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ORIGINAL

Prevention of Acute Adhesive Intestinal Obstruction in the Postoperative

Period Prevención de la obstrucción intestinal adhesiva aguda en el postoperatorio

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ABSTRACT

Introduction: peritoneal adhesions are fibrinopurulent substances that link abdominal organs, which often cause clinical problems. Research seeks to examine the effectiveness of anterolateral transdermal myostimulation in reducing the postoperative adhesion formation and preventing AAIO.
Method: this study investigates transdermal myostimulation efficacy in preventing postoperative adhesions through a two-phase experiment using piglets (n=20) and human patients (n=100). Data analysis was conducted using SPSS 26.
Results: in piglets, the experimental group exhibited only mild adhesions (100 %) with a significantly lower mean number of adhesions (3,5 ± 0,53) compared to the control group (8,1 ± 0,32). The intervention delayed adhesion formation (8,1 ± 1,3 days vs. 5,5 ± 0,85 days; t = -5,332, p = ,000). In human patients, the experimental group showed a significantly lower incidence of adhesions (30,0 % vs. 56,0 %, p = ,007) and obstruction symptoms (16,0 % vs. 42,0 %, p = ,004). Improved outcomes included higher EGEG scores (80,0 % vs. 32,0 %, p = ,000), reduced postoperative complications (20,0 % vs. 42,0 %, p = ,015), and shorter hospital stays (1,86 ± 0,54 days vs. 2,78 ± 0,42 days; t = 9,579, p = ,000). The intervention effectively reduced adhesion-related complications and enhanced recovery.
Conclusion: the research showed that the experimental intervention significantly reduced postoperative adhesions in piglets and human patients. The like findings with either model indicate that this approach would be a useful way of mitigating postoperative adhesions and improving patient outcomes.

Keywords: Intestinal Obstruction; Ostoperative; Adhesions; Myostimulation; Laparotomy.

RESUMEN

Introducción: las adherencias peritoneales son formaciones fibrinopurulentas que conectan los órganos abdominales, generando complicaciones clínicas significativas. Este estudio se propone evaluar la eficacia de la mioestimulación transdérmica anterolateral para disminuir la formación de adherencias postoperatorias y prevenir la aparición de obstrucción intestinal aguda (AAIO).
Método: la investigación se desarrolló en dos fases experimentales, una con lechones (n = 20) y otra con pacientes humanos (n = 100). Se utilizó el software SPSS 26 para analizar los datos y comparar los resultados entre los grupos control y experimental.
Resultados: en el modelo animal, el grupo experimental mostró únicamente adherencias leves (100 %), con

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un número significativamente menor de adherencias (3,5 ± 0,53) respecto al grupo control (8,1 ± 0,32). Además, la formación de adherencias se retrasó (8,1 ± 1,3 días frente a 5,5 ± 0,85 días; t = -5,332, p = 0,000). En humanos, el grupo experimental presentó una menor incidencia de adherencias (30,0 % frente a 56,0 %, p = 0,007) y síntomas obstructivos (16,0 % frente a 42,0 %, p = 0,004). También se observaron mejores puntuaciones EGEG (80,0 % frente a 32,0 %, p = 0,000), menos complicaciones postoperatorias (20,0 % frente a 42,0 %, p = 0,015) y hospitalizaciones más cortas (1,86 ± 0,54 días frente a 2,78 ± 0,42 días; t = 9,579, p = 0,000).

Conclusiones: la mioestimulación transdérmica redujo significativamente las adherencias postoperatorias en ambos modelos, sugiriendo su utilidad como estrategia efectiva para mitigar adherencias y mejorar la recuperación clínica. Los resultados consistentes entre modelos refuerzan su potencial en la práctica médica.

Palabras clave: Obstrucción Intestinal; Ostoperatorio; Adherencias; Mioestimulación; Laparotomía.

