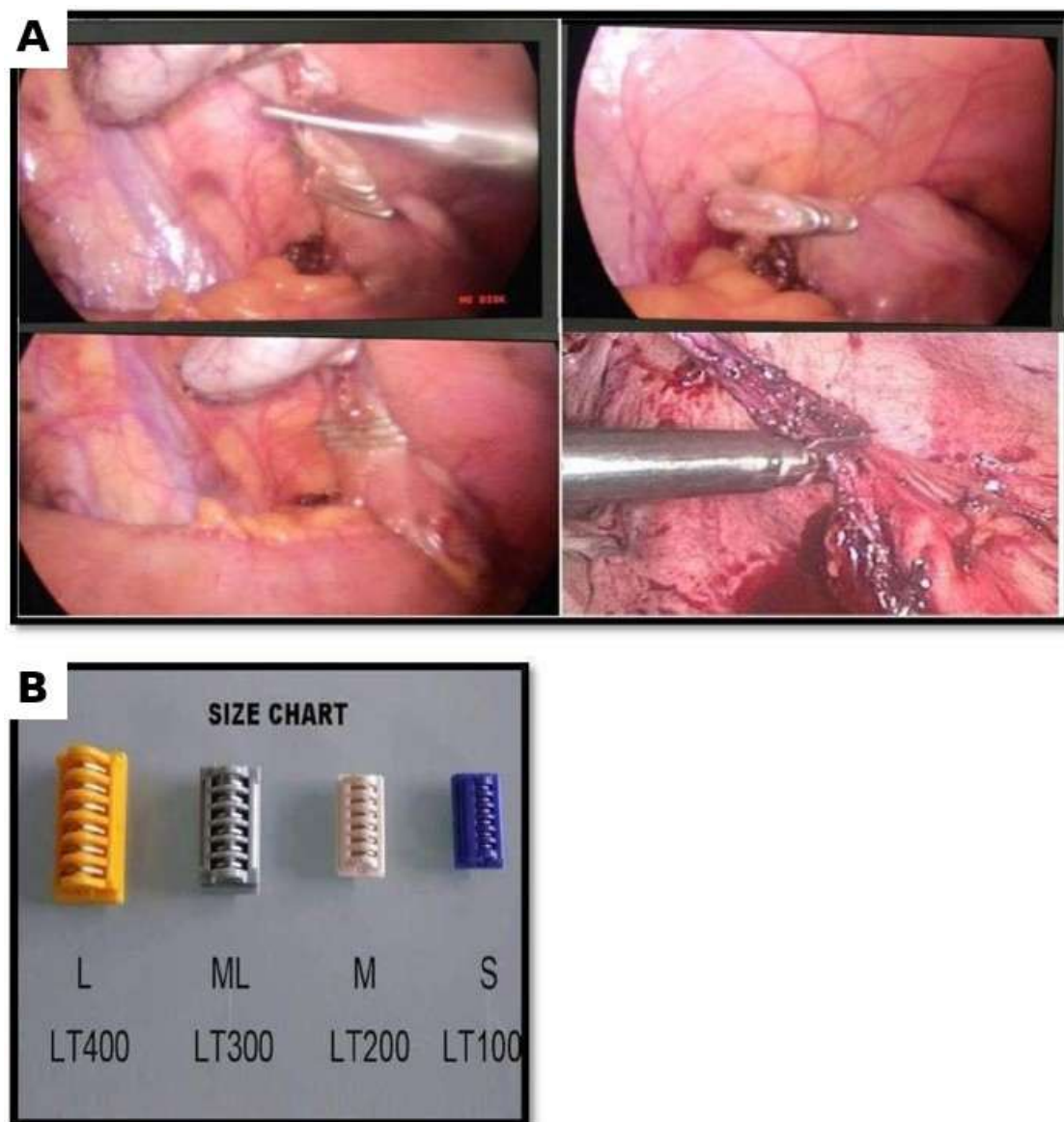


Figure 2. Metallic endoclip application. (A) Intra-operative sequence showing placement of clips at the appendiceal base and division of the appendix between the proximal clips. (B) Titanium clip cartridge size chart (S, M, ML, L).

