Comparative efficacy of Prolene and Prolene-Vicryl composite mesh for experimental ventral hernia repair in dogs

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Summary

In this study, efficacy of two hernia mesh implants viz. conventional Prolene and a novel Prolene-Vicryl composite mesh was assessed for experimental ventral hernia repair in dogs. Twelve healthy mongrel dogs were selected and randomly divided into three groups, A, Band C (n=4). In all groups, an experimental laparotomy was performed; thereafter, the posterior rectus sheath and peritoneum were sutured together, while, a 5 × 5 cm defect was created in the rectus muscle belly and anterior rectus sheath. For sublay hernioplasty, the hernia mesh (Prolene: group A; Prolene-Vicryl composite mesh: group B), was implanted over the posterior rectus sheath. In group C (control), mesh was not implanted; instead the laparotomy incision was closed after a herniorrhaphy. Post-operative pain, mesh shrinkage and adhesion formation were assessed as short term complications. Post-operatively, pain at surgical site was significantly less ($P<0.001$) in group B (composite mesh); mesh shrinkage was also significantly less in group B (21.42%, $P<0.05$) than in group A (Prolene mesh shrinkage: 58.18%). Group B (composite mesh) also depicted less than 25% adhesions (Mean ± SE: 0.75 ± 0.50 scores, $P\leq0.013$) when assessed on the basis of a Quantitative Modified Diamond scale; a Qualitative Adhesion Tenacity scale also depicted either no adhesions (n=2), or, only flimsy adhesions (n=2) in group B (composite mesh), in contrast to group A (Prolene), which manifested greater adhesion formation and presence of dense adhesions requiring blunt dissection. Conclusively, the Prolene-Vicryl composite mesh proved superior to the Prolene mesh regarding lesser mesh contraction, fewer adhesions and no short-term follow-up complications.

Key words: Adhesion, Dog, Hernioplasty, Mesh contraction, Ventral hernia

Introduction

Ventral hernias occur as a complication following improper healing of a previous incision or excessive pressure at the site of abdominal wall surgery, hence they are also referred to as "acquired false hernias" (since they do not initially have a complete peritoneal sac) or, "incisional abdominal hernias" (Stick, 2006).

Acute incisional hernias occur within the first 7 days after surgery (Slatter, 2003). Hence, ventral hernias are the most common complications after open laparotomies with a reported incidence ranging from 2% to 20% (Bucknall *et al*., 1982; Read and Yoder, 1989; Hsiao *et al*., 2000). In dogs and cats, the incidence rate of incisional hernias is approximately 11% and 8%, respectively (Smeak, 2003).

Predisposing factors for incisional hernias in dogs include intra-abdominal pressure because of pain, entrapped fat between hernia edges, and use of in-appropriate suture material, chronic steroid treatment, and infection (Smeak, 2003). Chronic incisional hernias occur more commonly secondarily to abdominal distention, deep facial infection, hypoproteinemia; skin wound dehiscence and cardio-pulmonary complications (Smeak, 2003).

When a huge defect makes approximation of local tissue impossible without undue tension, prosthetic implants (i.e. hernia meshes) are used for tension-free hernioplasty (Ahmed and Khan, 1995), more preferably in a sublay position, i.e. between the posterior rectus sheath and the muscle belly of rectus abdominis muscle, as per standard procedure for implantation; yet, recurrence rates of about 2-12% have still been reported (Israelsson *et al*., 2006).

Since its introduction in 1958, the non-absorbable polypropylene mesh has been extensively used for incisional hernia repair (Schumpelick and Klinge, 2003). However it is associated with greater post-operative complications, including an inflammatory response that mimics a foreign body reaction (due to its not being completely inert). The inflammatory reaction varies from individual to individual and directly depends upon the structure of the mesh and the amount of material used (Coda *et al*., 2003; Schachtrupp *et al*., 2003). As a result, the non-absorbable polypropylene mesh leads to adhesion formation, which results in chronic pain,

intestinal obstruction (Monk *et al*., 1994), and entero-cutaneous fistulae formation (Sanders and Kingsnorth, 2012).

