COMPARISON OF NYLON AND POLYVINYL CHLORIDE COATED FIBREGLASS NETS WITH A STANDARD MESH IN THE REPAIR OF HERNIA IN GOATS

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DEPARTMENT OF VETERINARY SURGERY AND MEDICINE
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NOVEMBER, 2011

DECLARATION

I declare that the work in this thesis entitled ‘‘**COMPARISON OF NYLON AND POLYVINYL CHLORIDE COATED FIBERGLASS NETS WITH A STANDARD MESH IN THE REPAIR OF HERNIA IN GOATS’’** has been performed by me in the Department of Veterinary Surgery and Medicine, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria under the supervision of Dr. S. T. Fadason, Professor A. Z. Hassan and Dr. S. N. A. Saidu.

The information derived from the literature has been duly acknowledged in the text and the list of references provided. No part of this thesis has been previously presented for another degree or diploma.

Augustine Andrew

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Signature **Date**

CERTIFICATION

This thesis titled "**COMPARISON OF NYLON AND POLYVINYL CHLORIDE COATED FIBERGLASS NETS WITH A STANDARD MESH IN THE REPAIR OF HERNIA IN GOATS"** by Augustine Andrew meets the regulations governing the award of Master of Science of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to my aged parents (Mr. Andrew Ptileri and Mrs. Christiana Andrew), my brothers (Emmanuel, Innocent, Paul and Justin), my sisters (Juliana, Grace (late) and Angelina) and those who lost their lives, loved ones and/or patients to hernia all over the world.

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ABSTRACT

Hernias are known to have deleterious effects on the productive and reproductive performance of patient. Meshes are used in the repair of hernias with large ring, but they are neither readily available nor affordable. This study was therefore aimed at finding a cheaper alternative by comparing nylon and polyvinyl chloride (PVC) coated fibre glass nets with the standard (ethicon®) mesh for experimental hernia repair in 9 Kano brown goats divided into three groups of 3 animals each. Vital and haematological parameters were assessed pre- and postsurgery. The tensile strengths, safety and efficacy of the two nets and their cost efficiency were also assessed. There was no significant (P□0.05) difference, in the vital and haematological parameters between the groups, pre- and postsurgery, except for significant (P□0.05) increase in PCV and Hb on day 8 postsurgery in the nylon group and also eosinophils and band neutrophils on day 3 postsurgery in the PVC group. There was 1.3N/mm^2 (7.5%) and 0.8N/mm^2 (1.6%) decrease in tensile strength of the nylon and PVC, respectively, post-sterilization. No complications noticed, except for the slight seroma observed 3 days postsurgery in an animal each, from the PVC and the ethicon® groups. The histopathology result revealed numerous new blood capillaries with few fibroblasts and macrophages. The nylon and PVC nets were also found to be 48,781 and 43,478 times, respectively, cheaper than ethicon® mesh. In conclusion, the nylon and the PVC coated nets can serve as a good substitute for the standard meshes for hernioplasty in goats, and can therefore, be recommended for such use in Veterinary surgery.

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CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

Hernia is the abnormal protrusion of an organ or tissue through the structure normally containing it (Blood and Studdert, 1997). It could be either acquired or congenital (Forrest *et al*., 1990; Blood and Studdert, 1997). A hernia may develop in various parts of the body but it is most common in the region of the abdomen (Mc Farland, 1980; Blood and Studdert, 1997). Predisposing conditions to hernia are: septic omphalitis, wound dehiscence after surgery, obesity, increased abdominal pressure and trauma (Noordsy, 1989b; Anon, 2010b). Hernias could be congenital due to the failure of the umbilical opening to properly close few days after birth (Horney and Wallace, 1984) and hereditary as mostly encountered in calves and piglets (Horney and Wallace, 1984; Gyang, 1992). It could also be acquired, resulting from abdominal trauma, stress of parturition, and as a complication of previous abdominal surgery, known as incisional hernia (Mc ILWraith, 1984; Slatter, 1993).

According to the condition of the contents, hernias could be reducible, irreducible, incarcerated, strangulated or with adhesions (Noordsy, 1989b; Slatter, 1993). Hernias could also be classified based on anatomical location as: inguinal, diaphragmatic, ventral abdominal, umbilical and scrotal (Noordsy, 1989b; Anon, 2010a). Hernias have several deleterious effects, such as lowering the productivity and reproductive efficiency of the affected animals (Abdin-Bey and Ramadan, 2001). In the late stage of pregnancy, gravid

uterine horn could be trapped in the hernia in a subcutaneous location, thereby making vaginal delivery difficult (Smith and Sherman, 1994). Hernias with strangulation, depending on the severity and duration of the condition, may even lead to the death of the patient (Muhammad, 2005). Mortality rates of 1.4, 10 and 21% were noted when strangulated hernias were presented within 24, 24-48 and after 48 hours respectively (Andrews, 1981).

Definitive diagnosis of traumatic abdominal hernia can be made by examination of the swelling, locating the ring and reducing the content into the abdominal cavity (Slatter, 1993). Diagnosis of irreducible or ill-defined traumatic abdominal hernia is more challenging and should be differentiated from neoplasm, hematoma, cyst, enlarged lymph nodes and abscesses (Slatter, 1993). The use of barium meal followed by an X-ray of the patient's digestive system (Contrast radiography) could be used to diagnose abdominal hernias (Abdin-Bey and Ramadan, 2001). To confirm the presence of hernia, an ultrasonographic examination or other scanning techniques such as computed tomography (CT) may also be performed (Anon, 2009).

Hernia correction could simply be done by suturing the body tissues (Herniorrhaphy) or by implantation of foreign material to give a greater strength (Hernioplasty) (Blood and Studdert, 1997). The choice of the technique to be employed depends on the size of the hernia ring (Blood and Studdert, 1997).

When a large defect makes the approximation of local tissues impossible without undue tension, prosthetic implants are used and the most commonly used synthetic material is a

monofilament plastic mesh made of polypropylene or polyethylene (Zimmerman, 1968). This material is well tolerated in wounds and is non absorbable (Goris, 1980). Granulation tissues and capillaries grow through the mesh, building a strong layer of connective tissue in four (4) to six (6) weeks (Slatter, 1993). The mesh should extend 1.5 to 3.0cm beyond the margins of the defect and is anchored to strong supportive structures with interrupted sutures (Slatter, 1993). The early post-operative complications that may be encountered are pain, seroma formation, and wound infection (Schumperlick *et al.,* 1996). The limitations of this technique include the possibility of rejection and irritation of adjoining tissue (Schumperlick *et al.,* 1996).

1.2 STATEMENT OF RESEARCH PROBLEMS

Abdominal wound dehiscence and incisional hernias are forms of wound failures with similar risk factors (Bartlett and Kingsnorth, 2009). Wound dehiscence is an acute wound failure ranging from superficial breakdown of skin without evisceration to complete failure of wound with evisceration whereas incisional hernia is mostly a chronic wound failure (John and Joseph 1962; Wong and Kingsnorth, 2002). Here the fascial layer degenerates beneath an intact skin thereby forming a sac (John and Joseph 1962; Wong and Kingsnorth, 2002).

Retrospective studies of post-surgical complications from students' Large Animal surgical exercise in the Faculty of Veterinary Medicine, Ahmadu Bello University Zaria, from 1989 to 1993 showed that wound dehiscence formed the highest occurrence rate of 79 (25.4 %) out of the total of 311 postsurgical complications recorded (Sanni *et al.,* 2002).

Ameh (2010) in another retrospective study of hernias in large animals at Ahmadu Bello University Veterinary Teaching Hospital, Zaria from 2002 to 2009 reported 16 (5.16%) hernias out of the total 310 surgical cases handled; with an incidence of 68.75% in ovine, 18.75% in bovine and 12.50% in caprine respectively.

The incidence of incisional hernia is reported to be as high as 11% in humans and 16% in large animals, depending on the surgical approach to the abdomen, predisposing factors and overall state of the patient (Slatter, 2003). Abdominal wound failure is the most common post-exploratory laparotomy complications encountered in both large and small animal students' wet laboratory at the Ahmadu Bello University Zaria (Sanni *et al.,* 2002; Sanni *et al.,* 2003). This study was therefore designed to seek convenient ways and cheap means of correcting incisional hernias that usually result from the aforementioned recurrent complications with the view of developing a model for having highly productive animals and indirectly improve the productivity of such animals.

1.3 JUSTIFICATION

Simple apposition of hernia ring with minimal or complete avoidance of tension at the healing suture line is essential for ideal healing (Mc Farland, 1980; Fubini and Ducharme, 2004). This may not be possible for hernias with large ring, unless the use of prosthesis is employed. The mesh helps in reducing recurrent rate of hernia and also allows faster recovery. Hernia repair is one of the most frequently performed surgical procedures worldwide, especially in industrialized countries where alloplastic (commercial) meshes are routinely used for tension- free repair of hernias. In less developed countries however,

those meshes are neither readily available nor affordable (Wilhelm *et al.,* 2007). This is also true for Nigeria. Based on the experimental study carried out by Wilhelm *et al.* (2007), in Uganda, it was discovered that cheap substitutes like nylon mosquito nets have properties similar to synthetic meshes.

Similar research was also carried out in humans using polyester mosquito net mesh in tension-free inguinal hernia repair in Ghana (Clarke *et al.*, 2009). According to Ravindranalt *et al.* (2003), based on research conducted on the preliminary multicentric trial of cheap indigenous mosquito net cloth for tension-free hernia repair on human patients in India, sterilized mosquito net was found to be 3700 times cheaper than the alloplastic mesh.

There is the need to evaluate the usability of the different types of local filtration meshes available in Nigeria for hernia repair.

1.4 AIM

The aim of this study was to assess and compare two (2) different types of filtration nets with a standard mesh in the repair of hernias with large ring in goats.

1.5 OBJECTIVES

The objectives of this study include:

1. To test the tensile strength of the 2 local filtration (Nylon and Polyvinylchloride coated glass fibre) nets.
2. To assess abdominal tissue adhesion formation in response to the filtration nets.

3. To evaluate the safety and efficacy of these nets in clinical practice during hernia repair.
4. To establish the cost efficiency of using filtration nets as against the standard meshes.

1.6 RESEARCH HYPOTHESIS

Null hypothesis: Filtration meshes would not serve as a satisfactory substitute for commercial meshes in hernioplasty in goats.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1 Definition

From a surgical perspective hernia is the abnormal opening in the body wall leading to the protrusion of an organ or tissue through the structure normally containing it (Gyang, 1992). In this condition, a weak spot or other abnormal opening in a body permits part of the organ to bulge through. A layman's term for hernia is rupture (http://hcna.radcliffe-oxford.com; Blood and Studdert, 1997). The term herniology denotes the study of hernia (Blood and Studdert, 1997). A hernia may develop in various parts of the body but it is most common in the abdominal region (Mc Farland, 1980; Blood and Studdert, 1997).

Hernia is characterized by the hernial opening otherwise called the ring, sac and the content. Traumatic hernias have been termed false hernias because they lack hernial sac, hence simply called ruptures or ruptured hernias (Cox, 1988). An inflamed sac or gland simulating strangulated hernia is referred to as pseudohernia (Blood and Studdert, 1997). Hernia ring may be a persistent prenatal opening (i.e., the umbilicus), a normal passage (i.e., the inguinal canal) or accidental rupture in the abdominal wall (Gyang, 1992). The sac may be made up of the skin, limited number of muscle fibres or fibrinous connective tissues and sometimes the parietal peritoneum (Gyang, 1992; Blood and Studdert, 1997). The parietal layer may be absent in certain ventral abdominal hernias because of rupture. Some authors confine the term sac to the peritoneal layer when present (Gyang, 1992).

The hernial sac is further divided into the neck, being the part nearest to the ring, the body, the intervening portion and the fundus which is the lowest part of the hernial sac (Noorsdy, 1989a; Gyang, 1992). The hernial content may be a loop of intestine (enterocele), omentum (omentocele/epiplocele), stomach (gastrocele), urinary bladder (vesicocele) or peritoneal fluid (Noorsdy, 1989a; Gyang, 1992).

2.2 PREDISPOSING FACTORS

The common cause of hernia is a defect in the anatomy of a natural body opening in the abdominal wall such as umbilicus and inguinal canal (Runnells *et al.,* 1965). Whereas acquired hernias could be predisposed by conditions like septic omphalitis, postsurgical wound dehiscence, increased intra-abdominal pressure (e.g. in advanced pregnancy and hydrops allantois), obesity and trauma or violent impact as it occurs in the cases of horn gouging or goring (Noorsdy, 1989a; Anon, 2010b). Sheep and goats are frequently presented with different types of hernias to Veterinary clinics (Fahd and Ahmed, 2007).

Abdominal hernias may occur when the abdominal wall is severely traumatized and may be high or low in the flank, along the costal arch or between the last few ribs (Keown, 1974). They are usually caused by violent force, such as from the impact of blunt objects, but they may also result from overstretching of the abdominal muscles (Tirgari, 1979). Fahd and Ahmed (2007), in surgical treatment for different forms of hernias in sheep and goats, discovered that trauma due to horning from other animals appeared to be the most common cause of abdominal hernias in these species and that the probable cause of inguinal hernias in females were pregnancy and the act of parturition whereas increased intra-abdominal pressure during mounting was the probable cause of both inguinal and scrotal hernias in

males. They also observed that abdominal hernias were found to have the highest incidence in both sheep (68.2%) and goats (71.43%) with females having greater chances of developing hernia than the males and this was assumed to be due to slaughtering of the males at earlier ages than the females, which reduces the possibility of admission of the males to Veterinary clinics.

The abdominal wall of a goat is relatively thin; hence muscle tearing and separation often occur from blunt trauma during shearing, fighting or crowding through narrow doorways (Smith and Sherman, 1994). Trauma or extreme abdominal distension in sheep occasionally leads to rupture of the ventral abdominal muscles, caudal to the umbilicus (Smith and Sherman, 1994). Fifty human patients were treated for abdominal trauma at the University of Maiduguri Teaching Hospital Nigeria between 1990 and 1997 and out these twenty three (46%) of these patients had penetrating abdominal injuries while 27 (54%) had blunt abdominal trauma. Road traffic accident (RTA) was reported to account for 74% of the blunt injury while gunshot injury accounted for 57% of the penetrating injuries (Dogo, *et al.,* 2000).

2.3 CLINICAL MANIFESTATIONS

The clinical signs or manifestation of hernia vary with the hernial size, the location and the state of the content (Gyang, 1992). Swelling is the classic sign of herniation. In uncomplicated hernias no pain is elicited on palpation, and the consistency of the swelling depends on the contents. Inflammation due to trauma or infection can be superimposed on the signs, making palpation difficult (Slatter, 1993). The site of the swelling may be some

distance from the hernial ring as a result of migration of the contents in the subcutaneous space (Slatter, 1993).