Group C - Standard endoloop: An 18-inch chromic catgut ligature housed in a plastic introducer was used to place two endoloops at the proximal appendiceal base, with an additional knot tied a few millimetres distally before the appendix was divided.[11,12]

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Figure 3. Standard endoloop ligature. (A) Endoloop introducer being passed onto the appendiceal base, with the packaged ligature device shown below. (B) Intra-operative view of the endoloop secured at the appendiceal base.

Statistical analysis: Data were analysed using SPSS version 23.0. Categorical variables were expressed as number and percentage, and continuous variables as mean and standard deviation. Categorical parameters were compared using the chi-square test and Fisher's exact test, and parameters not conforming to a normal distribution were compared using the Kruskal-Wallis test, with the Bonferroni post-hoc method applied to identify inter-group differences. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 105 patients who underwent laparoscopic appendectomy were included in the study and divided equally into the three study groups (35 patients each).

Demographic and clinical profile: The majority of patients belonged to the 21-30-year age group (38.09%), followed by those under 20 years (26.7%) and 41-50 years (14.28%), with the fewest patients in the above-60-years group (2.85%) (Table 1). There was a male preponderance (63.8% vs. 36.2% female) (Table 2). The most common presenting features were nausea/vomiting (59%) and pain in the right iliac fossa (58%), followed by migratory pain (41.9%) and fever (36.2%) (Table 3). Tenderness in the right iliac fossa was the most common sign (96.2%), followed by a positive McBurney's point (58%) and Blumberg's sign (48.5%) (Table 4).

Table 1. Age group-wise distribution of study participants

Age group (years)	Number (%)
< 20	28 (26.7)
21-30	40 (38.09)
31-40	13 (12.38)
41-50	15 (14.28)
51-60	6 (5.71)
> 60	3 (2.85)

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Total	105
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Table 2. Gender-wise distribution among study participants

Sex	Number (%)
Male	67 (63.8)
Female	38 (36.2)
Total	105

Table 3. Symptoms among study participants

Symptom	Number (%)
Pain in right iliac fossa	61/105 (58.0)
Migratory pain	44/105 (41.9)
Nausea/vomiting	62/105 (59.0)
Fever	38/105 (36.2)
Bowel complaints	18/105 (17.1)
Urinary complaints	15/105 (14.2)
Anorexia	10/105 (9.5)

Table 4. Signs among study participants

Sign	Number (%)
Tenderness in right iliac fossa	101/105 (96.2)
McBurney's point	61/105 (58.0)
Murphy's triad	38/105 (36.1)
Rovsing's sign	24/105 (22.8)
Blumberg's sign	51/105 (48.5)
Psoas test	18/105 (17.1)
Obturator test	31/105 (29.5)
Guarding in right iliac fossa	11/105 (10.5)

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Rigidity in right iliac fossa	1/105 (0.95)
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Investigations: The total leukocyte count was within the normal range ($4.5-11 \times 10^3$ cells/mm³) in 57.14% of patients, while 42% had leucocytosis ($> 11 \times 10^3$ cells/mm³) (Table 6). On ultrasonography, 76.2% of patients showed features of acute appendicitis, 16.2% sub-acute appendicitis, and 3.8% chronic appendicitis (Table 7).

Table 6. Total leukocyte count

TLC ($\times 10^3$ cells/mm ³)	Number (%)
< 4.5	3 (2.85)
4.5-11	60 (57.14)
> 11	42 (42.0)
Total	105 (100)

Table 7. Ultrasonography findings

USG finding	Number (%)
Acute appendicitis	80 (76.2)
Sub-acute appendicitis	17 (16.2)
Chronic appendicitis	4 (3.8)
Acute-on-chronic appendicitis	1 (0.95)
Acute appendicitis with appendicolith	2 (1.9)
Acute appendicitis with appendicular phlegmon	1 (0.95)
Total	105 (100)

Table 8. Technique of appendicular stump closure

Technique	Number (%)
Extra-corporeal knot tying	35 (33.3)
Metallic endoclips	35 (33.3)

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Standard endoloop ligature	35 (33.3)
Total	105 (100)

Comparison across groups: There was no significant difference in post-operative pain scores among the three groups; the majority of patients (83/105) had moderate-to-severe pain (VAS 4-6), while Group A had the highest proportion of patients with mild pain (44.2%) and Groups B and C had the highest proportion with very severe pain (28.5-40%) ($p = 0.94$) (Table 5).