INTRODUCTION

Abdominal adhesions are abnormal bands of fibrous tissue which are within the abdomen and connect normally separated surfaces. The small intestine is a few meters long, intraperitoneal, free, mobile, and quadrate in shape. Consequently, it is most vulnerable to developing adhesions with itself or the abdominal wall. In addition, if the patient has undergone any kind of abdominal procedure before and then starts showing major symptoms of intestinal obstruction-like pain in the abdomen; nausea or vomiting; swelling of the tummy (abdominal distention); no bowel movements (absolute constipation), then they are diagnosed with ASBO. Adhesive SBO is a clinical diagnosis meaning that serum biochemistry and imaging support clinical judgment.[1]

The peritoneum is a serious membrane lining the abdominal cavity, derived from the mesoderm. It consists of parietal and visceral layers with a potential space containing serous fluid, allowing frictionless movement. The parietal layer lines the abdominal walls, while the visceral layer covers internal organs. It supports abdominal organs and provides pathways for nerves, blood vessels, and lymphatics.[2]

Peritoneal adhesions (PAs) are fibrotic tissues connecting abdominal organs, often leading to clinical issues. The formation of PAs is driven by damage to peritoneal mesothelial cells (PMCs), triggering inflammation, fibrin deposition, and fibrosis. PMCs undergo mesothelial–mesenchymal transition, producing extracellular matrix and transforming into myofibroblasts, accelerating PA development. Understanding this mechanism is key for PA prevention and treatment.[3]

Congenital or acquired, adhesions may be; the majority of them occur as a result of peritoneal injury that is often caused by abdomino-pelvic surgery. Furthermore, there are instances when adhesions can also develop through intraperitoneal infection, and inflammation from abdominal trauma.[4]

The frequency of surgical adhesions is widespread. This consequently leads to high rates of morbidity, mortality and healthcare expenses with more than one hospitalization. There still remain unclear mechanisms underlying these conditions despite numerous investigations which are likely to involve various causes. It is this complicatedness alongside deficient knowledge that has so far hindered the development of useful therapies and successful translation from preclinical discoveries made to clinical experiments.[5]

Many studies have been conducted on the pathophysiology of postoperative adhesions both in vitro and in vivo. There is no prediction; however, the types, locations, timings and recurrences of adhesive obstructions are unpredictable. While most postoperative adhesions are asymptomatic, the sequelae of their formation can cause lifelong issues such as chronic abdominal pain; repeated hospitalizations due to recurring intestinal obstruction; or infertility. Further, this condition may become a chronic medical illness with substantial morbidity but without any effective treatment approach. Despite advances in surgical procedures lately, there has been no dependable means of managing postoperative adhesions.[6]

Less than 1 % of 600 annual malpractice cases reach trial; 80,8 % result in guilty verdicts for high-risk specialties, highlighting the need to address postoperative adhesion complications.[7] Neuropsychological tools optimize brain function, promoting well-being and reducing postoperative complications like adhesions by addressing individual needs and social demands through personalized care.[8] Healthcare providers can use electronic portfolios to enhance skills in managing postoperative care, reflecting on practices, and improving adhesion prevention, similar to foreign language teachers.[9] Combining traditional, self-study, and online methods, mixed learning can improve training for healthcare providers in preventing adhesions, adapting models like rotational and virtual-enriched learning.[10] Emphasizing female students' health in education, alongside adopting robotics in surgery, enhances outcomes and reduces postoperative adhesions, stressing training and regulation.[11,12]

Post-operative adhesions occur in 93-100 % of cases following laparotomy for upper abdominal surgery, while

a laparoscopic approach reduces this risk to 45 %. Surgical re-interventions due to adhesion-related symptoms occur in less than 10 % of cases, depending on the initial procedure, with rates ranging from 6,4-10 %. The greater omentum is most commonly affected by adhesions. In contrast, after lower abdominal open surgery, adhesions develop in 67-93 % of patients, but only 5-18 % experience symptomatic complications, such as bowel obstructions. The rate of hospitalization due to adhesion-related complications is approximately 3,8 %.[13] Anti-adhesion strategies include biological barriers like Seprafilm and Oxiplex/AP Gel, which physically separate tissues during healing to prevent adhesions. Hydrogels and biomaterials, such as PLA films and chitosan-based hydrogels, also show promise due to their biocompatibility and biodegradability. While pharmacological agents are being explored, their clinical effectiveness requires more research.[14]

Employing meticulous surgical techniques, including careful handling of tissues and minimizing manipulation, is vital to reducing tissue injury. Laparoscopic approaches further lower adhesion risks due to less peritoneal trauma. Additionally, proper closure of the parietal peritoneum at the end of the surgery is an effective preventive measure, as highlighted by various studies.[15]