In some traumatic hernias, the signs may not be obvious until after the traumatic incident (Slatter, 1993). For example in diaphragmatic hernias, swelling is usually not seen but physical signs such as respiratory difficulties, abnormal eructation, dysphagia, bloat, muffled thoracic auscultation with borborygmi sounds easily audible from the thorax may predominate (Fubini and Ducharme 2004). Other signs may include colic, decreased production and weight loss. Palpation per rectum in large animals may reveal a forward position of abdominal viscera and an empty feel to the caudal abdomen in general (Slatter, 1993; Fubini and Ducharme 2004). Other signs depend mainly on the nature and state of the contents of the hernia, for example reducible hernias compared with strangulated intestinal hernias (Slatter, 1993).

A reducible hernia with large hernial ring is not life threatening and the animal may not show any overt signs. However, hernias with small ring, such as inguinal hernias are subject to torsion, incarceration and colic and should be treated as an emergency case (Gyang, 1992).

2.4 ECONOMIC SIGNIFICANCE OF HERNIAS

Hernias may have several negative effects on the patient, some of which include decreased production and weight loss as commonly seen in long standing cases of diaphragmatic hernias (Abdin-Bey and Ramadan, 2001; Fubini and Ducharme 2004) and lowered reproduction of the affected animals (Abdin-Bey and Ramadan, 2001). In the late stage of

pregnancy, gravid uterine horn could be trapped in the hernia in a subcutaneous location, thereby making vaginal delivery difficult (Smith and Sherman, 1994). Hernias with strangulation, depending on the severity and duration of the condition, may even lead to the death of the patient (Muhammad, 2005). Mortality rates of 1.4, 10 and 21% were noted when strangulated hernias were presented within 24, 24-48 and after 48 hours respectively (Andrews, 1981).

2.5 HERNIA CLASSIFICATION

Until date, a general classification system that includes all kinds of hernias is not available. (http://www.ncbi.nlm.nih.gov/books). Hence classifications based on different authors are as follows:

2.5.1 Congenital or Acquired

Based on whether the patient was born with the condition or it was acquired after birth, hernias could be classified as being either congenital or acquired (Forrest *et al*., 1990; Blood and Studdert, 1997). Congenital umbilical hernias occur at birth whereas the acquired hernias are the forms that occur after birth resulting from factors like excessive straining and infection of the navel cord (Oehme and Prier, 1974).

2.5.1.1 *Incisional hernias*

Incisional hernias are acquired hernias formed when a surgically closed cavity disrupts, mostly on the abdomen. Acute incisional hernias generally occur within the first 7 days

after surgery, whereas chronic hernias are noted weeks to years postoperatively (Slatter, 1993). The incidence of incisional hernia is reported to be between 1 % and 11 % in humans and is as high as 16 % in large animals, depending on the surgical approach to the abdomen, predisposing factors, and overall status of the patient (George and Ellis, 1986; Gibson *et al.,* 1989).

Predisposing causes of acute and chronic incisional hernia vary and appear to be related. Reported risk factors for acute incisional hernia include increased intra-abdominal pressure due to entrapped fat between hernia edges, inappropriate suture material use, infection, chronic steroid treatment, and poor postoperative care (Larson and Vandertoll, 1984). Technical error in surgery is reportedly the most common cause of acute wound disruption (Ponka, 1980).

Factors associated with chronic incisional hernia in humans include obesity, hypoproteinemia, cardiopulmonary complications, abdominal distension, skin wound complications, especially deep infection (George and Ellis, 1986). They further reported that local wound complications, especially deep infection, are the most important predisposing causes of chronic incisional hernias.

2.5.2 External or Internal

Whether a hernia could be visibly seen from the outside of the animal's body mostly on the abdominal region, it is called an external hernia. But when the hernia could not be seen from outside of the animal's body (for example, diaphragmatic hernia) it is referred to as an internal hernias (http://www.ncbi.nlm.nih.gov/books).

2.5.3 Pathology of the Contents

According to the condition or pathology of the contents, hernias could be broadly classified as:

2.5.3.1 Reducible hernias

Are the ones in which the contents can be completely and easily returned into the abdominal cavity (Gyang, 1992).

2.5.3.2 Irreducible hernias

Are hernias in which their contents cannot be completely returned into the abdominal cavity because the content is incarcerated, strangulated or there are adhesions between the content and the sac or the ring (Gyang, 1992; Slatter, 1993). Incarcerated hernias are hernias in which the contents are too voluminous to pass through the hernial ring for it to be reduced. Strangulated hernias on the other hand are hernias in which the blood circulation is arrested, the lumen of the bowel is obstructed, and gangrene is likely to occur. Adhesive hernias are hernias where inflammatory adhesions have joined the contents of the hernia to the lining of the sac (Noordsy, 1989b).

2.6.4 Anatomical Location

2.6.4.1 Umbilical hernias

Umbilical hernias are also known as omphaloceles (Oehme and Prier, 1974). It is the protrusion of abdominal wall at the umbilicus. The defect and protruding viscera is covered with skin and subcutaneous tissue. It occurs sporadically in all species (Blood and Studdert, 1997), but mostly in domestic animals (Oehme and Prier, 1974). Congenital umbilical hernias occur at birth whereas the acquired hernias are the forms that occur after birth resulting from factors like excessive straining and infection of the navel cord (Oehme and Prier, 1974). Umbilical hernias are common in foals and pigs, uncommon in calves and rare in lambs and kids (Gyang, 1992).

The condition is believed to be hereditary in piglets and calves. In general, correction of umbilical hernia in food animals is a salvage measure and the Veterinarian should discourage the Farmer from using the animal as a breeding stock. Correction is also an elective procedure and it is best to wait for 6-12 months for the calf or foal to become big enough to withstand the trauma of surgery and anaesthesia (Oehme and Prier, 1974; Gyang, 1992). Often the condition may correct itself as the animal gets older, especially when the content is only intestine. In porcine species, the condition is often associated with navel abscess, requiring immediate attention (Gyang, 1992). Many techniques other than surgery have been described for treating umbilical hernias in large animal species. The results of some of the techniques is doubtful hence are rarely or no longer widely used (Gyang, 1992).Techniques which bring together the edges of the hernial rings produce better results. They however often require general anaesthesia or heavy sedation (Gyang, 1992).

2.6.4.2 Inguinal hernia

Inguinal hernia refers to passage of abdominal organs through the inguinal ring as a result of defect in the inguinal ring through which the abdominal contents protrude (Parks, 1981; Gyang, 1992). Two general categories have been developed to describe true hernias in the inguinal region.

Direct hernias: These are the type of hernias that occur when organs pass through the inguinal ring adjacent to the normal evagination of the vaginal process. They are less common in humans and small animals (Slatter, 1993).

Indirect hernias: These types of hernias are said to occur when an abdominal viscera enter the cavity of the vaginal process (Slatter, 1993). Because of this anatomical difference, direct hernias are usually large, and mostly do not cause incarceration or strangulation. In contrast, indirect inguinal hernias (scrotal hernias) often cause organ dysfunction because the vaginal process narrows considerably at the relatively inelastic inguinal ring (Slatter, 1993).

Inguinal hernias occur less frequently than umbilical hernias and result from a defect in the inguinal ring through which abdominal contents protrude. Inguinal hernia generally denotes direct and indirect hernias in females and direct hernias in males. Indirect hernias in males are considered separately as scrotal hernias. Factors potentially involved in inguinal hernia formation can be grouped into three major areas: Anatomical, hormonal, and metabolic. Enlargement of the entrance to the vaginal process, which, unlike that in humans, remains open, is the most important cause of inguinal hernias in domestic animals (Hayes, 1974).

A congenital persistent vaginal orifice is essential for development of indirect inguinal hernias in humans (Slatter, 1993). Evidence indicates that sex hormones have an important role in the aetiology of inguinal hernias. Most inguinal hernias occur during oestrus in pregnant bitches. Acquired inguinal hernias are much less frequent in neutered females (Walters *et al.,* 1993). Therefore, estrogen production is considered to have a close relationship to development of inguinal hernia in females. Sex hormones may change the strength and character of the connective tissue, thereby weakening or enlarging the inguinal rings.

Experimentally, sex hormone imbalance has been directly linked to formation of inguinal hernia in male and female mice (Slatter, 1993). Weakening of the abdominal wall may be due to altered nutritional or metabolic status of an animal (Parks, 1981). Obesity increases intra-abdominal pressure, forcing abdominal fat through the inguinal canals. Furthermore, accumulation of fat around the round ligament may dilate the vaginal process and inguinal canal, allowing herniation to occur (Slatter, 1993). It could also be predisposed by obesity. Obesity and the weight of the rumen or continuous standing on slopping rumps, opens the inguinal canal, allowing intestines to pass into the canal. The condition is often associated with breeding injury or castration (Gyang, 1992; Slatter, 1993).

Inguinal hernia is believed to be either congenital or hereditary in foals and piglets (Gyang, 1992). It was further reported that the condition is self-limiting in foals, usually disappearing before the animal is 6 months old. Some believe that the condition is usually present before castration, but usually not diagnosed prior to surgery. Clinically, it is seen as

a swelling around the inguinal region. Here diagnosis could be confirmed by rectal palpation of the portion of the intestine entering the inguinal canal (Gyang, 1992).

2.6.4.3 Scrotal hernia

This refers to the passage of the abdominal organs through the inguinal ring all the way into the *tunica vaginalis*, causing marked scrotal enlargement (Robbins and Angell, 1971). Scrotal swellings are common with hydrocele, varicocele and inguinal hernias being the usual causative factors (Edington and Gilles, 1976). Scrotal hernias are indirect hernias that result from defect in vaginal ring, allowing abdominal contents to protrude into the vaginal process beside the contents of the spermatic cord (Crowe and Archibald, 1984). This condition may be either congenital or hereditary, with anatomical defect or weakness in the vaginal orifice or occasionally acquired as a result of trauma (Crowe and Archibald, 1984; Gyang, 1992).

The relative size of the inguinal canal and the structures found within the inguinal rings differ between the sexes. The cremaster muscle in males is a continuation of the free caudal border of the internal oblique abdominal muscle. Normal contents of the spermatic cord (*ductus deferens* and associated artery and vein as well as the testicular artery, vein and nerves) pass through the inguinal rings within the vaginal process (Slatter, 1993). The condition seems to have a common predilection to the left side than the right in some animals (Slatter, 1993).

The main clinical feature is that the animal will have a swollen scrotum predominantly unilateral, although several bilateral cases have been reported (Elkins, 1983; Bellenger, 1996). Animal with scrotal hernia may mount but will not be able to thrust as a result of pain (Slatter, 1993). The external appearance of scrotal hernia depends on the content of the sac and the amount of vascular obstruction at the hernial ring. The swelling is usually cordlike, extending from the inguinal ring to the caudal aspect of the scrotum. Strangulated hernias have a dark discolouration of the tissue within the hernia which may be visible externally (Slatter, 1993).

Scrotal hernias must be distinguished from Lipomatosis, which is an accumulation of fat at the base of the scrotum. Diagnosis could also be confirmed by rectal palpation in large animals and by reduction of the hernial content and palpation of the ring when the animal is placed in dorsal recumbency and the base of the scrotum is grasped to push back the content. Scrotal hernias frequently cannot be reduced (Gyang, 1992; Slatter, 1993). Ultrasonography just like in other forms of hernias may be helpful in obtaining definitive diagnosis (Slatter, 1993). Often the testicle affected becomes aspermatic due to pressure on the spermatic cord (Gyang, 1992; Slatter, 1993).

2.6.4.4 Ventral abdominal hernias

Ventral abdominal hernias can occur anywhere in the abdominal wall, other than at the umbilicus or inguinal canal. They are usually associated with traumatic injury such as kicks, horn injuries as well as parturition (Gyang, 1992). In small ruminants ventral abdominal hernias commonly occur due to road traffic accidents. They are often associated with damage to the abdominal muscles, considerable inflammation and connective tissue

deposition and adhesions of the intestines to the hernia sac. In sheep, they can become big enough to accommodate a pregnant uterine horn and they are usually not life- threatening (Smith and Sherman, 1994). In this case, surgery could be delayed to allow the inflammation to subside or the pregnancy achieves full term before intervention (Gyang, 1992; Smith and Sherman, 1994). Surgical correction is by herniorrhaphy though large defects may require the use of plastic or polypropylene mesh implants to cover up the defect and support the abdomen (Gyang, 1992).

2.6.4.5 Diaphragmatic hernia

This is a defect or hole in the diaphragm that allows the abdominal contents to move into the thoracic cavity (www.en.wikipedia.org/wiki/Diaphragmatic). This condition is another indication, although rare, for surgical treatment of the pleural cavity in cattle. This can result from trauma, dystocia, or traumatic reticuloperitonitis. Clinical signs associated with diaphragmatic hernia include: decreased production, weight loss, dysphagia, colic, bloat, and respiratory difficulties (Fubini and Ducharme, 2004).

Physical examination may indicate muffled thoracic auscultation with borborygmi sounds audible from the thorax. Palpation per rectum in large animals may reveal forward position of the abdominal viscera and an empty feel to the caudal abdomen in general (Gyang, 1992; Fubini and Ducharme, 2004).

Radiography and ultrasonography can help confirm the presence of abdominal viscera in the thoracic cavity. Treatment is either by surgery or salvage of the affected animal (Gyang, 1992; Fubini and Ducharme, 2004).

2.7 HISTORICAL EVOLUTION OF HERNIA REPAIR

Hernia (known as *breuk* in Dutch, *rompure* in French, *keal* in Greek and rupture in English) has plagued humans throughout recorded history, and the first description of inguinal hernia in 1555 B.C., appeared in the *Ebers papyrus* (http://www.ncbi.nlm.nih.gov/books), whereas hernia reduction dated back to *Hammurabi of Babylon* and the *Egyptian papyrus* (http://www.medscape.org/viewarticle). Historically, the most common operation performed was hernia repair using the Bassini technique which was a repair made by stitching the muscles together (http://www.herniarepairs.com.au/history).

Disregarding the historical precursors of inguinal hernia management by barbers, rupture cutters, and bathing masters, the real history of inguinal hernia surgery began at the end of the nineteenth century (http://www.ncbi.nlm.nih.gov/books, 2001). The attempts to reduce hernial orifice were made by Marcy in 1871, Steele in 1874, and Czerny in 1876 (http://www.medscape.org/viewarticle; http://www.ncbi.nlm.nih.gov/books, 2001). It was not until the late 19th century that hernia surgeon Edoardo Bassini who was considered the father of modern day hernia surgery experienced a measurable degree of success in hernia repairs (Sachs *et al.,* 1997; http://www.medscape.org/viewarticle). Bassini's operation

(radical approach) epitomized the essential steps for an ideal hernia repair by repairing the posterior wall of the inguinal canal and reducing the internal inguinal ring (http://www.medscape.org/viewarticle; http://www.ncbi.nlm.nih.gov/books, 2001).

Bassini's concept was improved by Shouldice in 1945 and McVay and Anson in 1942, showing the importance of the fascia transversalis in inguinal hernia repair (http://www.ncbi.nlm.nih.gov/books, 2001;http://wikipedia.org/wiki/shouldice_Hernia_center).