In recent years, light weight large porous composite meshes, with reduced polypropylene content (about 50%) and an absorbable surface on the inner side, have been introduced and reported to meet physiological demands in a better way. The non-absorbable part of these meshes, which is composed of multifilament polypropylene and counts for only 30%, is combined with an absorbable part which is made of polyglactin 910 (Klosterhalfen *et al*., 2005). These characteristics minimize the mesh tendency to erode into bowel when used at inlay position (Hameed *et al*., 2009). Furthermore, composite mesh materials are reported to be associated with reduction in post-operative inflammation (Klinge *et al*., 1998), low hernia recurrence rates, moderate complication rate and short hospital stays (Iannitti *et al*., 2008).

This study was therefore conducted with the aim to investigate the efficacy of a novel Prolene-Vicryl composite mesh versus the conventional non-absorbable Prolene mesh for ventral hernioplasty in dogs, with respect to post-operative complications of pain, mesh shrinkage and degree of adhesion formation.

Materials and Methods

Selection of dogs and group allocation

After approval from the Animal Ethical Committee [No.: DAS 547, dated 10 April, 2013], 12 healthy mongrel dogs of either sex, aged between one to two years of age (average: 1.5 years), and average weight of 15-20 kg, were randomly selected and divided into three groups (A, B and C), each group comprising of 4 dogs. The dogs were housed in kennels at Pet Centre of University of Veterinary and Animal Sciences, Lahore for a period of 3 months. Health status was ascertained and necessary deworming and vaccination protocols were carried out before launch of surgical exercises.

Pre-operative preparation of animals

The dogs were kept off-feed 12 h before surgery and water was withheld 6 h before surgery.

Pre-anaesthesia

The dogs were pre-medicated using atropine sulphate injected intramuscularly at a dose rate of 0.04 mg/kg. Then afterwards, xylazine hydrochloride (Xylaz®, Farvet Laboratories' Netherlands) at the dose rate of 1.1 mg/kg was injected intramuscularly as a pre-anaesthetic sedative.

Anaesthesia and surgical technique

Induction and maintenance of anaesthesia for ventral hernioplasty was achieved using a combination of Xylazine (Xylaz® Farvet Laboratories' Netherland) at dose rate 1 mg/kg and ketamine (Ketasol® Indus Pharma (PVT) Ltd., Pakistan) at dose rate 5 mg/kg, administered intravenously.

After site preparation using standard approach, a laparotomy was performed in each dog, following which the peritoneum along with posterior rectus sheath were closed in a single layer using absorbable suture material [Polyglactin 910, number 2/0 (Vicryl®, Ethicon, USA)]. Thereafter, a defect of 5 × 5 cm was created on the rectus abdominis muscle belly and the muscular layer of anterior rectus sheath and, in order to mimic incisional/ventral hernia models. After this, mesh was placed in dogs of groups A and B in the sublay position as follows:

Group A

In group A, polypropylene (Prolene®, Ethicon, Johnson & Johnson, USA) mesh was fixed between posterior rectus sheath and rectus belly using polypropylene, size 2/0 (Prolene®, Ethicon, USA), non-absorbable suture material in a simple running interrupted appositional suture pattern. Thereafter, the ends of the anterior rectus sheath were apposed using absorbable polyglactin 910 size 2/0 (Vicryl®, Ethicon, USA) suture material in a simple interrupted suture pattern.

Group B

In group B, the polypropylene-polyglactin 910 composite mesh (Vypro®, Ethicon, Johnson & Johnson, USA) was similarly fixed between the posterior rectus sheath and rectus belly using polypropylene size 2/0 (Prolene®, Ethicon), non-absorbable suture material in a simple running interrupted suture pattern; thereafter, the ends of the anterior rectus sheath were apposed with absorbable polyglactin 910 size 2/0 (Vicryl®, Ethicon, USA) suture material in a simple interrupted pattern.