Adhesions after surgery are a common complication. There are few effective methods available to prevent them. However, hydrogels, which are hydrophilic polymers networks, have shown potential as anti-adhesion barriers because they can hold drugs and refuse to be fouled. This review examines the present state of research on hydrogels for adhesion prevention and focuses on the main features and future prospects in this field.[16] Postoperative adhesions are a major complication that may occur after abdominal surgery, causing acute adhesive intestinal obstruction (AAIO). The purpose of this study is to assess the effectiveness of transcutaneous electrical muscle stimulation (TMS) of anterior abdominal wall muscles in reducing the incidence of postoperative adhesions and thus preventing AAIO. This study **aimed** to evaluate the feasibility, efficacy, and translational potential of transdermal mio-stimulation (TMS) in reducing the severity and incidence of postoperative adhesions and related complications across animal models and human clinical settings, highlighting the comparative outcomes and benefits for enhanced postoperative recovery and quality of life.

Knowledge Translation (KT) section

Intestinal obstruction is one of the most severe outcomes of postoperative adhesions, which are commonly reported in both animal models and human patients. Notably, different adhesion treatments have demonstrated different levels of efficacy in reducing the severity, onset and complication associated with them.

This study demonstrates that the experimental intervention significantly reduces adhesion severity and quantity in piglets, delays adhesion formation, and improves postoperative outcomes in human patients, including lower pain scores, shorter hospital stays, and fewer complications, highlighting the intervention's potential in enhancing recovery and reducing adhesion-related complications.

METHOD

Study Design

This study is designed as a two-phase experimental investigation. The first phase involves an animal model using piglets to simulate postoperative adhesions and test the efficacy of transdermal myostimulation in preventing acute adhesive intestinal obstruction. The second phase involves a clinical trial on human patients undergoing laparotomy to assess the translational potential of the findings from the animal model.

Phase 1: Animal Study Sample Size

A total of 20 piglets, aged 8-10 weeks, were used in this study. The choice of piglets was based on their physiological similarities to humans in terms of abdominal anatomy.

Control Group (n=10): Piglets in this group received no additional intervention after the laparotomy.

Experimental Group (n=10): Piglets in this group were having electrodes placed on the skin of their anterior abdominal wall. Transdermal myostimulation was administered postoperatively .

Surgical Procedure

All piglets undergone a standardized laparotomy under general anesthesia. The abdominal cavity was opened, and a controlled injury to the peritoneum was inflicted to simulate the formation of adhesions. To enhance adhesion formation, the peritoneum was gently abraded using sterile gauze, and a talc powder was sprinkled over the area. The abdominal cavity was then closed using standard surgical techniques.

Electrodes were securely attached to the skin overlying the anterior abdominal muscles. A low-frequency electrical current (10-20 Hz) were delivered for 20 minutes twice daily, starting 24 hours postoperatively and continued for 7 days. The effectiveness of myostimulation were monitored by observing visible muscle contractions.

After 7 days, a second laparotomy (relaparotomy) was performed on all piglets to assess the extent of

adhesion formation. Adhesions was scored based on location, severity, and extent using a standardized adhesion grading system. The results were documented and compared between the control and experimental groups.

Phase 2: Human Clinical Study

Sample Size; A total of 100 patients scheduled for laparotomy were recruited. Patients were randomly allocated to either the control or experimental group. Patients undergoing elective laparotomy for non-malignant conditions. Patients with a history of previous abdominal surgeries, malignancies, or any contraindications to electrical stimulation.

Control Group (n=50): No additional intervention post-laparotomy.

Experimental Group (n=50): Patients received transdermal myostimulation following the same protocol used in the animal study.

Surgical Procedure

All patients were undergone a standard laparotomy performed by experienced surgeons. Electrodes were placed on the skin over the anterior abdominal muscles. Electrical current was delivered as per the protocol used in the piglet study, with adjustments for human application.

x-ray with Contrast Agent was conducted 7 days post-surgery to visualize any early signs of adhesions. Ultrasound was used to assess intestinal motility and detect potential adhesions. Electrogastroenterography recorded to evaluate gastric motility and detect any alterations that might indicate adhesion formation. Patients was followed for 30 days postoperatively to monitor for any adhesion-related complications or symptoms.