Halsted, a contemporary of Bassini, attempted to correct a flaw in the previous version of hernia repair using the external oblique aponeurosis to reinforce the natural tissues of the posterior wall (http://en.wikipedia.org/wiki/william_stewartHalsted). Perhaps his most useful contribution to the advancement of hernia surgery was his demonstration that hernia repair could routinely be performed under local anaesthesia (http://www.medscape.org/viewarticle; http://en.wikipedia.org/wiki/william_stewartHalsted).

The use of fascia grafts to close large hernial orifices and recurrent hernias dates back to Halsted in 1903, Kirschner in 1908, Rehn in 1914, and Koontz in 1926 (http://www.ncbi.nlm. nih.gov/books), whereas the use of alloplastic materials was first introduced by Stock in 1954 (http://www.ncbi.nlm.nih.gov/books). This was followed by the use of pre-peritoneal mesh by Rives in 1965 and by Stoppa in 1968 for unilateral and bilateral

inguinal hernias respectively, while Lichtenstein in 1970, advocated the use of mesh to bolster the repair of both direct and recurrent hernias (http://www.ncbi.nlm.nih.gov/ books).

Laparoscopic hernia repair was performed by Ger in 1982, whereas mesh- plug technique was introduced by Bogojavalensky in 1989. Following this discovery, three laparoscopic procedures have been established: intra-abdominal onlay mesh-(IPOM), by Fitzgbbons and Toy in 1990, the transabdominal preperitoneal mesh- implants (TAPP), by Arregui in 1991, and total extraperitoneal mesh (TEP), by Dulucq in 1991 (http://www.ncbi.nlm.nih.gov/books).

2.8 HERNIA REPAIR

Hernia repair is one of the most frequently performed surgical procedures worldwide (http://enzinearticles.com/?Hernia-And-it's-Repair). There are two types of hernia repair; these are herniorrhaphy and hernioplasty (Blood and Studdert, 1997; http://enzinearticles.com/?Hernia-And-it's-Repair).

2.8.1 Herniorrhaphy (Tension repair)

This is the traditional hernia surgery which is normally employed for many decades for the repair of simple hernias with small rings (Blood and Studdert, 1997). This basically

involves simple suturing of the hernia ring to close the defect without the use of prosthesis (Blood and Studdert, 1997; http://hernia.tripod.com/techcomp). This creates extreme tension on the muscle as it must be moved out of its anatomical location to cover the hernia defect. This produces swelling and pain. More importantly the tension inhibits full and effective healing of the edges (http://hernia.tripod.com/vocab). The result of the incomplete healing in the presence of this continued tension is that the muscle edges may pull apart causing a higher failure rate with recurrent (often larger and more complex) hernia (http://hernia.tripod.com/techcomp; http://hernia.tripod.com/vocab). Also, when the muscles are pulled together adjacent tissues are weakened which too may eventually herniate. Recovery is prolonged with reduced patient flexibility, prolonged pain and restriction imposed on activity (http://hernia.tripod.com/techcomp).

2.8.2 Hernioplasty (Tension free-repair)

This is the method employed for the repair of larger hernias. This is the procedure that involves the use of prosthesis which could be made up of plastic or steel mesh to cover the defect and to strengthen the abdominal wall (http://enzinearticles.com/?Hernia-And-it's-Repair). There are basically 3 techniques which can be considered tension free (http://hernia.tripod.com/techcomp). These are: Laparoscopic, Lichtenstein and tension-free mesh hernia repairs.

2.8.2.1 Laparoscopic hernia repair

This operation otherwise known as minimally invasive hernia repair (http://www.lapsurg.org/hernia, 2010) involves placing a mesh unto the hernia defect from inside the abdomen and it requires general anaesthesia, which is associated with definite risk (http://www.lapsurg.org/hernia, 2010). A telescope attached to a camera is inserted through small incision made under the navel with two other small incisions in the lower abdomen for the passage of the instruments, though with the risk of injury to the intestine. These instruments are used to position the mesh over the weakness, and then held in place with stitches, staples, titanium tacks or tissue glue depending on the preference of the individual surgeon (http://hernia.tripod.com/techcomp; http://www.lapsurg.org/hernia, 2010). While the post operative discomfort is relatively small, the recurrence rate is high (http://hernia.tripod.com/techcomp).

Laparoscopic technique requires general anaesthesia (because the abdominal cavity has to be inflated with air) and it is more often associated with serious intra-operative complications than in open repair. This has made this approach less popular except in extremely unusual cases where hernias, repaired multiple times elsewhere, have recurred so many times, and where open approach is not feasible (http://hernia.tripod.com/techcomp). There is increasing reports of a chronic pain syndrome with this method, possibly related to the use of staples or tacks to 'fix' the mesh internally. Hence the operation has not gained much popularity around the world (http://hernia.tripod.com/techcomp). The benefits of

laparoscopic hernia repair include; shorter operative time, less pain and shorter recovery time (http://www.lapsurg.org/hernia).

2.8.2.2 Lichtenstein hernia repair

This is a tension free repair performed "open" under local anaesthesia. A mesh is applied over the weakened site and sutured in place. This surgery has the advantage of safety with the use of local anaesthesia, and direct visualization of the hernia, without using a "telescope". Here incision of about 3-4 inches in length is made, though with high recurrence rate (http://hernia.tripod.com/techcomp). It was further reported that there is a great deal of surgical dissection which causes post operative pain and slightly prolonged recovery. Placing the mesh "over" the weakened site only is like repairing a "bubble in a tire" by patching it on the outside. Therefore, the author strongly believe that if mesh is to be used, it should be placed inside of the weakened area, under the muscle, not on top, otherwise a recurrent hernia may eventually lift the mesh up (http://hernia.tripod.com/techcomp).

2.8.2.3 Tension free mesh technique

Mesh material was first used for incisional hernia repair more than 50 years ago (Schumpelick *et al.,* 2006). It is now believed that this technique is truly the "state of the art" in hernia surgery, providing the safest, most effective repair with the least post-operative pain. This technique is done under safe, local anaesthesia via a small incision.

Once the hernia (content) is freed up by gentle dissection, it is returned through the ring into its proper position (http://hernia.tripod.com/techcomp). Rather than just covering the weakened area at this point, a specially designed mesh system which opens to cover and effectively repair the defect from the inside is gently positioned through the defect, followed by the placement of an additional sheet of mesh over the defect as an insurance reinforcement (http://hernia.tripod.com/techcomp). The advantage of abdominal wall reinforcement is that it permits the reconstruction of the abdominal wall as an anatomical unit (Schumpelick, *et al.,* 2006).

The mesh is placed in a completely tension free fashion with minimal amount of surgical dissection, hence there is little post operative pain, and patients return to normal activity within days (http://hernia.tripod.com/techcomp).

In industrialized countries the use of alloplastic meshes has become a standard procedure or current method of choice for hernia repair (Wilhelm *et al.,* 2007). Varieties of materials of either fascial auto grafts or prosthetic meshes have been found to considerably reduce the recurrence rate of hernia and allow faster recovery (Roland *et al.* 2000; Godara *et al.,* 2006). But then the use of prosthetic meshes is rare in developing countries because they are very expensive and not readily available (Godara *et al.,* 2006; Wilhelm *et al.,* 2007). Roland *et al.* (2000) in a study, comparing suture repair with mesh repair of incisional hernia, observed that among the patients with midline abdominal incisional hernias, mesh

repair was superior to suture repair with regards to the recurrence of the hernia, regardless of the size of the hernia.

2.9 TYPES OF PROSTHETIC MESHES

2.9.1 Characteristics of an Ideal Prosthetic Mesh

Many authors have attempted to define characteristics of the ideal prosthetic material for hernia repairs but attempts to achieve this 'ideal' have met with varying degree of success. Hence no currently available prosthesis is perfect or free of problems, and the choice of material requires compromise (http://www.medscape.org/viewarticle).

The characteristics of 'ideal' prosthetic mesh for hernioplasty therefore include: Should not be physically modified by tissue fluids, chemically inert, not excite inflammatory or foreign body reaction, non carcinogenic, not produce hypersensitivity reaction, capable of resisting mechanical strain, capable of being fabricated in the required, and constructed in a way such that sutures or cutting will not cause the mesh to unravel or fray, should be sterilizable, permeable and allow tissue ingrowths within it, stimulate fibroblastic activity to allow incorporation into tissue rather than sequestration or encapsulation, be sufficiently pliable so as not to cause stiffness or to be felt by the patient, strong enough to resist bursting by the maximum forces that can be created by intra-abdominal pressure or from an outer force (http://www.medscape.org/viewarticle).

2.9.2 Polypropylene

A thermoplastic polymer, polypropylene (also called polypropene) is one of the most versatile polymers available **(**http://www.plasticmoulding.ca/polymers/polypropylene.htm**).** Some of the physical properties of polypropylene include: Tensile strength of 0.95 - 1.30 N/mm^2 , maximum continued use temperature of 80 ^oC , melting point of 160 ^oC, and density of 0.905 g/cm^3 **(**http://www.plasticmoulding.ca/polymers/polypropylene.htm**).**

The most commonly used synthetic material in hernia repair is a monofilament plastic mesh made of polypropylene or polyethylene (Zimmerman, 1968). This material is well tolerated in wounds and is non absorbable (Goris, 1980). However these commercial meshes are not affordable and not readily available in developing countries such as Nigeria. But then cheap substitutes like nylon mosquito nets which have properties similar to synthetic meshes were previously tried in hernia repair in Uganda (Wilhelm *et al.*, 2007).

2.9.3 Nylon

The term "nylons" is a generic name referring to the group of plastics known as polyamide polymers **available in a homopolymer, co-polymer or reinforced form, used in the production of film and fibre.** (http://www.plasticmoulding.ca/polymers/nylons.htm).

Some physical properties of nylon include: Tensile strength of 90 - 185 N/mm^2, the maximum continued use temperature of 150 - 185 ^oC, melting point of 190 - 350 ^oC, and

density is 1.13 - 1.35 g/cm^3. Nylons are resistant to alkalies, moulds, solvents, moths but are damaged by strong acids, phenol, bleaches, and heat above 338˚ F (170˚ C) (http://www.plasticmoulding.ca/polymers/nylons.htm).

2.9.4 Polyvinyl Chloride (PVC) Coated Glass Fibre Net

Polyvinyl chloride (PVC) coated glass fibre net is an exceptionally durable fabric membrane produced with polyester, fibreglass and other types of reinforcements. PVC-coated mesh is weaved during fabrication, resulting in increased tensile strength (http://www.plasticmoulding.ca/polymers/pvc.htm).

Polyvinyl chloride is made up of a non toxic, biologically inert, chemically resistant, sterilizable, highly durable and flexible material with a very wide variety of applications (http://www.brettmartin.com). Some properties of PVC include: Tensile Strength of 2.60 N/mm,^{2} continued use temperature of 60 ^{o}C, Melting Point of 212 ^{o}C and Density of 1.38 g/cm^3 (http://www.plasticmoulding.ca/polymers/pvc.htm).

2.10 INDICATIONS FOR MESH HERNIA REPAIR

It is often difficult and sometimes impossible to repair large abdominal defects using conventional suturing patterns (Gyang, 1992; Slatter, 1993; Blood and Studdert, 1997). Thus prosthetic meshes are used to re-enforce or replace the missing abdominal wall tissues. Large hernias, very common with umbilical hernias and hernias unsuccessfully repaired previously are often candidates for mesh herniorrhaphy (Hernioplasty) (Fubini and

Ducharme, 2004). Materials commonly being used for this purpose include polypropylene (Marlex) or plastic (proxplast) mesh products (Fubini and Ducharme, 2004).

2.11 MESH REPAIR TECHNIQUES

Some of the techniques of mesh placement for hernia repair include the inlay, sublay, onlay and sandwich techniques (Ferrando *et al.,* 2001). Although polypropylene mesh has long been regarded as an implant of choice for repairing abdominal wall defects, there is still controversy regarding the best site of its placement (Ferrando *et al.,* 2001). Therefore the best position for insertion of prosthetic mesh material has not been conclusively established (Stumpf *et al.,* 2003).

In some studies however, it was found that the ideal position for mesh repair appears to be retro muscular, where the force of abdominal pressure holds the prosthesis against deep surfaces of muscles (Stumpf *et al.,* 2003). These authors believe that simple apposition of unscarred hernial ring with minimal tension is thought to lead to ideal healing. Several suture patterns are used but simple interrupted cruciate or simple continuous patterns are the most commonly used whereas in larger defects, tension-relieving sutures such as near-far-far-near placed at a regular interval may help appose the two sides (Fubini and Ducharme, 2004).

Further report showed that in older animals withholding solid food for 36-48 hours postoperatively reduces the rumen volume and greatly facilitates body wall closure. Mesh should be secured circumferentially around the hernial ring with interrupted horizontal

mattress sutures, making sure the mesh is taut. The reflected hernial fascia, subcutaneous tissue and the skin are then sutured over the mesh. Antimicrobial therapy should be used for mesh herniorrhaphies because of increased risk of infection associated with the mesh implantation (Fubini and Ducharme, 2004).

2.12 ANAESTHETIC PROTOCOL

Anaesthetic management of sheep and goats is usually uncomplicated with notable exception of pulmonary aspiration that may occur due to regurgitation resulting as an undesired effect of sedation or general anaesthesia in these species (Hall *et al.,* 2001).

Local analgesia techniques are very useful in sheep and goat practice because equipment involved is inexpensive, cardiovascular and respiratory depressions are less than produced by general anaesthesia, depending on the agents and techniques used (Hall *et al.,* 2001). Local anaesthetic agents may further induce toxic symptoms when used inappropriately, especially when an excessive volume of local anaesthetic agent is injected. Limiting the initial administration of lignocaine® to 6 mg/kg has been found to be safe. Administration of lignocaine® in excess of 10 mg/kg can result in sufficiently high blood levels to cause cardiovascular depression and central nervous system stimulation (Hall *et al.,* 2001).

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

The research was carried out in the Large Animal Surgery Unit of the Ahmadu Bello University Veterinary Teaching Hospital Zaria, a town in Kaduna State situated in the Northern Nigeria with the geographical coordinates of 11^{O} 4' North and 7^{o} 42' East (Anon, 2005; Anon, 2010c).

3.2 EXPERIMENTAL ANIMALS

The nine Kano Brown goats aged between one to two years and with an average weight of twenty Kilograms were used in the study. The animals were purchased from Makarfi market, Kaduna State, Nigeria and were transported to the departmental pens of the Department of Veterinary Surgery and Medicine Ahmadu Bello University, Zaria, (Plate I) where they were kept and fed *ad libitum* with wheat offal, groundnut hulms and beans husks throughout the duration of the research.

The animals were ear-tagged for identification (Table 3.1) and were then acclimatized for a period of two weeks during which thorough clinical examinations were conducted on them and their weights assessed. The animals were treated with albendazole 7.5mg/ Kg per os once and sulphadimidine 150mg/Kg intramuscularly for 5 consecutive days against helminths and coccidia respectively based on the laboratory results until further samples gave negative results.