Closure of laparotomy incision

After successful mesh placement, length and width of the mesh were measured using a linear scale for calculation of mesh area at the time of mesh implantation. After this, the subcutaneous tissues were apposed in continuous suture pattern using absorbable suture material (Polyglactin 910, Vicryl®, Ethicon, USA; size 1/0). Finally, the skin was closed in a cruciate suture pattern using non-absorbable suture material, i.e. polypropylene (Prolene®, Ethicon, USA; size 2/0).

Group C

Dogs served as control. In these dogs the incisional hernia was induced through a laparotomy and repaired through a herniorrhaphy involving suturing of successive layers without placement of any supportive mesh implant. In other words, the laparotomy incision was closed as routine, with the peritoneum and posterior rectus sheath closed as a single layer, using absorbable suture material [Polyglactin 910, number 2/0 (Vicryl®, Ethicon, USA)]. No mesh was implanted over the posterior rectus sheath and the defect of 5 × 5 cm created on the rectus abdominis muscle belly and muscular layer of anterior rectus sheath sutured using absorbable polyglactin 910 size 2/0 (Vicryl®, Ethicon, USA) suture

material in a simple interrupted pattern. The sub-cutaneous tissue and skin were apposed in routine fashion as for groups A and B.

Post-operative management

Post-operatively, all dogs were maintained on fluid therapy using Lactated Ringer's Solution[@] 500 ml/day for 7 days. Anti-biotic, Ceftriaxone Sodium [Injection Oxidil® 500 mg, Sami Pharmaceuticals (Pvt Ltd., Pakistan)] and analgesic, Diclofenac Sodium [Injection Dicloran® 75 mg/3 ml, Sami Pharmaceuticals Pvt Ltd., Pakistan] were used intramuscularly twice daily for a total duration of one week. Wound dressing was done daily using Povidine-Iodine solution (Pyodine® Brookes Pharmaceuticals Pvt. Ltd., Pakistan) and skin ointment (Mycitracin®, Pfizer Pakistan Ltd.). The skin sutures were removed on 10th post-operative day.

Mesh explantation

Prolene and Prolene-Vicryl composite meshes were subsequently removed from groups A and B, respectively, after the 12th week, post-surgically. Before mesh explantation, measurements of mesh length and width were taken, and percentage and character/type/ tenacity of adhesions formed thus noted.

For mesh explantation, a laparotomy was performed under general anaesthesia. The defect in rectus muscle belly was re-opened and mesh removed from over the posterior rectus sheath by suture removal. Thereafter, rectus muscle belly, anterior rectus sheath, subcutaneous tissue and skin were closed as before, and animals maintained on post-operative antibiotics, analgesics and antiseptic dressings for one week in the same way as narrated above.

Parameters of evaluation

A) *Pain scoring*

Pain at the site of surgery was assessed post-operatively during regular examination and palpation in all three groups A, B and C, on fortnightly (14 day) intervals till day 84, using a Pain Grading scale (as shown in Table 1). The pain grades were assigned according to the severity of pain during examination.

B) *Mesh shrinkage*

The percentage mesh contraction was calculated by area measurements of the mesh, both at the time of surgery (implantation/Baseline measurement), and at the time of explantation (i.e. after 12th week of surgery), using the formula as given by (Byrd *et al*., 2011).

$$\text{Percentage mesh contraction} = \frac{(\text{Baseline measurement} - \text{explants measurement})}{\text{Baseline measurement}} \times 100$$

For area calculations, mesh length and mesh width were measured at initial implantation as well as at the time of explantation, using a linear scale.