Table 9. Comparison of post-operative pain (Visual Analogue Scale)

VAS score	Group A (n=35)	Group B (n=35)	Group C (n=35)	Total	p-value
1-3 (mild)	3 (44.2%)	2 (28.5%)	2 (28.5%)	7	0.19
4-6 (moderate-severe)	27 (32.5%)	29 (34%)	27 (34%)	83	0.06
7-9 (very severe)	5 (33.3%)	4 (26.6%)	6 (40%)	15	0.20
10 (worst)	0	0	0	0	1.00
Total	35	35	35	105	0.94

The mean operative time was longest in Group A (57 ± 3.81 min) and shortest in Group B (49 ± 4.41 min), with Group C intermediate (56 ± 3.8 min); this difference was not statistically significant ($p = 0.26$). Similarly, the mean stump-closure time and mean hospital stay did not differ significantly among the groups (Table 9).

Table 10. Comparison of duration of surgery, stump closure, and hospital stay

Parameter	Group A	Group B	Group C	p-value
Mean duration of surgery (min)	57 ± 3.81	49 ± 4.41	56 ± 3.8	0.26

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Mean duration of stump closure (min)	3.71 ± 0.42	2.73 ± 0.35	3.20 ± 0.38	0.71
Mean hospital stay (days)	4.45 ± 1.31	3.97 ± 1.29	3.97 ± 1.29	0.8

Intra-operative complications occurred in 5 patients overall: bleeding from the stump in 2 patients (Group B) and adhesions in 3 patients (1 in Group A, 2 in Group C) (Table 10). Technique-related complications were seen in 4 patients: leakage from the stump in 1 (Group C), stump appendicitis in 1 (Group A), and a wide-calibre/oedematous base in 2 (Group B) (Table 11).

Table 11. Comparison of intra-operative complications

Complication	Group A	Group B	Group C	Total	p-value
Bleeding from stump	0	2	0	2	0.68
Organ injury	0	0	0	0	1.00
Adhesions	1	0	2	3	0.41
Total	1	2	2	5	

Table 12. Comparison of technique-related complications

Complication	Group A	Group B	Group C	Total	p-value
Leakage from stump	0	0	1	1	0.83

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Slippage of ligature/clips	0	0	0	0	1.00
Stump appendicitis	1	0	0	1	0.64
Caecal erosion	0	0	0	0	1.00
Wide-calibre/oedematous base	0	2	0	2	0.83
Retained faecolith	0	0	0	0	1.00
Faecal fistula	0	0	0	0	1.00
Total	1	2	1	4	

Post-operative complications occurring within 72 hours of surgery were seen in 20 patients overall, most frequently post-operative fever (7 patients) and post-operative ileus (5 patients), both of which resolved with conservative management; these were more frequent in Group A but did not reach statistical significance (Table 12). There were no instances of re-exploration or conversion to open surgery. Two patients in Group B required a change of technique to standard endoloop due to a wide, oedematous appendiceal base; two patients were re-admitted, one in Group A (stump infection) and one in Group B (colitis) (Table 13).