Plate I: Experimental animals as housed in the departmental pens of the Veterinary Surgery and Medicine, Ahmadu Bello University, Zaria, Nigeria.

3.3 EXPERIMENTAL DESIGN

The animals were randomly divided into three groups (3) of three (3) animals each which comprised of two (2) bucks and a doe in each of the groups (Table 3.1).

Table 3.1: Experimental Protocol for comparison of filtration nets and Standard mesh for hernia repairs in goats

Groups	Designation	Number of animals	Animal Tag Number	Sex of the Animals	Material Used for the Hernioplasty
A	Experimental	3	151 152 154	Male Male Female	Nylon (Viorny®)
B	Experimental	3	153 155 156	Female Male Male	Polyvinylchloride coated glass fibre (Ossy Bahama®)
C	Control	3	157 158 159	Male Male Female	Polypropylene and polyglactin910 (Ethicon®)

3.4 PROSTHETIC MATERIALS

Two local filtration nets, nylon (Viorny$^{(R)}$) (Plates II and V) and polyvinylchloride coated glassfibre (Ossy Bahama$^{(R)}$ fibreglass insect screening) (Plates III and VI) were purchased from Sabon-gari market, Zaria while the Ethicon$^{(R)}$ containing polypropylene and polyglactin 910 (Plates IV and VII) was purchased from Benjamin Nicholas, Nig Ltd, Kano. The safety and efficacy of these nets in clinical practice were evaluated via wound healing assessment and histopathology and compared with the standard hernia repair mesh. The cost efficiency of using local filtration nets as against the standard mesh was also evaluated.

3.5 TENSILE STRENGTH TESTING

The tensile strength (which is the greatest stress a material can withstand without breaking) of the two filtration nets and the standard mesh were assessed at the Strength of Materials and Heat Treatment Laboratory of the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, using Tensometer (Hounsfield Tensometer®, serial number 3179, manufactured by Tensometer limited, 81 Morland road Croydon, London). The tensile strength of the standard mesh was tested as bought because it was sterilized before packaging; while those of the two nets were tested before and after sterilization by autoclaving.

The materials to be tested were trimmed to required sizes, then the thickness of the ethicon®, nylon and the polyvinyl chloride coated fibre yarn measured with micrometer screw gauge were 0.47, 0.25 and 0.45µm respectively.

The width, also measured by the same instrument was 15mm, which was the distance between the two jaws of the Tensometer. The material to be tested was then fixed in between the jaws and the maximum force needed to break the material was recorded in Newton. The tensile strength was then calculated using the formula shown below;

Tensile Strength = Force (Kilo Newton) x 1000 ÷ Area (width x thickness).



Plate II: The packaged nylon filtration net label for the group A experimental animals

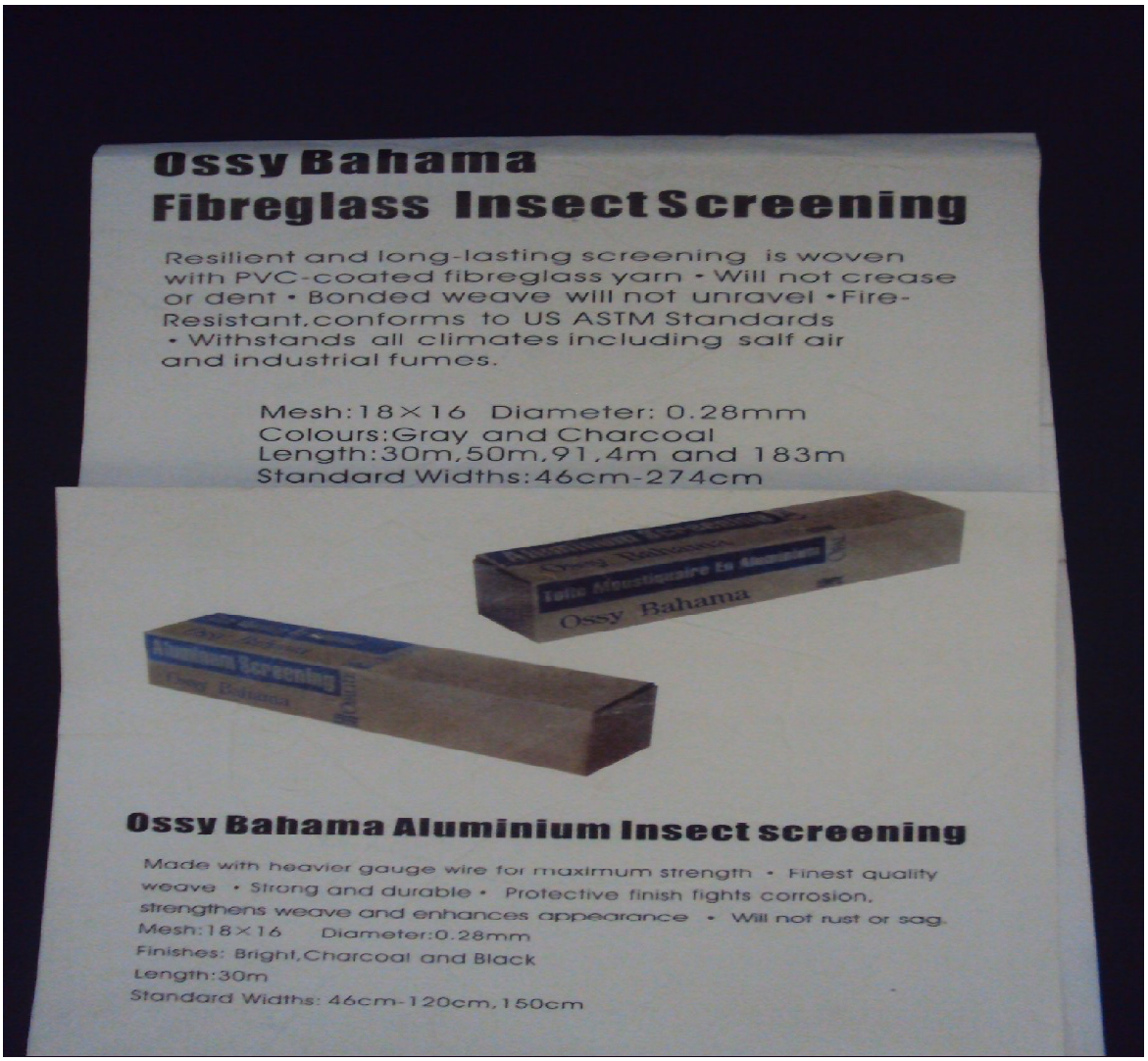


Plate III: The polyvinyl chloride filtration net label for the group B experimental animals



Plate IV: The packaged standard hernia repair mesh, Ethicon® (Polypropylene and polyglactin 910), for the control group of animals

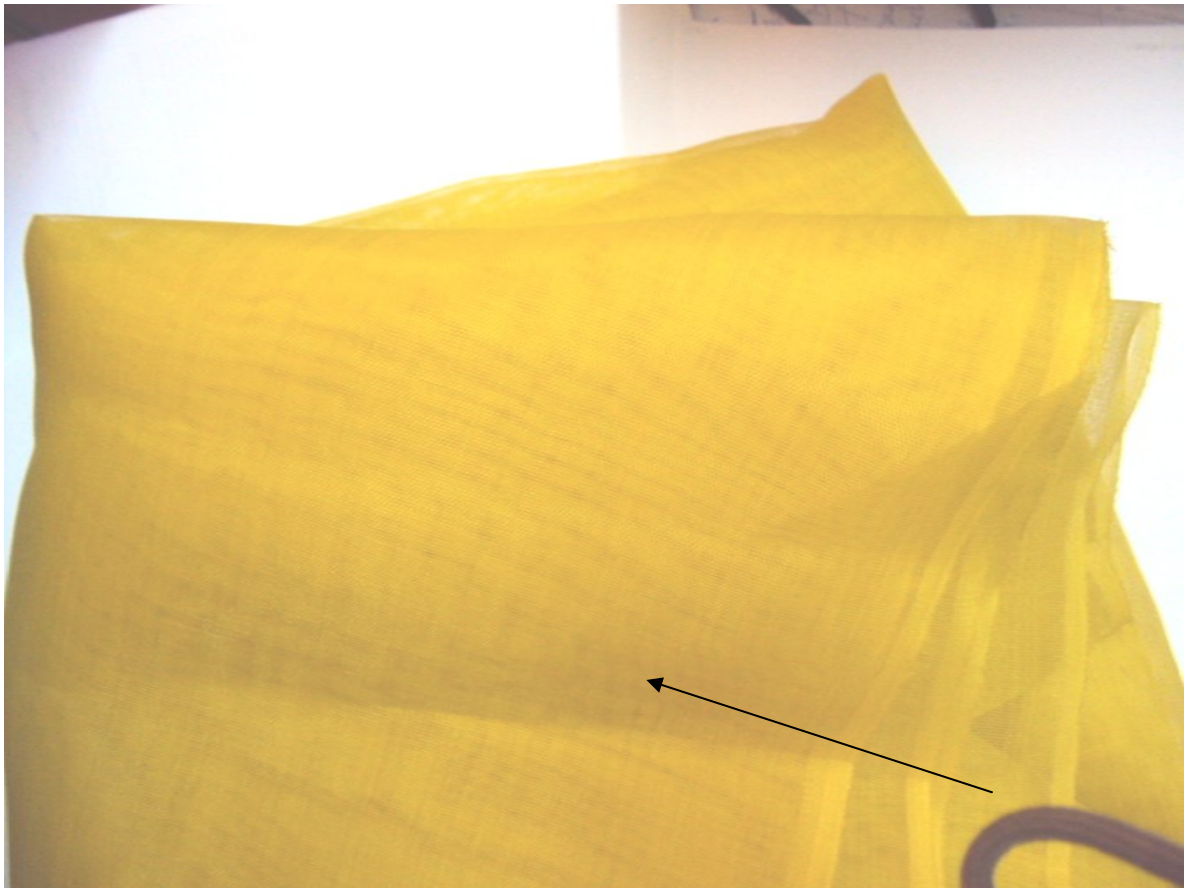


Plate V: The nylon filtration nets (arrow) before trimming to the required size for the hernia repair in the group A experimental animal



Plate VI: The polyvinyl chloride coated fibre glass (PVC) (arrowed) before trimming to the required size for the hernia repair in the group B experimental animals

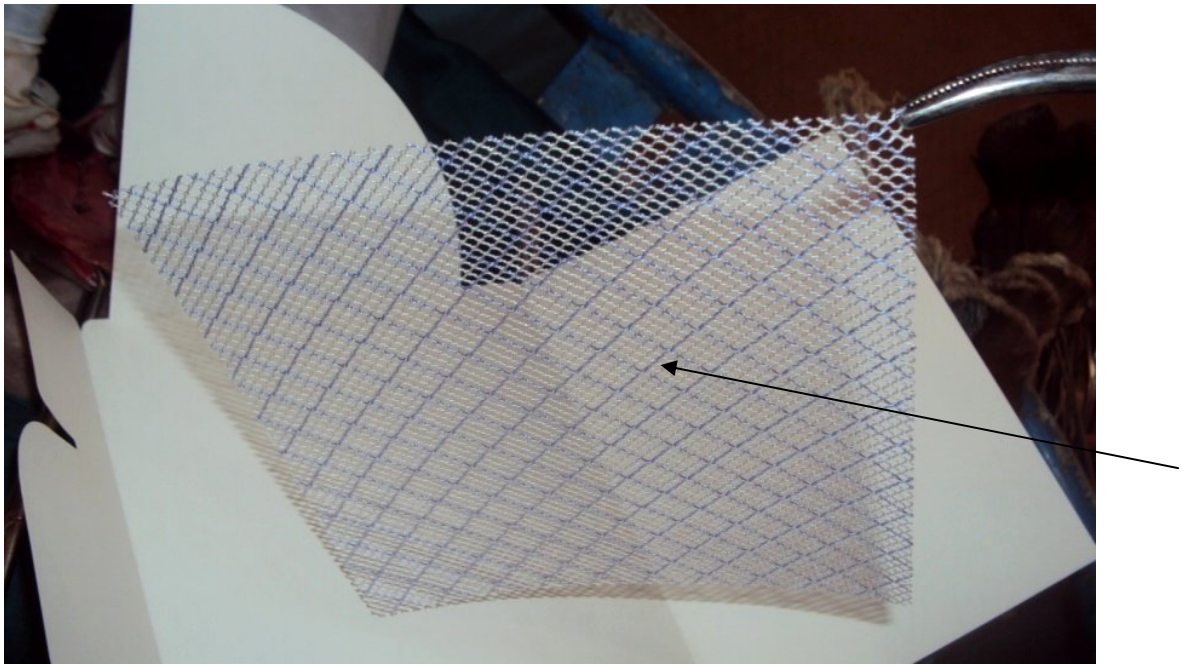


Plate VII: The Standard hernia repair mesh (Ethicon®) (arrow) before trimming to the required size for the hernia repair in the control group of animals.

3.6 PRESURGICAL PREPARATION OF PATIENTS

The animals were deprived of water and feed for twelve (12) and twenty four (24) hours respectively prior to the surgery. The paramedian area cranial to the pubis and caudal to the last rib and from the ventral midline to the distal one-third ($1/3^{rd}$) of the abdomen were liberally shaved, scrubbed and 0.05% chlorhexidine antiseptic solution applied.

3.7 ANAESTHETIC PROTOCOL

The animals were sedated with Xylazine at the dose rate of 0.05mg/kg intravenously and local anaesthesia was achieved through a ring block (Plate VIII) by infiltrating 7ml of 2 % lidocaine HCl subcutaneously into the tissues in the left paramedian area, thereby creating anaesthetic wall enclosing the proposed incision site (Noorsdy, 1989b Hall *et al.,* 2001).

3.8 SURGICAL PROCEDURE

The surgical site was again scrubbed, antiseptic applied and then draped in a rectangular fashion (Plate IX). A left longitudinal abdominal paramedian skin incision measuring 7cm long was made and then undermined to expose the muscle layers (Plates X and XI). Thereafter a circular incision of 5cm in diameter was made on the posterior layer of the rectus sheath and the incision continued until the peritoneum was reached then the circular portion of the muscle tissue was excised (Plate XII).



Plate VIII: Goat restrained and being administered lidocaine hydrochloride via ring block.