C) *Adhesion scoring*

Adhesions at the surgical site were assessed via two parameters as follows:

i) The Modified Diamond scale (as given in Table 1): (Greca *et al*., 2001) to measure the proportion of mesh covered with adhesions 12 weeks' postoperatively in dogs of groups A and B, respectively; and the proportion of adhesion formation after herniorrhaphy in group C (at 12 weeks' post-operatively).

ii) The Adhesion Tenacity scale (as given in Table 1): to measure the tenacity/character of adhesions in groups A and B, respectively (Garrard *et al*., 1999).

Table 1: Scores for assessment of: **A**) Grades of pain in groups A, B and C; **B**) quantitative adhesion scoring (percentage) after mesh implantation in dogs of groups A (Prolene mesh) and B (composite mesh); and **C**) Adhesion Tenacity scale for qualitative assessment of type of adhesions after mesh implantation in dogs of groups A (Prolene mesh) and B (composite mesh)

A) Pain Grading scale for assessment of pain at surgical site in dogs of groups A (Prolene mesh), B (composite mesh) and C (herniorrhaphy, control)

Scores	Grades of pain
1	None
2	Mild
3	Moderate
4	Severe
5	Unbearable

B) Modified Diamond scale for quantitative adhesion scoring (percentage) after mesh implantation in dogs of groups A (Prolene mesh) and B (composite mesh)

Scores	Percent adhesions
0	No adhesion
1	Less than 25%
2	25%-50%
3	More than 50%

C) Adhesion Tenacity scale for qualitative assessment of type of adhesions after mesh implantation in dogs of groups A (Prolene mesh) and B (composite mesh)

Scores	Types of adhesions
0	No adhesions
1	Flimsy adhesions, easily broken manually
2	Dense adhesions requiring blunt dissection to separate viscera from mesh
3	Very dense adhesions with viscera matted to mesh surface and requiring sharp dissection to separate viscera from mesh

Statistical analysis

The results were statistically analyzed with the help of SPSS 16 using ANOVA (for parameters of pain grading and percentage modified adhesion quantitative analysis, Fig. 1); and Two-Sample Independent t-test (for percentage mesh contraction, Table 2; and qualitative adhesion analysis, Fig. 2).

Results

Pain scoring

Pain evaluation in group A dogs (Prolene mesh) manifested moderate pain, with an average score of 2.28

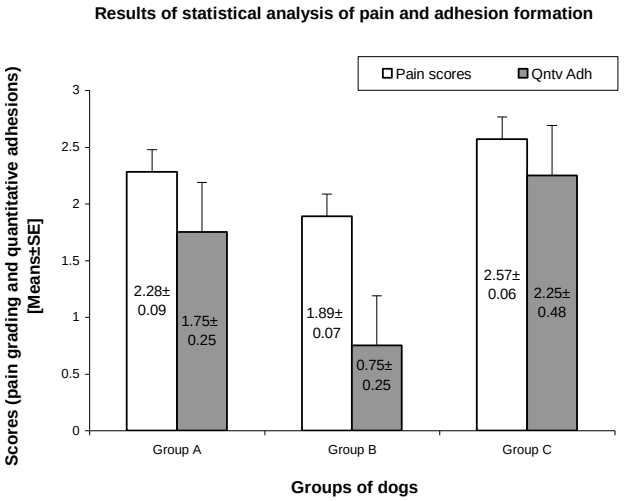

Fig. 1: Results of statistical analysis of pain grade scores and quantitative (percentage) adhesion formation after mesh hernioplasty (groups A and B), and herniorrhaphy (control group C)