Table 13. Comparison of post-operative complications

Complication	Group A	Group B	Group C	Total	p-value

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Post-operative pain	1	2	1	4	0.84
Port-site infection	2	1	1	4	0.62
Intra-abdominal abscess	0	0	0	0	1.00
Intra-abdominal haematoma	0	0	1	1	-
Post-operative fever	3	2	2	7	0.89
Post-operative ileus	2	1	2	5	0.84
Intestinal obstruction/perforation	0	0	0	0	1.00
Total	8	6	6	20	

Table 14. Comparison of other events

Event	Group A	Group B	Group C	Total	p-value
Re-admission	1	1	0	2	0.74
Re-exploration	0	0	0	0	1.00

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Limitation of technique	0	2	0	2	0.41
Conversion rate	0	0	0	0	1.00
Total	1	3	0	4	

Finally, the mean cost was significantly different among the three groups, being lowest for metallic endoclips ($\text{₹}475 \pm 153$) and highest for standard endoloop ligature ($\text{₹}1300 \pm 437$), with extra-corporeal knot tying intermediate ($\text{₹}689 \pm 230$) ($p = 0.0126$) (Table 14).

Table 15: Comparison of mean cost

Parameter	Group A	Group B	Group C	p-value
Cost (₹)	689 ± 230	475 ± 153	1300 ± 437	0.0126

DISCUSSION

Appendicitis remains the most common cause of an intra-abdominal surgical emergency,[1] and laparoscopic appendectomy is now the preferred surgical approach in most centres because of its favourable outcomes, particularly in patients with an uncertain diagnosis or a higher body mass index.[3,9] Adequate closure of the appendiceal stump is critical to minimise post-operative complications, and several techniques are available for this purpose. In the present study, extra-corporeal knot tying, metallic endoclips, and standard endoloop ligature were compared with respect to post-operative

pain, operative time, hospital stay, complications, and cost.

In our cohort, the majority of patients were in the 21-30-year age group, consistent with the findings of Kumar et al., who reported a higher incidence of appendicitis in the 16-30-year age bracket,[19] and with the observation of Addiss et al. and Primatesta et al. that incidence peaks around 20 years of age and declines thereafter.[21,22] A male preponderance (63.8%) was noted, similar to the reports of Rothrock et al. and Khairy et al.,[23,24] and consistent with the findings of Al-Omran et al.[25] and Maini et al.[26] Clinical presentation and examination findings in our study were

consistent with the classical description of acute appendicitis in Bailey & Love's Short Practice of Surgery.[27]

Regarding diagnostic work-up, 42% of patients had leucocytosis, in keeping with reports that total leukocyte count, though not diagnostic on its own, aids clinical decision-making,[28,29] and that combining leukocyte count with other inflammatory markers improves diagnostic accuracy.[30,31,32] Ultrasonography demonstrated features of acute appendicitis in 76.2% of patients, consistent with previously reported sensitivity and specificity of ultrasonography in the diagnosis of acute appendicitis.[33-35]

The mean operative time was shortest with metallic endoclips (49 minutes) compared with extra-corporeal knot tying (57 minutes) and standard endoloop (56 minutes), although this difference did not reach statistical significance in our cohort. A similarly shorter operative time with endoclips compared with endostaplers has been reported by Hanssen et al.,[40] and Nadeem et al. similarly found metallic endoclips to require significantly less operative time than extra-corporeal knotting.[39] Hospital stay was comparable across the three groups, in line with the findings of Nadeem et al.,[39] though

somewhat longer than reported by Caglià et al. for the endoloop technique.[41]

Intra-operative complications were infrequent and comparable across groups, with bleeding confined to the metallic endoclip group and adhesions seen with extra-corporeal knot tying and standard endoloop; these were attributed to dense adhesions and inflammation rather than the closure technique itself, consistent with the findings of Nadeem et al.[39] Technique-related failure of metallic endoclips occurred in 2 of 35 patients (a 90% success rate), both due to a wide or oedematous appendiceal base, underscoring the need for caution when applying clips in such cases, as also emphasised in previous reports.[16,18]

Post-operative complications, principally fever and ileus, were more frequent in the extra-corporeal knot-tying group, similar to the pattern reported by Nadeem et al.,[39] whereas Mahmood et al. reported a higher complication rate with metallic endoclips in their cohort.[44]

Cost was significantly higher with standard endoloop ligature than with metallic endoclips or extra-corporeal knot tying, consistent with previous reports that polymer/metallic clips are more cost-effective than endoloops,[37,38] and that intracorporeal or extra-corporeal sutures

are generally the least expensive option, followed by endoloops and then staplers.[12] Overall, the three techniques evaluated in this study demonstrated comparable safety and complication profiles, with the choice between them best guided by cost, operator experience, and the local appendiceal base characteristics encountered intra-operatively.