Plate IX: A Goat restrained on dorsal recumbency with forelimbs and hind limbs secured with ropes and surgical site draped in a rectangular fashion



Plate X: Measurement of the length of the incision to be made on the skin of the goat

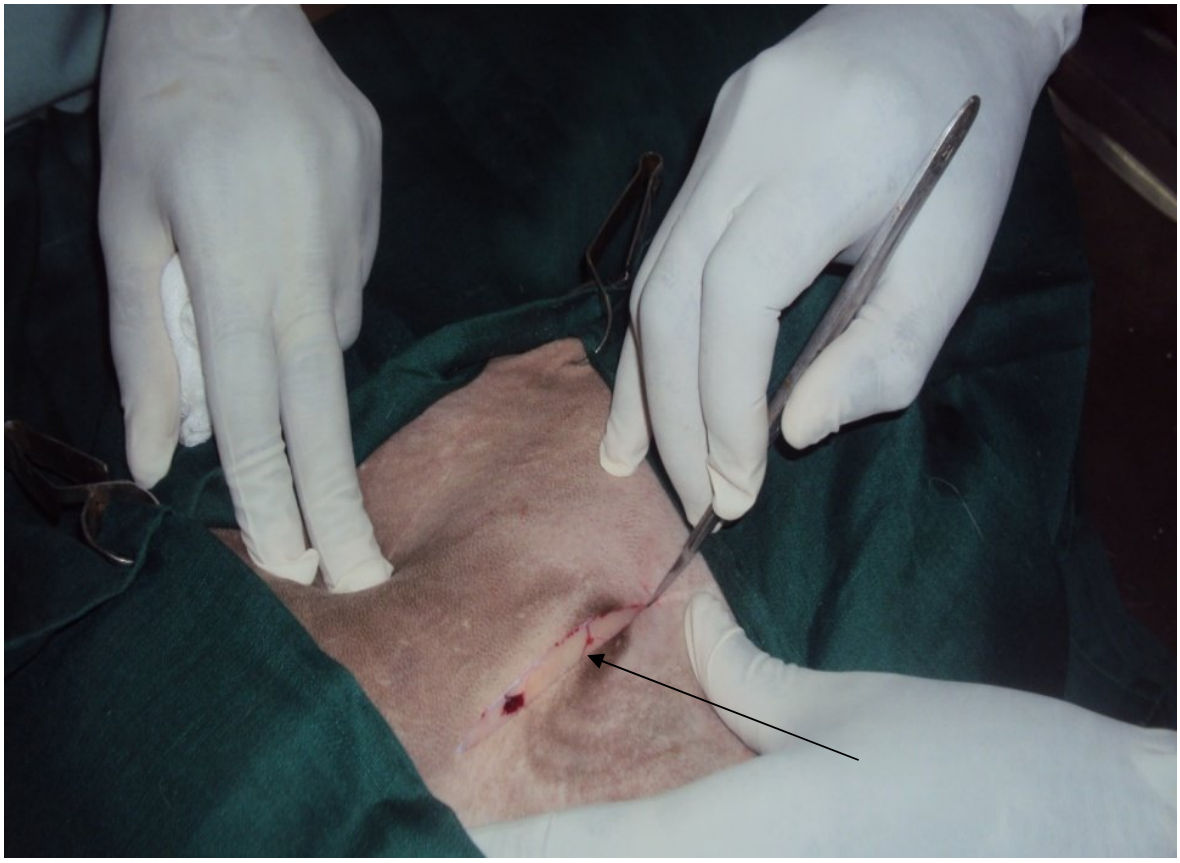


Plate XI: A seven centimeter longitudinal skin incision made on the left ventrolateral abdomen of the goat (Arrow).

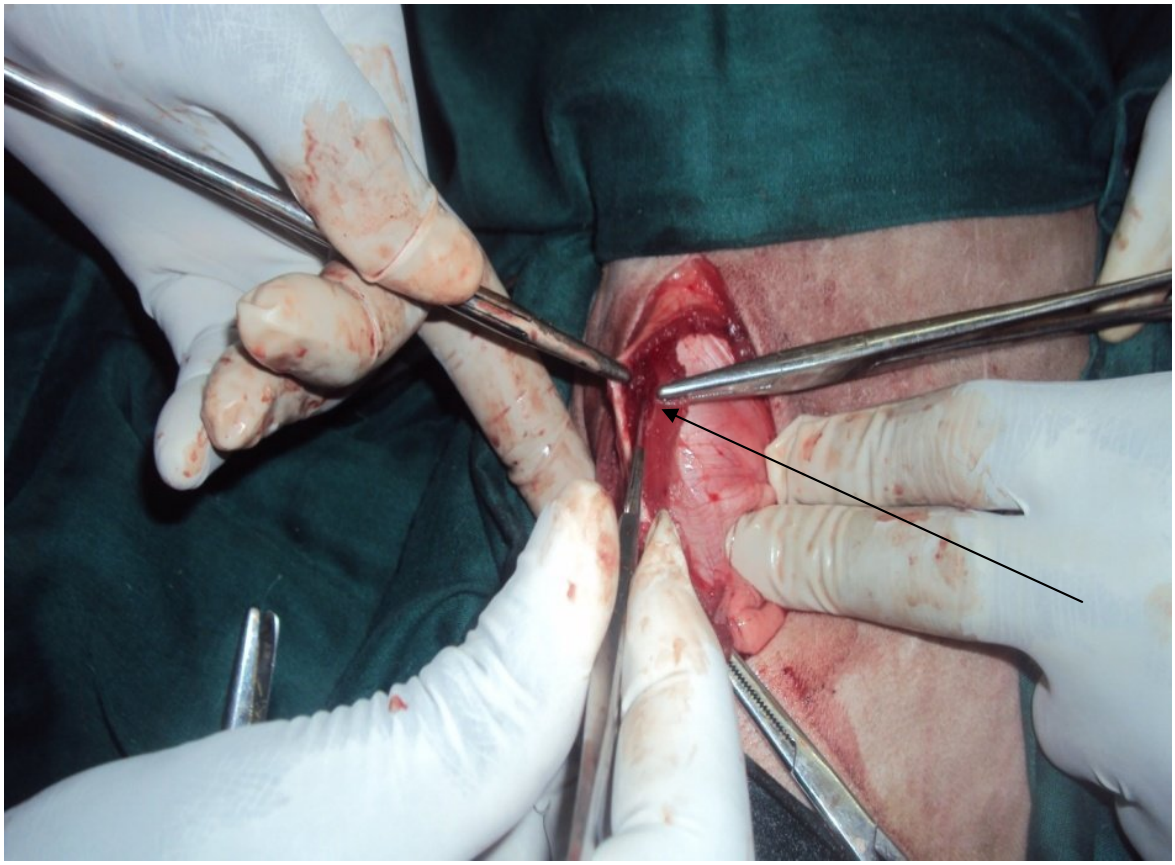


Plate XII: Separation of muscle layers of the ventral abdomen of a goat in a circular fashion for the sublay mesh fixation (Arrow).

In Group A, a 12 cm diameter of sterilized nylon filtration nets (Plate XIII) were implanted into the layers of the separated rectus sheath with simple continuous suture pattern using nylon size 2 and was later reinforced with simple interrupted suture pattern using same suture material (Plate XIV). Intraperitoneal medication was achieved with the combination of procaine penicillin (Shijiazhuang Pharmaceutical Group Zhongnuo Pharmaceutical Company Ltd. China) and streptomycin (Anhui Right Company Ltd., China) at the dose of 200,000IU and 200mg respectively. When implanting the net, 3 cm of the net extended beyond the margin of the defect created before anchoring it to the muscle layers. The subcuticular layer was then closed with chromic catgut size 1 using subcuticular suture pattern, while the skin was sutured with interrupted horizontal mattress suture pattern using size 2 braided silk (Plate XV).

The same procedure was carried out on animals in groups B and C but using sterilized polyvinylchloride coated fibre glass nets on group B (Plates XVI and XVII) and polypropylene standard (Ethicon®) mesh on group C (XVIII and XIX), the control group.

All the animals were injected with Piroxicam (Yikang Pharmaceutical Company., Ltd. China) 20 mg total dose each, intramuscularly to relieve pain due to surgical trauma. The analgesic administration was repeated after forty eight hours post surgery. Oxytetracyline Gentian-violet spray (Veterinary Pharmaceutical Products, Pantex Holland) was applied for three consecutive days post-operatively.

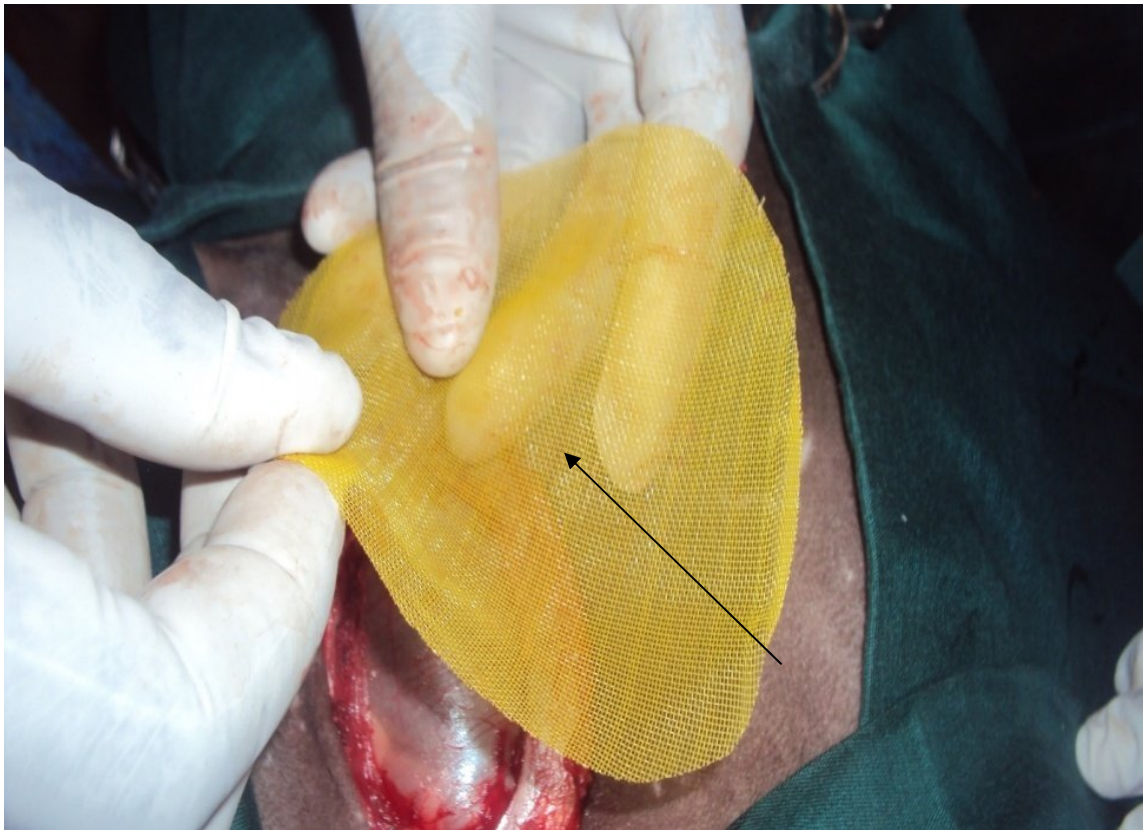


Plate XIII: A trimmed sterilized nylon filtration net measuring twelve centimeters in diameter (Arrow) for the implantation in group A animals.

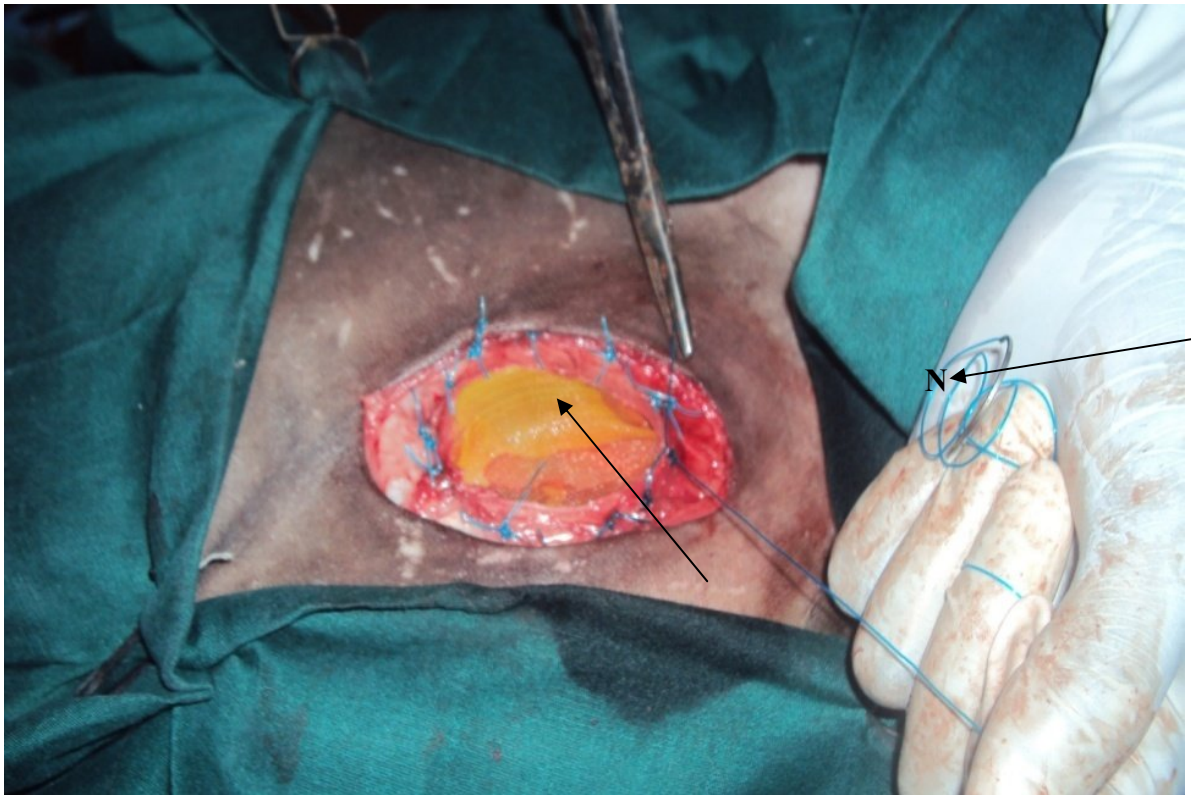


Plate XIV: The sterilized nylon filtration net (arrow) being sutured to the rectus abdominus muscle with simple continuous suture using nylon size 2 (arrowed N) and then reinforced with simple interrupted suture pattern with the same suture material



Plate XV: Skin apposed with interrupted horizontal mattress suture pattern using braided silk size 2 suture