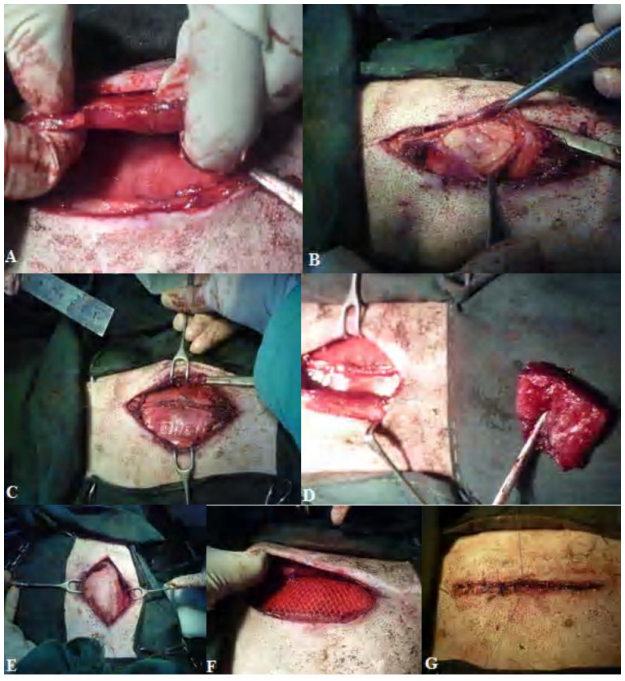

Fig. 2: Ventral midline laparotomy for placement of mesh in sublay position. **A**) Anterior rectus sheath and rectus abdominis muscle belly. **B**) Incision into the peritoneum. **C**) Closure of peritoneum in a simple interrupted suture pattern using absorbable suture material, polyglactin 910, size 2/0 (Vicryl®, Ethicon, USA). **D**) Removal of piece of defect of 5 cm × 5 cm from rectus abdominis muscle belly and anterior rectus sheath. **E**) Placement of polypropylene (Prolene®, Ethicon, Johnson & Johnson, USA) mesh in sublay position in group A dogs. **F**) Placement of polypropylene-polyglactin 910 composite mesh (Vypro®, Ethicon, Johnson & Johnson, USA) mesh in sub-lay position with non-absorbable (Prolene) suture material, size 2/0. **G**) Skin closure using non-absorbable polypropylene, size 2/0 (Prolene®, Ethicon, USA) suture material in a cruciate suture pattern

± 0.198 [Mean ± SD], (P<0.05). Contrarily, group B dogs (Prolene-Vicryl composite mesh) depicted mild pain, with an average score of 1.89 ± 0.139 [Mean ± SD], at P<0.01. Group C dogs (control group) depicted the highest degree of (moderate) pain scores with an average value of 2.57 ± 0.118 [Mean ± SD], at P<0.05, Table 1, Fig. 1.

Mesh shrinkage

Mesh shrinkage (values summarized in Table 2) was one of the most important parameters studied. Percentage mesh contraction was calculated using the formula given by Byrd *et al*. (2011), whereby length and width of the mesh were measured using a linear scale at the time of surgery (i.e. mesh implantation) and after 12th week post-operatively, at the time of explantation, under general anaesthesia.

In our experimental trials, mesh shrinkage manifested a statistically significant difference of P<0.05. Consequently, group B (Prolene-Vicryl composite mesh) depicted a much lesser mesh shrinkage (Mean ± SD: 15 ± 2.16 cm), which establishes its efficacy as a more beneficial implant for hernioplasty, with little known complications. Contrarily, group A (Prolene mesh) manifested greater mesh shrinkage (Mean ± SD: 27.75 ± 2.5 cm), and along with its associated complications, it was considered less advantageous and inferior among the two implants, Table 2.

Adhesion scoring

i) Quantitative adhesion scoring using the Modified Diamond scale (Table 1) as used by Greca *et al*. (2001) depicted statistically significant (P<0.05) adhesion scores between the three groups: hence, group B (Prolene-Vicryl composite mesh) superceded over the other two groups due to formation of less than 25% adhesions (Mean ± SD: 0.75 ± 0.50 scores), P≤0.013; whereas both the groups A (Prolene mesh) and C (control) depicted greater degree of adhesion formation (25-50% adhesions) with Mean ± SD scores of 1.75 ± 0.50 and 2.25 ± 0.957, respectively (Fig. 1).