CONCLUSION

Various techniques are used to secure the appendiceal base during laparoscopic appendectomy, and despite extensive research, no consensus exists on the preferred method. In this study, extra-corporeal knot tying, metallic endoclips, and standard endoloop ligature demonstrated comparable complication rates, operative times, and hospital stays. Standard endoloop and extra-corporeal knot tying were associated with higher costs than metallic endoclips. The simplicity of metallic endoclips makes them well suited to surgeons in training, whereas extra-corporeal knotting remains a reliable and economical option for experienced surgeons or those working in resource-constrained settings. Careful technique is required during stump closure, as excessive force with clips or ligatures can cause tissue injury, and metallic clips are best avoided in an oedematous or wide-

calibre appendiceal base because of the risk of slippage or tissue cutting. Overall, all three techniques are safe, feasible, and practical options for appendicular stump closure in laparoscopic appendectomy; metallic endoclips offer a shorter operative time and lower cost, while extra-corporeal knot tying provides an economical alternative that requires no specialised instrumentation beyond a knot pusher.

REFERENCES

1. Sahm M, Pross M, Lippert H. Acute appendicitis - changes in epidemiology, diagnosis, and therapy. *Zentralbl Chir.* 2011;136(1):18-24.
2. Gomes CA, Junior CS, Costa Ede F, Alves PdeA, de Faria CV, Cangussu IV, et al. Lessons learned from the laparoscopic management of complicated grades of acute appendicitis. *J Clin Med Res.* 2014;6(4):261-6.
3. Boomer LA, Cooper JN, Deans KJ, Minneci PC, Leonhart K, Diefenbach KA. Impact of delay in appendectomy on surgical site infection in children with appendicitis. *J Pediatr Surg.* 2014;49(6):1026-9.
4. Semm K. Endoscopic appendectomy. *Endoscopy.* 1983;15(2):59-64.
5. Sauerland S, Jaschinski T, Neugebauer EA. Comparison of laparoscopic and open surgery for suspected appendicitis.

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| <p>Cochrane Database Syst Rev. 2010;(10):CD001546.</p> <p>6. Tuggle KR, Ortega G, Bolorunduro OB, Oyetunji TA, Alexander R, Turner PL, et al. A review of laparoscopic versus open appendectomy in complicated appendicitis using the NSQIP database. <i>J Surg Res.</i> 2010;163(2):225-8.</p> <p>7. Ciarrocchi A, Amicucci G. Meta-analysis comparing laparoscopic versus open appendectomy among obese patients. <i>J Minim Access Surg.</i> 2014;10(1):4-9.</p> <p>8. Macarulla E, Vallet J, Abad JM, Hussein H, Fernandez E, Nieto B. A prospective randomized trial of laparoscopic versus open appendectomy. <i>Surg Laparosc Endosc.</i> 1997;7(4):335-9.</p> <p>9. Williams NS, Bulstrode CJK, O'Connell PR. <i>Bailey & Love's Short Practice of Surgery.</i> London: Hodder Arnold; 2008.</p> <p>10. Hart R, Rajgopal C, Plewes A, Sweeney J, Davies W, Gray D, et al. Laparoscopic versus open appendectomy: a prospective randomized trial of 81 patients. <i>Can J Surg.</i> 1996;39(6):457-62.</p> <p>11. Rakic M, Jukic M, Pogorelic Z, Mrklic I, Klicek R, Družijanic N, et al. Analysis of endoloops and endostaples for appendiceal stump closure during laparoscopic appendectomy. <i>Surg Today.</i> 2014;44(9):1716-22.</p> | <p>12. Kiudelis M, Ignatavicius P, Zviniene K, Grizas S. Comparing intracorporeal knotting with invaginating suture versus endoloops in appendiceal stump closure. <i>Wideochir Inne Tech Maloinwazyjne.</i> 2013;8(1):69-73.</p> <p>13. Cristalli BG, Izard V, Jacob D, Levardon M. Laparoscopic appendectomy using a clip applier. <i>Surg Endosc.</i> 1991;5(4):176-8.</p> <p>14. Di Saverio S, Mandrioli M, Sibilio A, Smerieri N, Lombardi R, Catena F, et al. Cost-effective technique for laparoscopic appendectomy: outcomes and costs in complicated acute appendicitis cases. <i>J Am Coll Surg.</i> 2014;218(3):e51-65.</p> <p>15. Langer M, Safavi A, Skarsgard ED. Pediatric laparoscopic appendectomy: management of the appendiceal base with clip, ligature, or staple? <i>Surg Technol Int.</i> 2013;23:81-3.</p> <p>16. Ates M, Dirican A, Ince V, Ara C, Isik B, Yilmaz S. Polyglactin intracorporeal knot-tying suture vs. titanium endoclips for appendiceal stump closure in laparoscopic appendectomy: a prospective randomized study. <i>Surg Laparosc Endosc Percutan Tech.</i> 2012;22(3):226-31.</p> <p>17. Beldi G, Muggli K, Helbling C, Schlumpf R. A prospective, randomized clinical trial using endoloops for laparoscopic appendectomy. <i>Surg Endosc.</i> 2004;18(5):749-50.</p> |
|---|--|