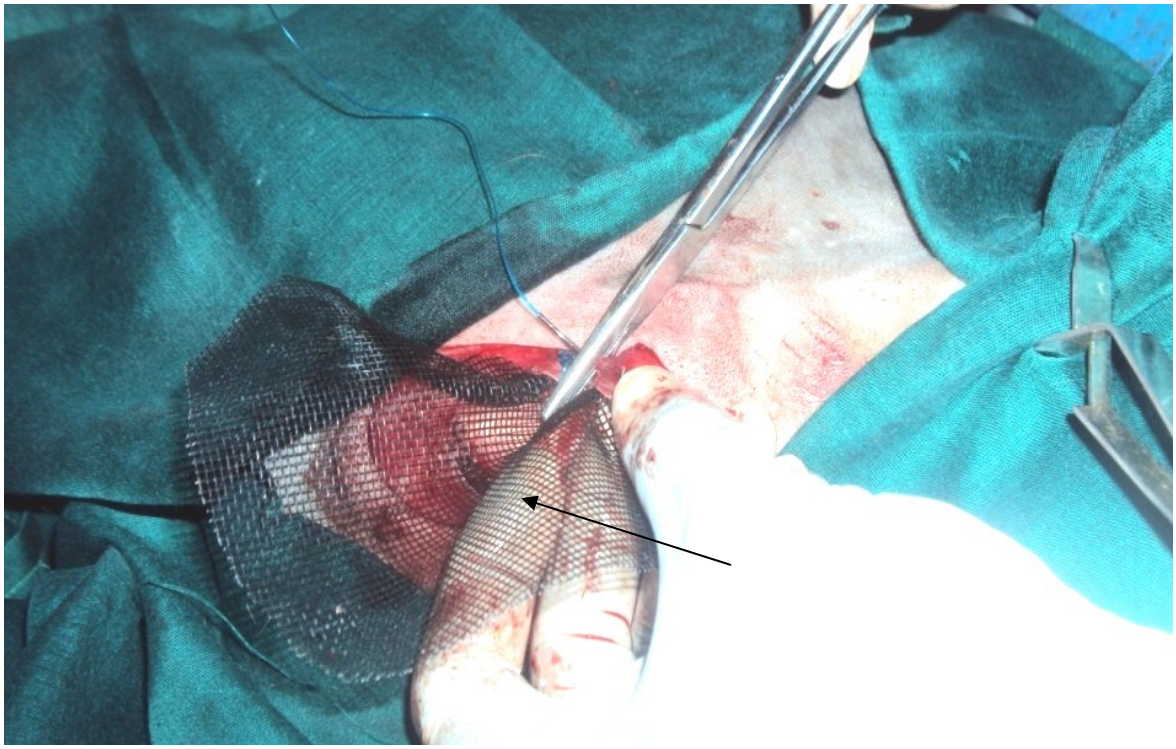


Plate XVI: Trimmed sterilized polyvinylchloride (PVC) coated fibre glass net (arrow) measuring twelve centemeters in diameter being implanted in one of the group B animals



Plate XVII: The sterilized PVC coated fibre glass net (arrow) sutured into the rectus abdominus muscle with simple continuous suture pattern using size 2 nylon and then reinforced with simple interrupted suture pattern using the same suture material

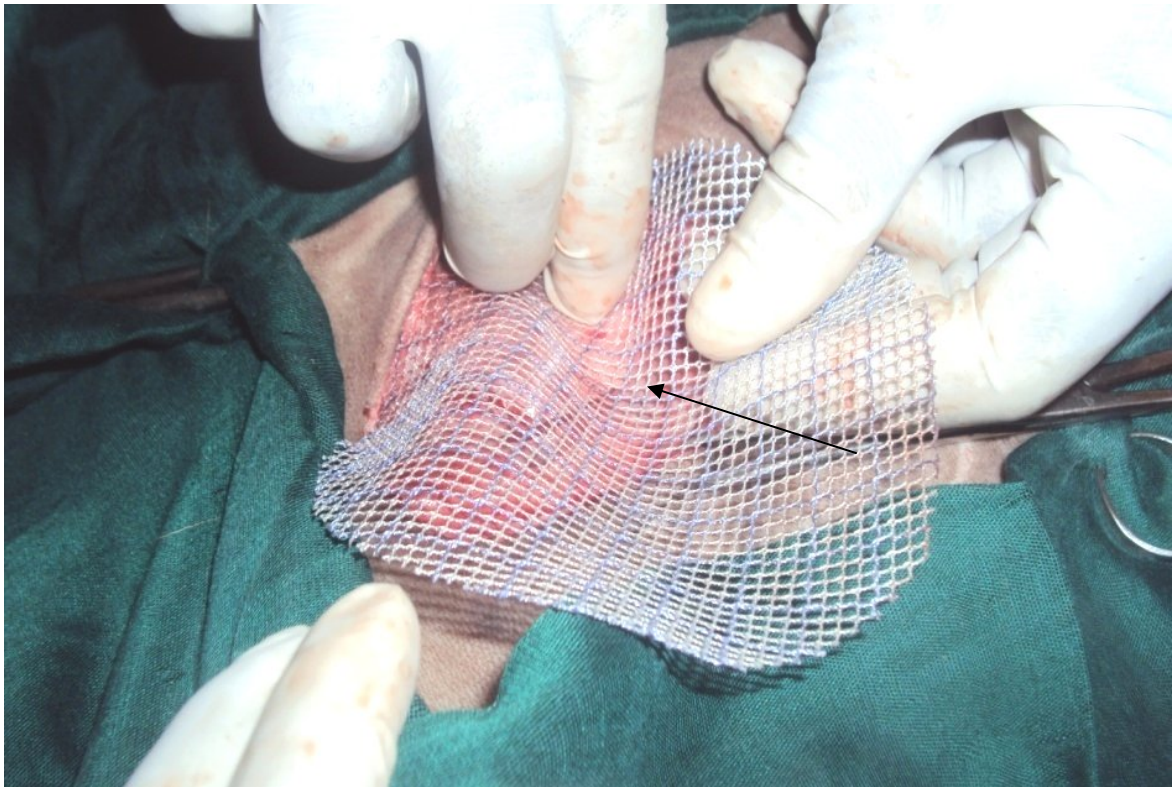


Plate XVIII: **Trimmed standard hernia repair mesh (arrow) measuring twelve centimeters in diameter for the implantation in the control group**

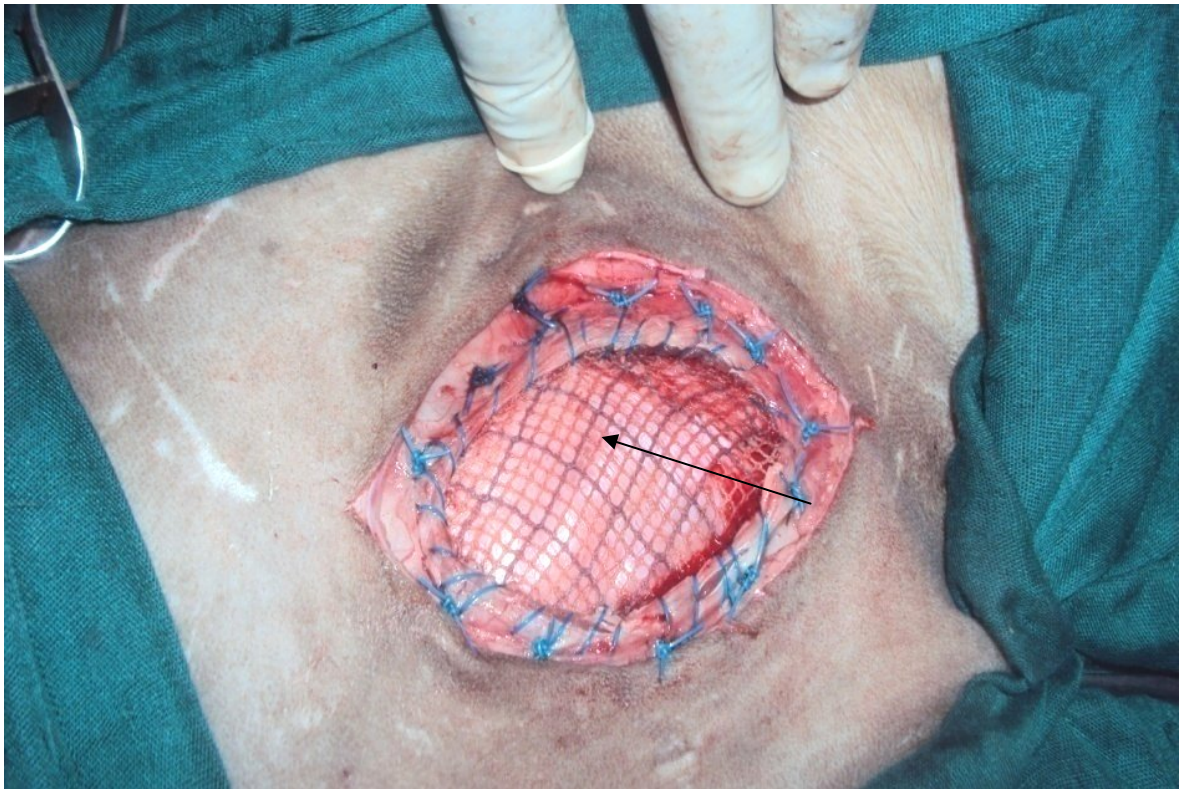


Plate XIX: The standard mesh (arrow) sutured into the rectus abdominus muscle with simple continuous suture pattern using nylon size 2 and then reinforced with simple interrupted suture pattern using same suture material

3.9 CLINICAL EXAMINATIONS

The clinical examination involved assessment of the vital parameters both prior and after the hernioplasty, evaluation of the process of wound healing and haematological values.

3.9.1 Vital Parameters

The vital parameters (temperature, pulse and respiratory rates) of all the animals in all the groups were assessed both before and after the surgical exercise.

3.9.2 Wound Healing Assessment

The wound healing process was assessed on days 3, 8 and 28 based on the method of Wilhelm *et al.* (2007). The wounds were further assessed on day 56 postsurgery.

3.10 HAEMATOLOGICAL EVALUATION

Four millimetre (4 ml) blood samples were taken from the jugular vein of each of the animals in all the groups using 10ml syringes and transferred into a sterile sample bottle containing ethylenediaminetetraacetic acid (EDTA). The samples were subjected to haematological evaluations on days of wound healing assessment. The skin sutures were removed on the fourteenth day postsurgery.

3.11 TISSUE HISTOPATHOLOGY AND EXAMINATION OF THE REMOVED MESHES

The animals in all the experimental groups were sacrificed eight weeks (56 days) post-operatively. The abdominal muscles containing the mesh were removed and full thickness biopsies from the centre of the mesh were fixed in 10% formalin. The samples were then processed in the Histopathology Laboratory of the Department of Pathology and Microbiology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria. The histopathological sections were stained with Hematoxylin and Eosin (H and E) and then examined microscopically (x400) Wilhelm *et al.* (2007).

3.12 STATISTICAL ANALYSIS

Data were expressed as mean ± SEM, then subjected to one-way analysis of variance (ANOVA), followed by Turkey's post hoc test using Graphpad prism version 4.0 for windows from Graphpad software, San Diego, California, USA. Values of P□ 0.05 were considered significance.

CHAPTER 4

RESULTS

4.1 TENSILE STRENGTH TESTING

The tensile strengths of the prosthetic materials used for study before and after sterilization by autoclaving are summarised (Table 4.1).

4.2 CLINICAL EXAMINATIONS

4.2.1 Presurgical and Postsurgical Vital Parameters

The vital parameters of the goats assessed prior to the surgeries and for 5 consecutive days postsurgery were presented in form of graphs (Figures 4.1, 4.2 and 4.3).

4.2.2 Wound Healing Assessment

Three days after the surgery, slight seroma formations were observed around the surgical sites in two animals each in groups B (Plate XX) and C (Plates XXI). The seroma fluid was drained and the wounds healed thereafter without any further complication.

4.2.3 Haematological Evaluation

The mean of pre- and postsurgical haematological values based on groups are summarised in Tables 4.3 and 4.4 respectively. Whereas the mean values of the individual haematological parameters with regards to days (3, 8, 28, and 56 postsurgery) of assessment for both the experimental and the control groups of goats are presented in Appendices 4.1- 4.12.

Table 4.1: Tensile strength for the prosthetic materials used for the study pre-autoclaving

Prosthetic Materials	Force (Newton)	Tensile Strength (N/mm^2)
Nylon	65	17.3
Polyvinyl Chloride Coated Fibre glass Yarn	185	49.3

Table 4.2: Tensile strength for the prosthetic materials used for the study post- autoclaving

Prosthetic Materials	Force (Newton)	Tensile Strength (N/mm^2)
Nylon	60	16
Polyvinyl Chloride Coated Fibre glass Yarn	182	48.5
Ethicon®	28	7.5

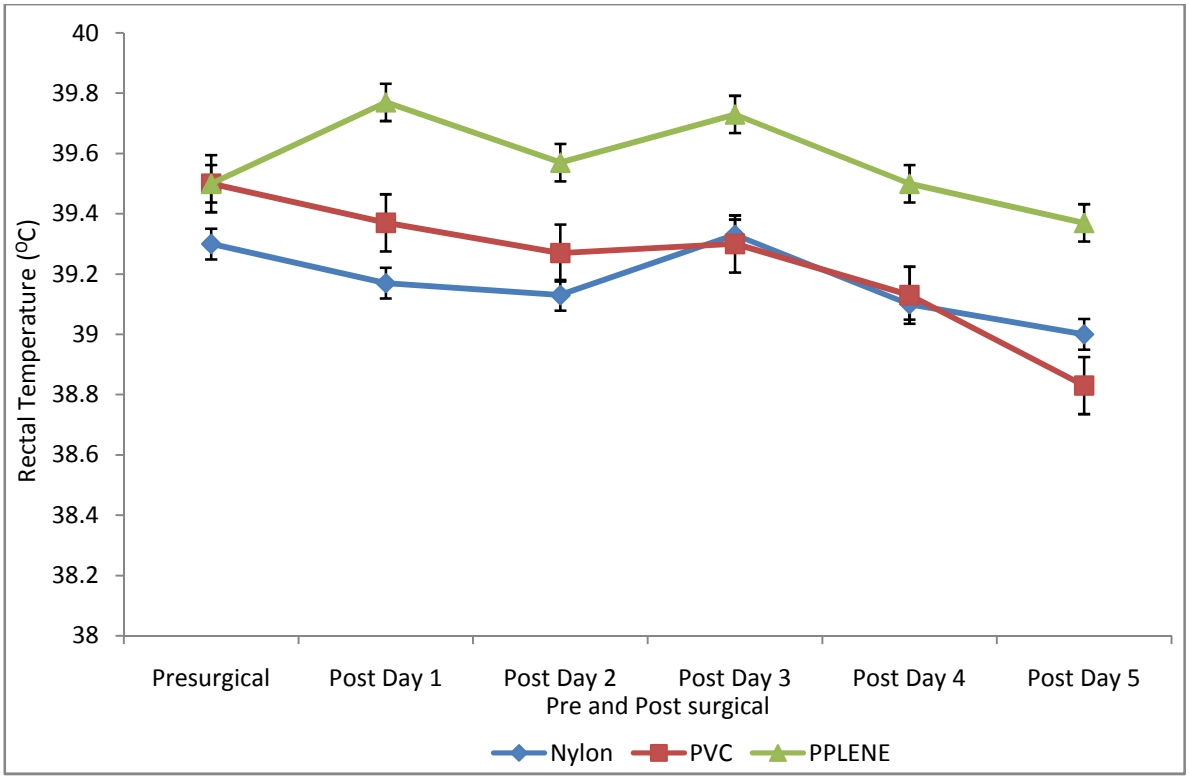


Figure 4.1: Pre- and postsurgical rectal temperature of the experimental and control group of goats

Key: PVC=Polyvinyl Chloride coated fibreglass nets, PPLENE=Polypropylene (Ethicon®).