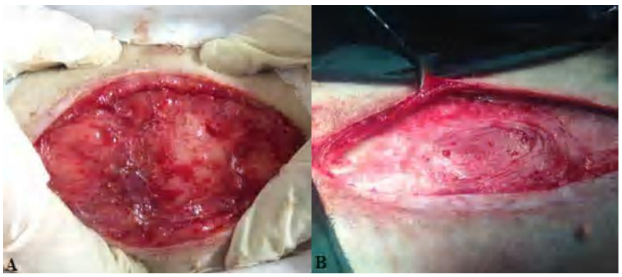

Fig. 3: A) Dense adhesion requiring blunt dissection to separate connective tissue from mesh group A (Prolene treated group), and **B**) Thin, flimsy (easily removable) adhesions in group B (Prolene-Vicryl composite mesh treated group)

ii) Qualitative adhesion scoring using the Adhesion Tenacity scale (Table 1) as narrated by Garrard *et al*. (1999) also strongly emphasized the superiority of the Prolene-Vicryl composite mesh; in group B (Prolene-Vicryl composite mesh), 50% of the dogs depicted presence of thin, flimsy adhesions which could easily be

Table 2: Percentage measurement of mesh shrinkage at day 0 and day 84 in group A (Prolene mesh) and group B (Prolene-Vicryl composite mesh) dogs

Dogs	0 day (L)	0 day (W)	84 day (L)	84 days (W)	Area 0 (day)	Area 84 (day)	% Mesh contraction	P-value
A1	7.5 cm	7.5 cm	4.8 cm	5.1 cm	56.25 cm^2	24.48 cm^2	56.48%	0.0002481
A2	7.5 cm	7.5 cm	5.0 cm	4.9 cm	56.25 cm^2	24.50 cm^2	56.44%	
A3	7.5 cm	7.5 cm	4.6 cm	5.2 cm	56.25 cm^2	23.92 cm^2	57.47%	
A4	7.5 cm	7.5 cm	4.9 cm	4.8 cm	56.25 cm^2	23.52 cm^2	58.18%	
B1	7.5 cm	7.5 cm	6.4 cm	6.6 cm	56.25 cm^2	42.24 cm^2	24.90%	
B2	7.5 cm	7.5 cm	6.6 cm	6.9 cm	56.25 cm^2	45.54 cm^2	19.04%	
B3	7.5 cm	7.5 cm	6.5 cm	6.8 cm	56.25 cm^2	44.20 cm^2	21.42%	
B4	7.5 cm	7.5 cm	6.7 cm	6.9 cm	56.25 cm^2	46.23 cm^2	17.81%	

L: Length, W: Width, and A: Area. $P<0.01$, hence mesh shrinkage is statistically significant with Mean ± SD: 27.75 ± 2.5 for group A dogs and 15 ± 2.16 for group B dogs

broken down manually, while 50% depicted no adhesion formation. Contrarily, in group A (Prolene mesh), 75% of the dogs manifested score 2 (dense) adhesions which required blunt dissection to separate the connective tissue from the mesh. Only, one dog, A3, showed the presence of flimsy adhesions, which were easily removed (Fig. 3).

Discussion

In human beings and animals, ventral or "incisional hernias", commonly occur as a complication following improper healing of a previous incision or excessive pressure at the site of an abdominal surgery (Stick, 2006). Large defects make local tissue approximation quite impossible without creating tension, hence, for larger ventral hernias the use of prosthetic implants in a sublay position serves as the preferred choice (Israelsson *et al*., 2006).

Among prosthetics, the non-absorbable poly-propylene mesh has been globally accepted and extensively used for sublay incisional hernioplasty (Schmidbauer *et al*., 2005). However, the adverse effects associated with its use make it an unfavourable choice among the newer more efficacious implants.