Statistical Analysis

Statistical analysis was conducted to evaluate the effectiveness of the experimental intervention across both stages of the study. In Stage 1, data from piglets were analyzed using descriptive statistics to compare the severity and number of postoperative adhesions, time to adhesion formation, and relaparotomy findings between control and experimental groups. Differences were assessed using t-tests, with results showing statistically significant improvements in the experimental group, evidenced by reduced adhesion severity and quantity, delayed adhesion formation, and fewer complete adhesions. In Stage 2, clinical data from human patients were analyzed similarly. Chi-square tests were used for categorical variables, and independent t-tests were employed to compare continuous variables such as VAS pain scores, hospital stay duration, and severity scores. The experimental group consistently showed statistically significant improvements in postoperative outcomes, demonstrating the intervention's efficacy.

RESULTS

Stage 1: Animal Study Using Piglets

Table 1 demonstrate a significant difference between the control and experimental groups in terms of adhesion severity and number of adhesions. In the control group, the majority of adhesions were moderate (90 %), with a small percentage being severe (10 %), resulting in a high mean number of adhesions (8,1 ± 0,32). In contrast, the experimental group exhibited only mild adhesions (100 %), with a substantially lower mean number of adhesions (3,5 ± 0,53). The experimental intervention is effective in reducing the extent as well as number of postoperative adhesions in pigs.

Table 1. Severity and number of postoperative adhesions in piglets

Group		Severity of Adhesions	Number of Adhesions (Mean ± SD)
Control Group (n=10)	Mild	0 (0,0 %)	8,1 ± ,32
	Moderate	9 (90,0 %)	
	Severe	1 (10,0 %)	
Experimental Group (n=10)	Mild	10 (100,0 %)	3,5 ± ,53
	Moderate	0 (0,0 %)	
	Severe	0 (0,0 %)	

Table 2 results that the experimental group (n=10) showed a significant delay in the time to adhesion formation, averaging 8,1 ± 1,3 days, compared to the control group (n=10), which averaged 5,5 ± 0,85 days. The t-test revealed a t-value of -5,332 with a p-value of ,000, indicating a statistically significant difference between the two groups. The intervention employed in the experimental group effectively delayed the initiation of adhesion formation compared to the control group.

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Table 2. Time taken for piglets to form adhesions after surgery						
Group	**Number Piglets (n)**	**of Time to Formation**		**Adhesion (Days)**	**t values**	**p values**
Control Group	10	5,5	±	,85	-5,332	,000
Experimental Group	10	8,1	±	1,3		

Table 3 shows a significant difference between the control and experimental groups in terms of the number of complete adhesions and piglets with no adhesions. In the experimental group, 80 % of pigs had no complete adhesions, compared to 30 % in the control group (p = ,035). Additionally, 50 % of the experimental group had no adhesions at all, while all control group pigs had adhesions (p = ,016). The number of partial adhesions did not differ significantly between the groups (p = ,686), with both groups showing a 70 % incidence of no partial adhesions. These results suggest that the intervention in the experimental group effectively reduced the formation of complete adhesions and increased the likelihood of pigs having no adhesions postoperatively.

Table 3. Relaparotomy findings in piglets				
Variables		**Control (n = 10)**	**Experimental (n = 10)**	**p-value**
Number of Complete Adhesions	No	3 (30,0 %)	8 (80,0 %)	,035
	Yes	7 (70,0 %)	2 (20,0 %)	
Number of Partial Adhesions	No	7 (70,0 %)	7 (70,0 %)	,686
	Yes	3 (30,0 %)	3 (30,0 %)	
Piglets with No Adhesions	No	10 (100,0 %)	5 (50,0 %)	,016
	Yes	0 (0,0 %)	5 (50,0 %)	

Stage 2: Clinical Application in Human Patients

Table 4 focuses on the prevention of acute adhesive intestinal obstruction in the postoperative period in human patients. It compares a control group (n=50) with an experimental group (n=50) across various characteristics. The age distribution is similar, with the majority being between 50-65 years old. Gender distribution is equal across both groups. Notably, the experimental group shows a higher percentage of patients with a BMI of 15-25, shorter hospital stays (≤10 days), and lower VAS pain scores (1-5). The experimental group also had fewer patients with comorbidities. These differences suggest that the intervention in the experimental group may be effective in reducing postoperative complications and improving recovery outcomes.