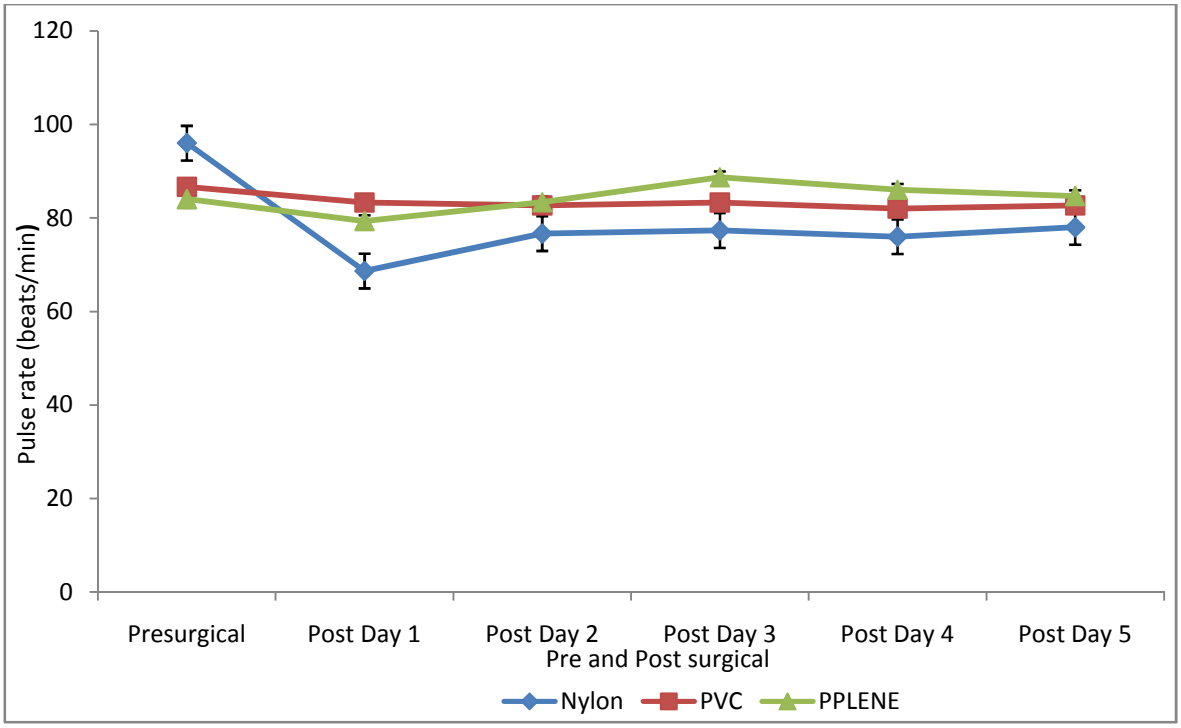


Figure 4.2 Pre- and postsurgical pulse rates of the experimental and control group of goats

Key: PVC=Polyvinyl Chloride coated fibreglass nets, PPLENE=Polypropylene (Ethicon®).

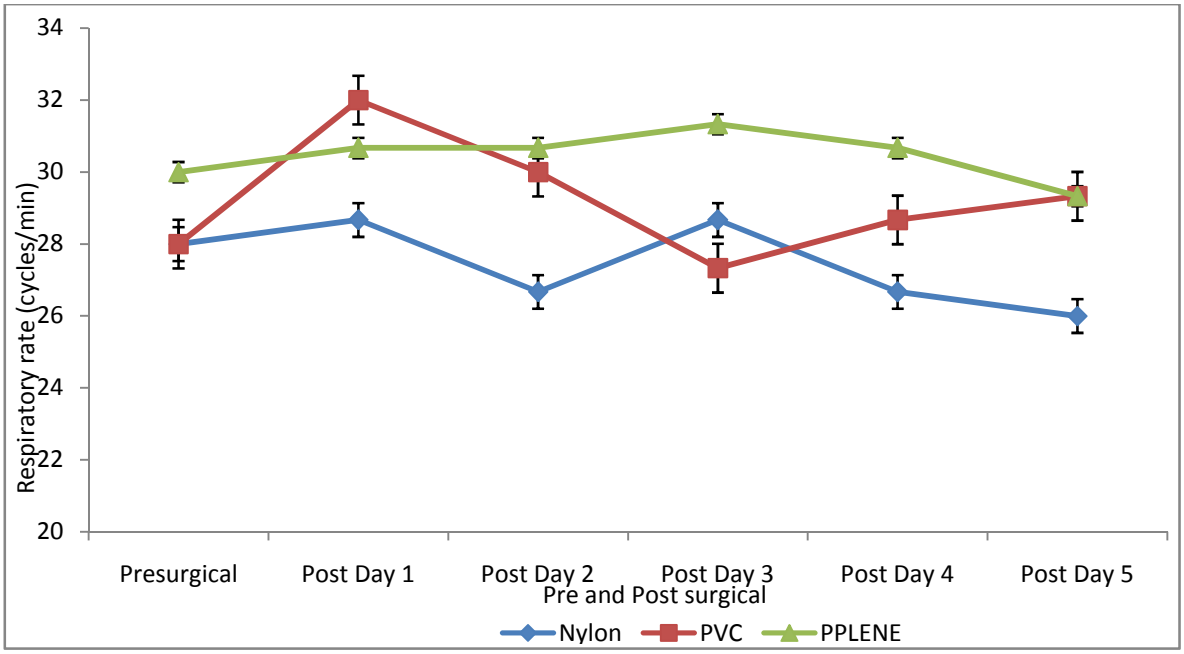


Figure 4.3 Pre- and postsurgical respiratory rates of the experimental and control group of goats

Key: PVC=Polyvinyl Chloride coated fibreglass nets, PPLENE=Polypropylene (Ethicon®).



Plate XX: Seroma formation (arrow) in animal from group B (PVC coated glass fibre mesh) three days post surgery



Plate XXI: Seroma formation (arrow) in animal from group C (Standard hernia repair mesh) three days post surgery

Table 4.3: Mean presurgical haematological values of both the control and the experimental groups of animals

PARAMETERS	NYLON Mean ± SEM	P.V.C Mean ± SEM	ETHICON® Mean ± SEM
PCV *(%)*	36.0± 3.0	36.0± 3.0	35.7± 1.5
HB *(g/dL)*	12.0± 1.0	12.0± 0.2	12.0± 0.5
WBC *(x 10^9/L)*	8.5± 0.9	8.2± 0.8	7.1± 0.5
T. PRO *(g/L)*	8.1± 0.2	7.4± 0.5	7.5± 0.8
NEUT *(%)*	38.0± 6.2	36.7± 1.7	35.7± 4.4
LYMPH *(%)*	60.0± 8.1	53.0± 2.1	56.3± 5.0
MONO *(%)*	0.7± 0.3[a]	3.0± 0.6[a]	2.0± 0.6
EOSIN *(%)*	1.3± 1.3	4.7± 0.9	4.3± 0.9
BAND *(%)*	0.3± 0.33	2.7± 0.33	1.7± 0.9

Note: Values with the same superscripts are significantly different (P□0.05).
Key: PVC= Polyvinyl Chloride coated fibreglass nets, SEM= Standard error of mean.

Table 4.4: Mean postsurgical haematological values of both the control and the experimental groups of animals

PARAMETERS	NYLON Mean ± SEM	P.V.C Mean ± SEM	ETHICON® Mean ± SEM
PCV *(%)*	35.8± 1.1[b]	33.5± 1.1	31.4± 1.5[b]
HB *(g/dL)*	11.9± 0.4b	11.2± 0.23	10.4± 0.5[b]
WBC *(x 10^9/L)*	8.3± 0.3	7.8± 0.2	8.6± 0.6
T. PRO *(g/L)*	7.2± 0.2	7.3± 0.2	7.3± 0.3
NEUT *(%)*	44.1± 3.2	39.0± 3.6	42.7± 3.7
LYMPH *(%)*	57.3± 2.5	57.1± 1.5	55.2± 2.5
MONO *(%)*	1.3± 0.4	1.2± 0.4	0.9± 0.2
EOSIN *(%)*	2.0± 0.5	3.1± 0.5	3.4± 0.4
BAND *(%)*	0.4± 0.2a	3.1± 0.5	0.4± 0.2[b]

Note: Values with the same superscripts are significantly different (P□0.05).
Key: PVC=Polyvinyl Chloride coated fibreglass nets, SEM= Standard error of mean.

4.3 GROSS AND HISTOPATHOLOGICAL OBSERVATIONS

4.3.1 Gross Appearance

4.3.1.1 Experimental group A (Nylon)

There were no complications noticed before sacrifice. The animals were in good body conditions except the female animal from group A that was slightly emaciated. There was no mesh rejection noticed. Fibrous connective tissue and fascial development were seen through the mesh (Plate XXII). The implanted meshes were buried by connective tissues/ fascia. The nylon sutures were intact but not yet fully buried (Plate XXII). Adhesion of greater omentum to the mesh measuring about 3-5cm (Plate XXIII) was noticed**.** There were no adhesions formed on the abdominal viscera (Plate XXIV).

4.3.1.2 Experimental group B (Polyvinylchloride coated fibre glass)

There were no complications noticed before sacrifice. The animals were all in good body condition. There was no mesh rejection noticed on sacrifice of the animals (Plate XXV). Sutures and the implanted meshes were intact and the mesh was completely buried by connective tissues/fascia except for the suture materials that were slightly exposed (Plate XXV). Adhesion of greater omentum to the meshes measured about 3-4cm (Plate XXVI). Excessive adipose tissue deposits were observed in the abdominal cavity of most of the group members but without adhesion of the abdominal viscera (Plate XXVII).

4.3.1.3 Control group, C (Polypropylene and polyglactin 910)

There were no complications noticed before sacrifice. The animals were all in good body condition. There was no mesh rejection noticed when the animals were sacrificed (Plate XXVIII).

Sutures and the implanted meshes were intact and the mesh was completely buried by connective tissues/fascia except for the suture materials that were slightly exposed. (Plate XXVIII). Adhesion of greater omentum to the meshes measured about few centimetres (Plate XXIX). Excessive adipose tissue deposits were in the abdominal cavity of most of the group members but without adhesion of the abdominal viscera (Plate XXX).



Plate XXII: The Gross appearance of the implanted nylon net (Group A) in a goat sacrificed 56 days postsurgery



Plate XXIII: Measurement of the degree of adhesion formed around the implanted mesh in goat from the nylon treated group (Group A) 56 days postsurgery



Plate XXIV: The viscera free of adhesions in a goat from nylon treated group (Group A) sacrificed 56 days postsurgery



Plate XXV: The gross appearance of the implanted polyvinyl chloride coated fibre glass net (Group B) in a goat sacrificed 56 days postsurgery



Plate XXVI: Measurement of the extent of adhesion formed around the implanted mesh in the PVC coated fibre glass treated goats (Group B) sacrificed 56 days postsurgery



Plate XXVII: The viscera (Arrow) free of adhesions in a PVC coated fibre glass net treated goat (Group B) sacrificed 56 days postsurgery

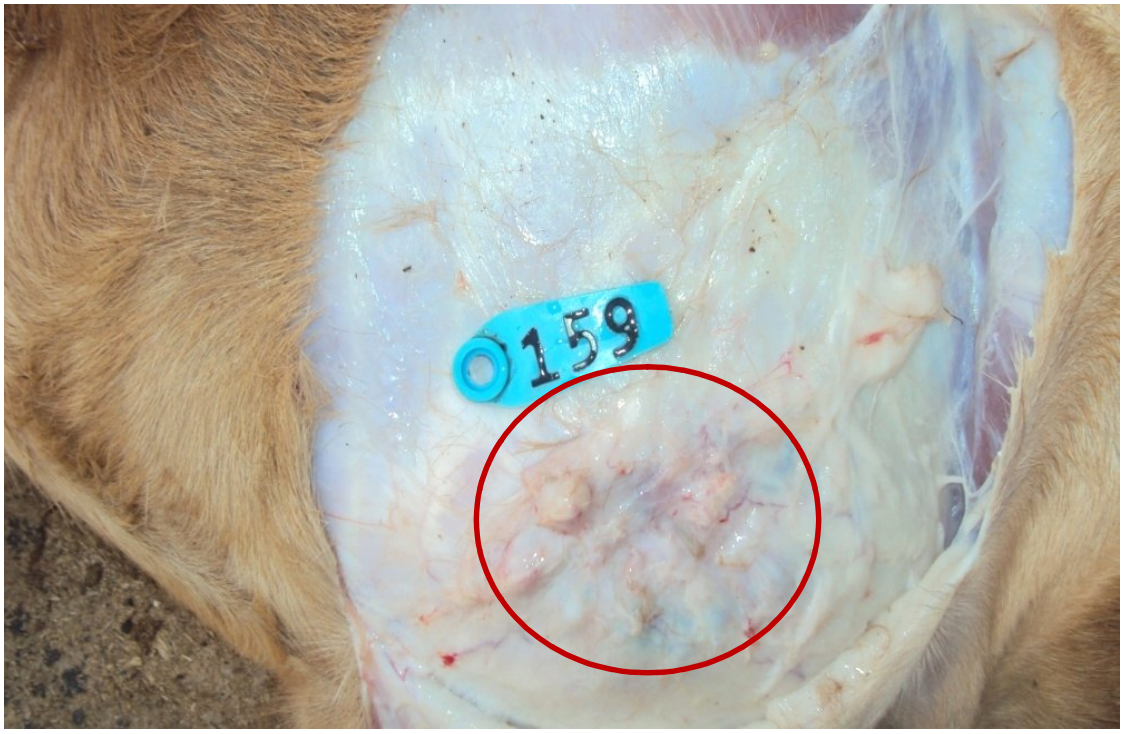


Plate XXVIII: The gross appearance of the implanted standard (Ethicon®) hernia repair mesh (Group C), Control Group, in a goat sacrificed 56 days postsurgery



Plate XXIX: Measurement of the extent of adhesion formed around the implanted mesh in a goat treated with ethicon® (Group C), the control Group, sacrificed 56 days postsurgery



Plate XXX: The viscera free of adhesions in a goat from ethicon® treated group (Group C) sacrificed 56 days postsurgery

4.3.2 Histopathological Findings

The histopathology of normal muscle tissue (Plate XXXI) taken from the nylon experimental group of animals when the circular muscle tissue was excised to create the experimental hernia was used to compare with the slides from both experimental (XXXII and XXXIII) and control (XXXIV) groups. Few fibroblast and macrophages with numerous new blood capillaries were observed in all the groups

4.4 COST EFFICIENCY OF PROSTHESIS

Nylon (Viorny$^{(R)}$) was purchased at the cost of ₦250 per yard (41 Kobo per 15cm) and polyvinylchloride coated glass fibre (Ossy Bahama$^{(R)}$ fibreglass insect screening) at the cost of ₦280 per yard (46 Kobo per 15 cm) were much cheaper than Ethicon$^{(R)}$ (containing polypropylene and polyglactin 910) which was purchased at the cost of ₦20, 000 per 15 cm size.