The present project was thus designed to compare the efficacy of two mesh implants readily available in Pakistan, including the conventionally used non-absorbable poly-propylene (Prolene®, Ethicon, Johnson & Johnson, USA) mesh and the novel Prolene-Vicryl composite mesh (Vypro®, Ethicon, Johnson & Johnson, USA), which is comprised of a combination of absorbable polyglactin 910 (Vicryl) on its inner side, in addition to the non-absorbable polypropylene component on its outer side. This paper records the clinical outcomes on the basis of post-surgical complications including pain evaluation mesh shrinkage and adhesion formation after sublay mesh hernioplasty.

In our experimental study, pain evaluation showed statistical significance at $P<0.05$. Dogs in group A (Prolene mesh) and group C (control), manifested moderate pain ($P<0.05$); contrarily, group B dogs (Prolene-Vicryl composite mesh) depicted only a mild pain, post-operatively, with a highly significant difference when compared with the other two groups ($P<0.01$). The results were in agreement with the findings Monk *et al*. (1994) and Bangash *et al*. (2012) reported earlier, regarding short hospital stays, low post-operative pain, and minimal complication rates with polypropylene-polyglactin 910 composite meshes.

Mesh shrinkage was one of the most important parameters studied. In our experimental trials, mesh shrinkage manifested a statistically significant difference of $P<0.05$. Consequently, group B (Prolene-Vicryl composite mesh) depicted a much lesser mesh shrinkage (Mean ± SD: 15 ± 2.16 cm) which establishes its efficacy as a more beneficial implant for hernioplasty, with little known complications. On the other hand, group A (Prolene mesh) manifested greater mesh shrinkage (Mean ± SD: 27.75 ± 2.5 cm), and due to its associated complications, was considered less advantageous and inferior among the two implants. These results are also in close agreement with the findings of García-Ureña *et al*. (2007) who reported greater inflammatory reaction and mesh shrinkage in polypropylene mesh when applied at onlay versus inlay position; and Byrd *et al*. (2011), regarding better prognostic results with absorbable composite meshes, at inlay position.

Quantitative adhesion scoring using the Modified Diamond scale manifested superiority of the Prolene-Vicryl composite mesh, group B, owing to less than 25% adhesion formation in contrast to the greater degree of adhesion formation (25-50% adhesions) in the other two groups, i.e. dogs implanted with the Prolene mesh and the control group. Likewise, the qualitative adhesion scoring using the Adhesion Tenacity scale also strongly emphasized the superiority of the Prolene-Vicryl composite mesh, since in dogs implanted with the Prolene-Vicryl composite mesh, either thin, flimsy (easily removable) adhesions developed or no/minimal adhesion formation was recorded. Contrastingly, the Prolene mesh group predominantly depicted development of dense adhesions which required blunt dissection for separation. These results were also in complete agreement with earlier reports as narrated by Alberto *et al*. (2005), Byrd *et al*. (2011), Bangash *et al*. (2012) and Bilsal and Abci (2012) regarding superiority of large-porous, light-weight absorbable meshes over heavy-weight non-absorbable meshes, since they exhibit less inflammatory response because have more vascularization, less macrophages, lymphocytes, and fibroblast count. Due to less inflammatory response they have less adhesion formation. Furthermore, that the non-absorbable polypropylene mesh not being completely inert, generates an inflammatory response similar to that

incited by a foreign body (Klinge *et al*., 1999; Coda *et al*., 2003; Schachtrupp *et al*., 2003; Bellón *et al*., 2008), as a result of which greater degree of adhesion formation ultimately results in chronic pain, intestinal obstruction (Monk *et al*., 1994), and entero-cutaneous fistulae formation (Sanders and Kingsnorth, 2012).

Conclusively, it can be inferred that the large, porous, light-weight Prolene-Vicryl composite mesh is safer and more efficacious as compared to the conventional heavy-weight non-absorbable polypropylene mesh, in terms of fewer post-operative complications and better outcomes.

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Conflict of interest

The authors do not hold any financial and personal relationships with other people or organizations that might inappropriately influence or bias this work.

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