Table 4. Demographic and clinical characteristics			
Variables	**Sub-categories**	**Control (n = 50)**	**Experimental (n = 50)**
Age Group	35-50	17 (34,0 %)	16 (32,0 %)
	50-65	28 (56,0 %)	27 (54,0 %)
	> 65	5 (10,0 %)	7 (14,0 %)
Gender	Female	27 (54,0 %)	27 (54,0 %)
	Male	23 (46,0 %)	23 (46,0 %)
BMI Group	15 - 25	12 (24,0 %)	24 (48,0 %)
	25 - 35	38 (76,0 %)	25 (50,0 %)
	> 35	0 (0,0 %)	1 (2,0 %)
Hospital Stay Days	≤ 5	0 (0,0 %)	11 (22,0 %)
	6 - 10	11 (22,0 %)	35 (70,0 %)
	> 10	39 (78,0 %)	4 (8,0 %)
VAS Pain Score	1-5	20 (40,0 %)	46 (92,0 %)
	5-10	30 (60,0 %)	4 (8,0 %)
Comorbidities	No	30 (60,0 %)	34 (68,0 %)
	Yes	20 (40,0 %)	16 (32,0 %)

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Table 5 results showed a significantly lower incidence of adhesions (30,0 % vs. 56,0 %, p=,007) and symptoms of obstruction (16,0 % vs. 42,0 %, p=,004) in the experimental group. The experimental group also demonstrated improved intestinal motility (80,0 % vs. 60,0 %, p=,024) and significantly higher EGEG scores (80,0 % vs. 32,0 %, p=,000). Additionally, postoperative complications (20,0 % vs. 42,0 %, p=,015), recurrent adhesions (8,0 % vs. 34,0 %, p=,001), recurrent obstructions (2,0 % vs. 14,0 %, p=,030), and quality of life improvement (66,0 % vs. 38,0 %, p=,004) were all notably better in the experimental group. These findings suggest that the intervention in the experimental group was effective in reducing postoperative complications and improving patient outcomes.

Table 5. Study Characteristics and outcomes

Variables	Sub-categories	Control (n = 50)	Experimental (n = 50)	x^2	p value
Incidence of Adhesions	No	22 (44,0 %)	35 (70,0 %)	6,895	,007
	Yes	28 (56,0 %)	15 (30,0 %)		
Symptoms of Obstruction	No	29 (58,0 %)	42 (84,0 %)	8,208	,004
	Yes	21 (42,0 %)	8 (16,0 %)		
Normal Intestinal Motility	No	20 (40,0 %)	10 (20,0 %)	4,762	,024
	Yes	30 (60,0 %)	40 (80,0 %)		
Improved EGEG Scores	No	34 (68,0 %)	10 (20,0 %)	23,377	,000
	Yes	16 (32,0 %)	40 (80,0 %)		
Postoperative Complications	No	29 (58,0 %)	40 (80,0 %)	5,657	,015
	Yes	21 (42,0 %)	10 (20,0 %)		
Recurrent Adhesions	No	33 (66,0 %)	46 (92,0 %)	10,187	,001
	Yes	17 (34,0 %)	4 (8,0 %)		
Recurrent Obstructions	No	43 (86,0 %)	49 (98,0 %)	4,891	,030
	Yes	7 (14,0 %)	1 (2,0 %)		
Quality of Life Improvement	No	31 (62,0 %)	17 (34,0 %)	7,853	,004
	Yes	19 (38,0 %)	33 (66,0 %)		

Table 6 shows the results of study on the prevention of acute adhesive intestinal obstruction in the postoperative period in humans, the experimental group demonstrated significantly better outcomes compared to the control group. In the experimental group, 1,04 ± 0,19 was the lower severity score than that of the control group (1,82 ± 0,38) and had a t-value of 12,660 and p value of ,000 as well. The VAS pain score in the experimental group was also diminished (1,08 ± 0,27), with a lesser magnitude compared to that of the control group (1,60 ± 0,49); this is represented by t = 6,500, p = ,000 for both groups, respectively. This way it can be suggested that the experimental group had a better experience in terms of length of stay in hospital during post operation recovery period on average it stood at (1,86 ± 0,54 days) as opposed to (2,78 ± 0,42 days) for the controls giving a t-value which was equal to 9,579 and finally ,000 indicating an overall improvement in postoperative recovery parameters thus projecting significant impact of treatment intervention programs on patients' health care outcomes.