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18. Partecke LI, Kessler W, Patrzyk M, Heidecke CD, Bernstorff WV. Comparing closure methods of the appendiceal stump in laparoscopic appendectomy. *Surg Technol Int.* 2011;21:85-91.
19. Kumar N, Narayanan S, Satheesha BV, Murlimanju BV, Suhani S, Mamatha H, et al. Appendicitis and appendectomy: a retrospective survey among the South Indian population. *J Surg Acad.* 2013;3(2):10-3.
20. Vishram S. *Clinical and Surgical Anatomy.* 2nd ed. New Delhi: Elsevier; 2007. p.178-9.
21. Addiss DG, Shaffer N, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. *Am J Epidemiol.* 1990;132(5):910-25.
22. Primates P, Goldacre MJ. Appendectomy for acute appendicitis and other conditions: an epidemiological study. *Int J Epidemiol.* 1994;23(1):155-60.
23. Rothrock SG, Pagane J. Acute appendicitis in children: emergency department diagnosis and management. *Ann Emerg Med.* 2000;36(1):39-51.
24. Khairy G. Acute appendicitis: is removal of a normal appendix still existing and can we reduce it? *Saudi J Gastroenterol.* 2009;15(3):167-70.
25. Al-Omran M, Mamdani M, McLeod RS. Epidemiologic features of acute appendicitis in Ontario, Canada. *Can J Surg.* 2003;46(4):263-8.
26. Maini SK, Gupta N, Malviya VK. Demographic profile of patients undergoing emergency and interval appendectomy in central India. *Int J Health Clin Res.* 2021;4(14):88-90.
27. O'Connell PR, McCaskie AW, Williams NS. *Bailey & Love's Short Practice of Surgery.* 27th ed. Boca Raton: CRC Press; 2018.
28. Kamran H, Naveed D, Nazir A, Hameed M, Ahmed M, Khan U. Role of total leukocyte count in diagnosis of acute appendicitis. *J Ayub Med Coll Abbottabad.* 2008;20(3):86-8.
29. Pogorelić Z, Kostovski B, Jerončić A, Šušnjar T, Mrklić I, Jukić M, et al. A comparative study of endoloop ligatures and nonabsorbable polymeric clips for closing the appendiceal stump during laparoscopic appendectomy in children. *J Laparoendosc Adv Surg Tech A.* 2017;27(6):645-50.
30. Shoshtari MH, Askarpour S, Alamshah M, Elahi A. Diagnostic value of quantitative CRP measurement in patients with acute appendicitis. *Pak J Med Sci.* 2006;22(3):300.
31. Yang HR, Wang YC, Chung PK, Chen WK, Jeng LB, Chen RJ. The role of leukocyte count, neutrophil percentage, and