Table 6. Comparison of severity, pain, and hospital stay

Variables	Control (Mean ± SD)	Experimental (Mean ± SD)	t test	p values
Severity Score	1,82 ± 0,38	1,04 ± 0,19	12,660	,000
VAS Pain Score	1,60 ± 0,49	1,08 ± 0,27	6,500	,000
Hospital Stay Days	2,78 ± 0,42	1,86 ± 0,54	9,579	,000

DISCUSSION

Phase one of the current study demonstrates the efficacy of the experimental intervention in reducing the severity, frequency, and onset of postoperative adhesions in piglets. The intervention significantly decreased adhesion severity, with the experimental group exhibiting only mild adhesions, in contrast to the control group, which primarily showed moderate to severe adhesions. Additionally, the experimental group had a significantly lower number of adhesions compared to the control group. In a related study, a new rat model for abdominal

adhesions was developed using Kaolin, which consistently formed adhesions at a concentration of 0,005 g/mL without compromising rat viability. However, higher doses led to significant morbidity and mortality. Similar to the current piglet study, the treatment group in the rat model showed a significant reduction in both adhesion formation and severity compared to the control group.[17] Another study highlights that surgery frequently leads to postoperative tissue adhesions, causing chronic pain and complications. Although anti-adhesion barriers available in gels, solutions, and films are designed to prevent these adhesions, none have proven fully effective. Recent research aims to enhance the effectiveness of these barriers.[18] The significant reduction in postoperative adhesions observed in piglets in the current study aligns with findings from rat models, underscoring the ongoing challenge of improving anti-adhesion barriers in surgical practice.

Moreover, the experimental group experienced a notable delay in the formation of adhesions, indicating that the intervention not only reduced the severity and quantity of adhesions but also extended the time before they appeared. This delay is crucial, as it provides a longer window for recovery without the complications associated with adhesions. Another study also looked at different prophylactic approaches to postoperative adhesions such as surgical techniques, medical therapies and new materials. The article highlighted that while understanding adhesion mechanisms has advanced significantly, many of the suggested remedies have not been tested in clinical settings. The authors suggested that there was a need for more research on combination therapies that included both mechanical barriers and drugs so as to make them work better.[19] In another study, Chitogel combined with Deferiprone and/or Gallium Protoporphyrin were evaluated for their efficacy in preventing abdominal adhesions after surgery in rats. Results revealed that Chitogel with Deferiprone, especially at 5 mM concentration significantly reduced adhesion formation while maintaining the tensile strength of the enterotomy site thereby making it a promising therapy against adhesion.[20] Such intervention can be experimented on to reduce or even delay postoperative adhesions. More studies are needed to prove these findings and develop combination therapeutic strategies for improved post-surgery anti-adhesion measures.

When relaparotomy was conducted, the experimental group had comparatively fewer complete adhesions and a greater proportion of piglets with no adhesion at all. The intervention effectively prevented the formation of severe adhesions and increased the likelihood of complete recovery without adhesions. However, the number of partial adhesions remained similar between the two groups, suggesting that the intervention's impact was more pronounced in preventing complete adhesions. Similarly, a systematic review evaluated 185 studies on 67 unique adhesion barrier agents (37 natural and 30 synthetic) for preventing postoperative adhesions. Ten materials showed positive results in both animal and human studies. While multiple barriers demonstrated success in animal models, few have translated to human use, and no single barrier is widely adopted globally.[21] Another study assessed the tensile strength of the abdominal wall in pigs before and after performing relaxing incisions. The findings showed that relaxing incisions on the anterior and posterior sheaths of the rectus abdominis muscle significantly reduced tensile strength by 12 % and 9,8 %, respectively, with no statistical difference between the sides, indicating that relaxing incisions weaken the ventral abdominal wall.[22] Furthermore, a study highlighted that postoperative peritoneal adhesions (PPA) cause severe complications such as intestinal obstruction and infertility. Various forms of biomaterials like alginate, hyaluronan, and synthetic polymers are used as anti-adhesion fabrics such as hydrogels and films. One of the major breakthroughs with regard to antiadhesion barriers has been in the development of animal models for testing these materials; this includes a number of novel hepatectomy based models.[23] Moreover, a separate study presented a sandwiched trilayer patch devised for effective recovery from intestinal injury involving both leakage-free sealing and antiadhesion characteristics. The inner adherent stratum is immediately adhered using -NHS chemistry while the outer excluder prevents fouling by means of zwitterion effects. This patch designed with a strong and flexible interlayer demonstrated good wet adhesion, mechanical strength and inertness in rats and pigs thereby giving promising clinical potential for gut injuries.[24] While complete adhesions were eliminated, partial adhesions persisted following experimental intervention on severe adhesions in piglets. Although much progress has been made in finding ideal antiadhesion strategies, no single barrier has achieved global adoption into human surgical applications so far. Phase two of the current study is a comprehensive assessment of how experimental intervention has an effect on post-operative outcomes in human patients. The clinical parameters for which this intervention caused significant improvements include reducing hospitalization period and pain scores, as well as reducing comorbidities among patients in the experimental group. These findings then indicate that it not only minimized post-operative complications but also improved overall recovery by reducing pain and shortening discharge time. Over 90 % of abdominal surgeries lead to abdominal adhesions after surgery leading to chronic pains, bowel obstructions, infertility and consequently repeated surgeries. It is important to note that PAAs are developed due to imbalance between fibrinogenesis and fibrinolysis which is exasperated by inflammation and tissue hypoxia. Preventing PAA will reduce complications with their related hospitalizations while lowering healthcare costs hence further studies are needed towards their effective prevention strategies.[25] However, another research found out that present preventives against adhesions following abdominal surgery were limited in their success and thus sparked interest in Traditional Chinese Medicine (TCM). TCM, having

been practice for ages ago has shown some promise through Chinese medicinal herbs, formulas as well as acupuncture regarding possible means of stopping postoperative abdominal adhesion.[26] More research was done involving effects of aerosolized human amnion-derived matrix particulate solution (HAMPS) on rat's peritoneal adhesion formation. While HAMPS decreased adhesions as well as inflammation, although results were not statistically significant it showed there could be significance at the 12,5mg/cc treatment level. This indicates that more studies are needed to confirm these findings and substantiate HAMPS functionality.[27] Also included was a review on pathophysiology and signaling pathways involved in postoperative peritoneal adhesions together with traditional herbal medicine used for prevention versus modern medical treatments. Numerous techniques have demonstrated promise for preventing them; however, the outcome is inconsistent resulting from most studies performed on animals thereby necessitating further research to substantiate these strategies for clinical applications.[28] In conclusion, this intervention had a highly significant positive effect on postoperative outcomes like shortening hospital stays and pain levels in patients. Nonetheless, future research is warranted to develop effective approaches for preventing post-operative abdominal adhesions in a clinical environment.

The current study provides further evidence of the effectiveness of this particular intervention, demonstrating a lower incidence of adhesions and obstructive symptoms in the experimental group compared to their control counterparts. The experimental group also showed improved intestinal motility as well as higher EGEG scores which indicate better post-operative gastrointestinal function. This is underlined by the reduction in postoperative complications and recurrent adhesion and obstruction making it clear that this intervention significantly improves patients' life quality. Similarly, another study emphasized the persistent challenges in diagnosing and treating painful abdominal adhesions and adhesive intestinal obstructions, highlighting the importance of early intervention. It is post-surgical blood supply, oxygenation or peristalsis that foster adhesion creation. Because they are less complicated minimally invasive techniques such as laparoscopic adhesiolysis should be used while reducing fibroblast activity, hypoxia, and inflammation will provide new means of prevention.[29] Another study highlighted that postoperative adhesions are a common complication following abdominal and pelvic surgeries, often resulting from peritoneal irritation due to surgical trauma or infection. These adhesions can manifest weeks to years' post-surgery. This balance between fibrin deposition and degradation is critical for peritoneal healing which must be understood for effective preventive strategies.[30] Additionally, there are fibrotic tissue formations leading to post-surgery-associated adhesions caused by disrupted peritoneal mesothelial cells with infiltrating immune cells. This review emphasizes on understanding these mechanisms for development of effective anti-adhesive strategies particularly focusing on different immune cell roles in developing an adhesive condition after injury at the level of the peritoneum.[31] Moreover, clinical morbidity from ARCs was measured using an international Delphi study conducted to develop a clinical adhesion score for abdominal and pelvic surgery. Inter-observer reliability was high with 0,95 based on this score containing 22 outcomes with 23 weight factors for clinical observation, and further studies were needed to validate its use in the clinic.[32] This study provides evidence for the effectiveness of interventions in terms of reduced adhesions and obstructions, improved gastrointestinal function, and an imperative need for early minimally invasive procedures to avoid postoperative complications.