Shreyas N et al / A PROSPECTIVE COMPARATIVE EVALUATION OF THE SAFETY AND EFFECTIVENESS OF EXTRA-CORPOREAL KNOT TYING SUTURE, METALLIC ENDOCLIPS, AND LOOP LIGATURE FOR CLOSURE OF THE APPENDICULAR STUMP IN LAPAROSCOPIC APPENDECTOMY

- C-reactive protein in diagnosing acute appendicitis. *Am Surg.* 2005;71:344-7.
32. Wu HP, Chang CF, Lin CY. Predictive value of C-reactive protein in the diagnosis of acute appendicitis in children. *Acta Paediatr Taiwan.* 2003;44:227-31.
 33. Lessin MS, Chan M, Catallozzi M, Gilchrist MF, Richards C, Manera L. Selective use of ultrasonography for acute appendicitis in children. *Am J Surg.* 1999;177(3):193-6.
 34. Abu-Yousef MM, Bleicher JJ, Maher JW, Urdaneta LF, Franken E Jr, Metcalf A. High-resolution sonography of acute appendicitis. *AJR Am J Roentgenol.* 1987;149(1):53-8.
 35. Chen SC, Wang HP, Hsu HY, Huang PM, Lin FY. Accuracy of ED sonography in the diagnosis of acute appendicitis. *Am J Emerg Med.* 2000;18(4):449-52.
 36. Bener A, Suwaidi MH, Ghazawi IE. Diagnosis of appendicitis. *Can J Rural Med.* 2002;7:26-9.
 37. Pogorelić Z, Sopta M, Jukić M, Nevešćanin A, Jurić I, Furlan D. A comparison of polymeric clips and endoloop ligatures for closing the appendiceal stump in laparoscopic appendectomy. *J Laparoendosc Adv Surg Tech A.* 2017;27(12):1318-25.
 38. Mohamed Yousef AM, Taha AM, Gaber A, Abdelhameid M, Omar MA, Abdelshafy M. Evaluation of handmade extracorporeal loop versus metallic clips for appendicular stump closure in laparoscopic appendectomy. *Open Access Libr J.* 2016;3(10):1-9.
 39. Nadeem M, Khan SM, Ali S, Shafiq M, Elahi MW, Abdullah F, et al. Comparison of extra-corporeal knot-tying suture and metallic endo-clips for appendiceal stump closure in uncomplicated acute appendicitis. *Int J Surg Open.* 2016;2:11-4.
 40. Hanssen A, Plotnikov S, Dubois R. Laparoscopic appendectomy using a polymeric clip to close the appendicular stump. *JSLS.* 2007;11:59-62.
 41. Caglià P, Tracia A, Spataro D, Borzì L, Lucifora B, Tracia L, et al. Appendix stump closure with endoloop in laparoscopic appendectomy. *Ann Ital Chir.* 2014;85:606-9.
 42. Gonenc M, Gemici E, Kalayci MU, Karabulut M, Turhan AN, Alis H. Intracorporeal knotting versus metal endoclip for appendiceal stump closure in uncomplicated appendicitis during laparoscopic appendectomy. *J Laparoendosc Adv Surg Tech A.* 2012;22(3):231-5.
 43. Arcovedo R, Barrera H, Reyes HS. A new knot for extracorporeal knot-tying in laparoscopic surgery. *Surg Endosc.* 2007;21(10):1764-7.

**Shreyas N et al / A PROSPECTIVE COMPARATIVE EVALUATION OF THE SAFETY AND
EFFECTIVENESS OF EXTRA-CORPOREAL KNOT TYING SUTURE, METALLIC ENDOCLIPS,
AND LOOP LIGATURE FOR CLOSURE OF THE APPENDICULAR STUMP IN LAPAROSCOPIC
APPENDECTOMY**

44. Mahmood S, Ullah MK, Jawaaid SN, Akbar S, Tariq A, Sarwar M. Comparing extracorporeal knot tying versus metallic endo-clip for laparoscopic appendiceal stump closure in patients with uncomplicated acute appendicitis. Med Forum Mon. 2021;32(12).