Finally, the current study indicates that the severity of postoperative adhesions and VAS pain scores were much lower in the experimental group than in the control group, while hospital stay was shorter. These findings reaffirm an earlier study that showed that not only were there decreases in adhesion's severity with the intervention, but also improvements in recovery generally as patients experienced less pain and left hospital quickly. Laparoscopic surgery is associated with risks as well as benefits. Key strategies to improve safety include pregnancy exclusion testing for women of childbearing age, adequate pre-operative discussions and availability of appropriate equipment for use during surgery. To minimize complications and enhance outcomes.[33,34,35] Necessary considerations before and after any operation includes thromboprophylaxis, proper patient positioning, safe equipment use, careful monitoring, and appropriate discharge advice. Advanced therapies to prevent postsurgical adhesions are emerging using biocompatible nanocomposites like hydrogels or electrospun nanofibers. Materials can be engineered into smart 3D scaffolds responsive to stimuli so that they can have varied abilities such as prevention of adhesion formation or bacterial infection or healing tissues among others. Yet more research is required to determine their clinical potential and market viability.[36] Postoperative adhesions significantly impact patients' quality of life often requiring expensive treatments such as re-operation and prolonged hospitalization. A review focuses on mechanisms underlying growth of adherences on patients' bodies surfaces together with new approaches applicable in treating this condition. Emerging options currently being developed including electors pun fibrous mats, hydrogels, nanospheres appear useful in developing effective biomaterials for anti-adhesion which will lead to better clinical outcomes.[37] Additionally, another study tested how effective it would be to combine a Foley intrauterine balloon with an IUD when preventing re-adhesion after hysteroscopic adhesiolysis and the results indicated a significant reduction in re-adhesion and an improvement in pregnancy rates for cases of moderate IUA after the procedure. In severe cases, however,

it was not as effective. For moderate adhesions prolonged Foley balloon placement seemed to work best and had no significant complications associated with it.[38] The study shows that advanced anti-adhesion therapies like nanocomposites can be useful in reducing postoperative adhesion severity as well as physical pain while warning on the importance of precautions during laparoscopic surgery.

CONCLUSION

The current study showed that the experimental procedure effectively decreased the severity and number of adhesions following surgery in piglets. Compared to the control group with many adhesions, only mild ones were noted in the experimental group with a significantly lower number of overall adhesions. Furthermore, formation of adhesion was delayed for animals in the treatment group thus indicating that they were protected by the intervention. Therefore, it can be concluded that this intervention may potentially serve as a promising strategy for abating postoperative adhesions in animal models.

In terms of clinical practice on human patients, there were fewer cases of acute adhesive intestinal obstruction among those placed under the experiment than those assigned to controls. This resulted into less rates of anastomotic leakages, increased bowel functioning and other enhanced recovery parameters reflected by increased EGEG scores. The experimentally treated individuals also experienced reduced complications after surgery as well as recurrent adhesion and blockage that improved their lives' quality. These findings indicate that this method might help minimize postoperative complications among humans.

On the whole, both animal and human studies have consistently shown this intervention is capable of decreasing both incidence and severity levels associated with adhesions thereby improving outcomes during post operative period. In view of these results being consistent across piglets and humans, it is possible to say what has been done is right since such uniformity strengthens claims about efficacy of this intervention. In view of these findings; it is possible that these results may influence surgical interventions by providing a way to minimize risks related to peritonitis and other factors leading to post-operative infections due to formation appendicitis like syndromes following any kind operation or reduce surgical procedures intended at treating appendicitis-like symptoms without causing any harm on patients during postsurgical care periods.

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CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

ETHICAL CONCERN

The principles of the Declaration of Helsinki were followed for human clinical trials, including the informed consent of all participants before participation in the study. Patients' personal information was anonymized to protect their confidentiality.

The interventions used in the study were aimed at improving patients' health, reducing the number of postoperative complications, and accelerating recovery. Thus, the study was conducted with strict adherence to ethical standards aimed at ensuring the safety and well-being of participants and did not contradict the principles of nonmaleficence.

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