▲

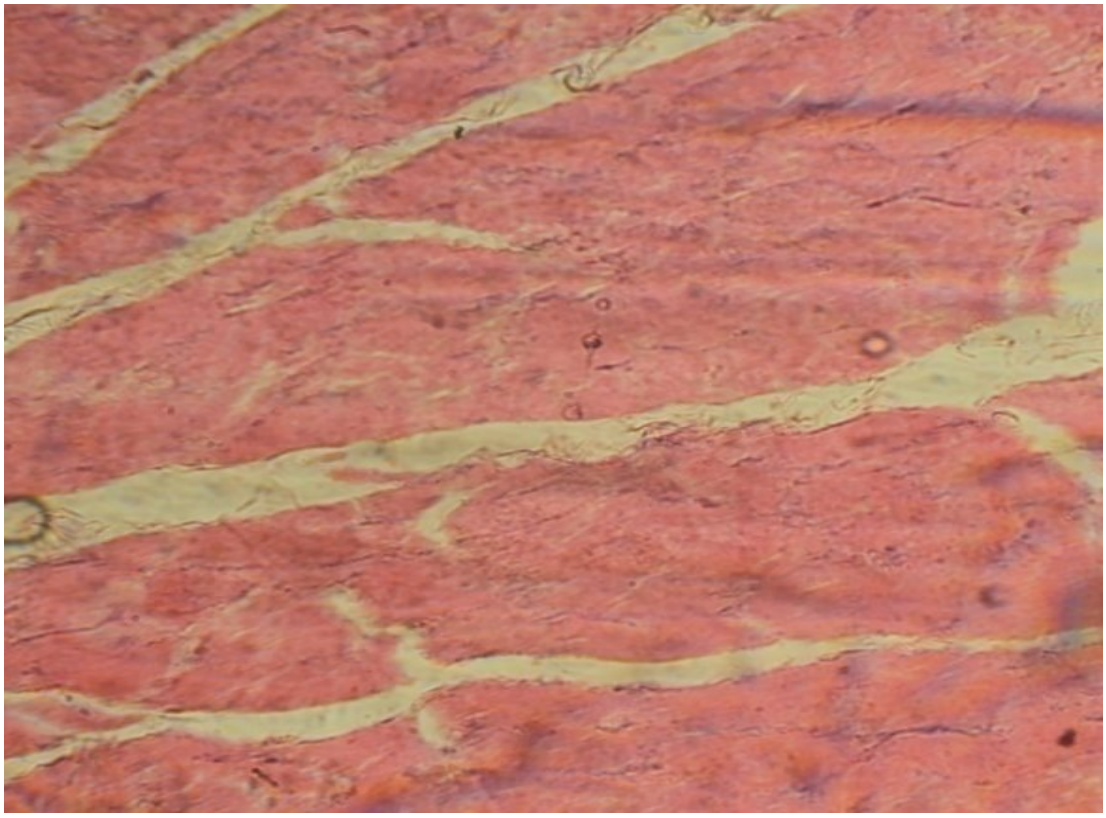


Plate XXXI: Photomicrograph of a normal muscle tissue (H and E stain x 400)

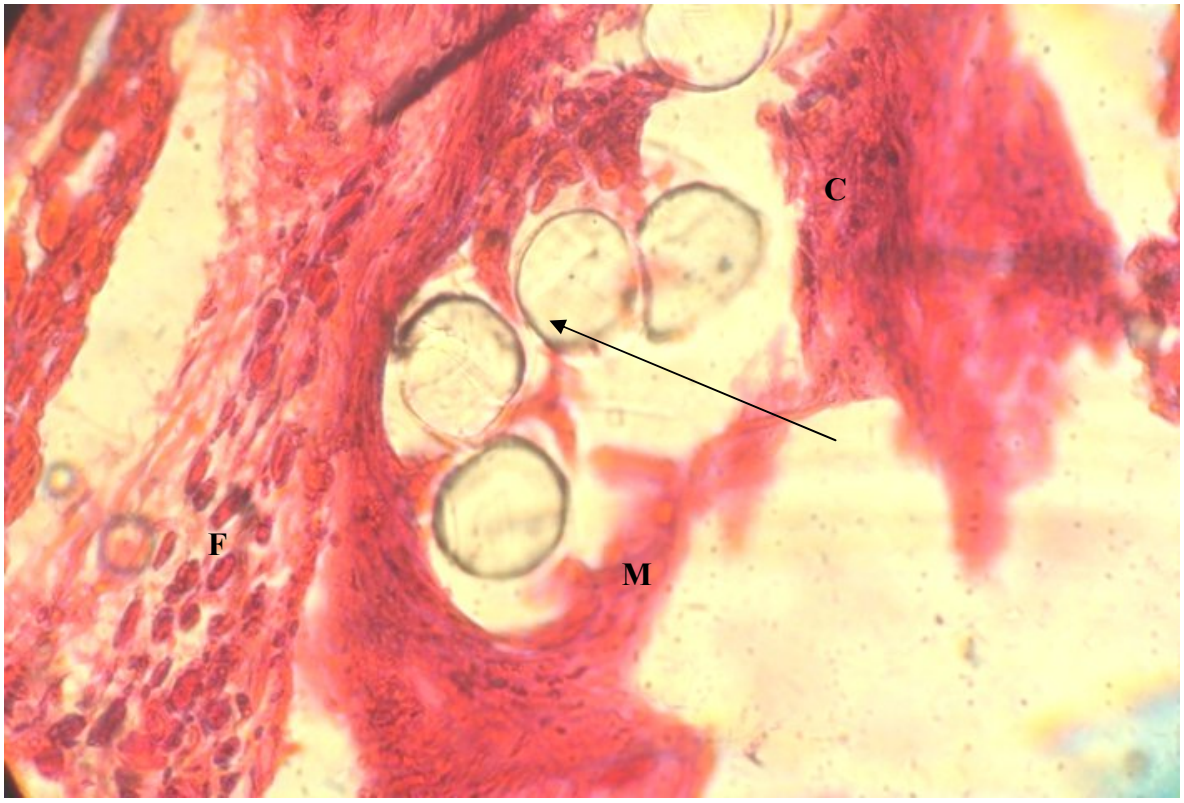


Plate XXXII: Photomicrograph of muscle tissue containing nylon filtration net (arrow). Note the less number of fibroblast (F), macrophages (M) and numerous blood capillaries(C) (H and E stain x 400)



Plate XXXIII: Photomicrograph of muscle tissue containing polyvinyl chloride coated glass fibre net (Arrow). Note the less number of fibroblast, macrophages and numerous blood capillaries (H and E stain x 400)

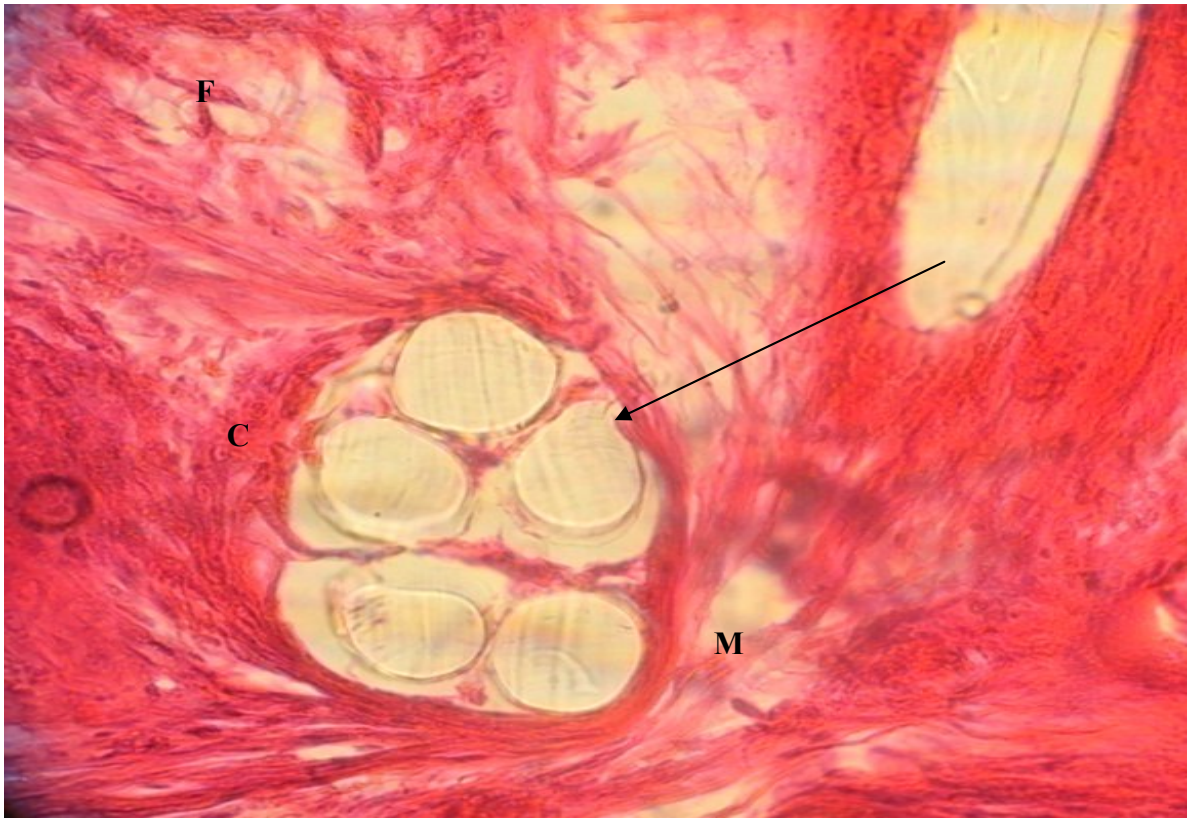


Plate XXXIV: Photomicrograph of a section of muscle tissue containing the implanted Standard (polypropylene) mesh (arrow) from the control group. Note the few fibroblast (F), macrophages (M) and numerous new capillaries(C) around the mesh (H and E stain x 400)

CHAPTER 5

DISCUSSION

The observed results from this study indicate that the tested nets have a higher tensile strength than the standard (polypropylene and polyglactin) mesh used for hernia repair and that sterilization by autoclaving has minimal effect on the tensile strength of the filtration nets used, with 1.3N/mm^2 (7.5%) and 0.8N/mm^2 (1.6%) decrease in tensile strength of the nylon and polyvinyl chloride coated fibreglass, respectively, post-sterilization (Tables 4.1 and 4.2). Being able to withstand sterilization by autoclaving is one of the characteristic of an ideal mesh for hernia repair (http://www.medscape.org/viewarticle).

There was no significant (0.05) difference in the presurgical vital parameters, in all the animals between the groups. They all fell within normal ranges except for pulse rate that was slightly above normal in group A goats.

Postsurgical the mean of vital parameters for all the goats between the groups also fell within the normal range except for slight increase in the mean respiratory rate in the control group possibly due to post surgical discomfort and pain (http://medmnemonics.wordpress.com) despite the fact that pain reliever was given post surgically.

The observed slight seroma formation 3 days after the surgery (groups B and C), which is one of the early post-operative complications of mesh hernia repair (Schumperlick *et al.,* 1996) were probably due to anatomical dead space formed from the removal of the full thickness of the abdominal muscles during the process of creating the experimental hernia ring (Wilhelm *et al.,* 2007) and the closure of the skin incision with horizontal mattress which is a tension suture which is often required for hernia repair but offers an improper drainage system from the surgical site.

After the seroma fluid was drained, wounds healed without any further long term complications such as mesh rejection by tissues and irritation of adjoining tissues (Schumperlick *et al.,* 1996) with regards to the duration of this experiment.

There were also no significant (0.05) differences in some of the pre- and postsurgery haematological values, between the groups, except for significant (P 0.05) increases in PCV, Hb and total protein on day 8 postsurgery in the nylon group compared to the standard mesh. Also eosinophils and band neutrophils on day 3 postsurgery in the polyvinyl chloride coated fibreglass group when compared to nylon and the standard mesh.

Slightly emaciated noticed the doe in the nylon filtration net experimental (Group A) animas might have been probably due to the burden of lactation. The doe kidded successfully without rupturing either the nylon filtration net used for the hernia repair or the

sutures despite the increased intraabdominal pressure due to advanced pregnancy and straining during parturition which is a major predisposing factor to herniation in female animals (Noordsy, 1989b; Anon, 2010b).

Since there were no meshes displacement or rupture of the surgical sites is an indication that there was no mesh rejection in the group A (nylon) animals. It further implies that it is well tolerated by the body (http://www.medscape.org/viewarticle). Fibrous connective tissue and fascial development were seen through the mesh. The implanted meshes were buried by connective tissues/fascia though not completely due to the fact that the animal was emaciated. The nylon sutures were intact but not yet fully buried. Adhesion of greater omentum to the mesh measuring about 3-5cm was due to the omentopexy that was done by suturing the greater omental sheet to the experimental hernia ring created to prevent contact between the viscera and the filtration net to avoid adhesion of the viscera with either the ring or the net**.** There were no adhesions formed between the abdomen and the viscera. This is also an indication that there was no rupture of the omentum due to the tension free nature of the hernia repair (Schumpelick, *et al.,* 2006).

The result of polyvinylchloride coated glass (Group B) experimental animals showed that the mesh was well tolerated by the animal's bodies (http://www.medscape.org/viewarticle). This was also an indication that hernia repair was tension free since the omentum that was sutured to the hernia ring on the abdominal wall was still intact.

There were also no complications noticed before sacrifice, in the control group of animals where the commercial mesh for hernia repair were used. The experiment did not affect the body condition of the animals even in pregnant animal where the pregnancy was carried close to term but was aborted probably due the stress of surgery or head butt from the group members. There was no mesh rejection noticed when the animals were sacrificed. Sutures and the implanted meshes were intact and the mesh was completely buried by connective tissues/fascia except for the suture materials that were slightly exposed. This study showed that Polypropylene in the control group was well tolerated by the body. It is one of the materials commonly used for hernioplasty because it has been proven to be safe and well tolerated by body tissues (Fubini and Ducharme, 2004).

Adhesion of greater omentum to the meshes measured about 3-4 centimetres owing to the omentopexy done. Excessive adipose tissue deposits were in the abdominal cavity of most of the group members which was an indication that the animals were in good body condition. No adhesions were noticed between the abdominal wall and the viscera which could also be attributed to the tension free technique used (Schumpelick, *et al.,* 2006) thereby securing the greater omentum from rupture due to the weight of the abdominal content on the experimentally created hernia.

The numerous blood capillaries with a few macrophages and fibroblasts observed in all the groups was a good indication of a possible muscle tissue regeneration and vascularisation.

The filtration nets, nylon and polyvinylchloride coated glass fibre used for the experiment were found to be 48,781 and 43,478 times cheaper than the commercial mesh for mesh for hernia repair (Ethicon$^{(R)}$) respectively. This result indicates that nylon and polyvinylchloride coated glass fibre nets are cheaper and readily available.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The study showed that both nylon and Polyvinylchloride coated (PVC) glass fibre filtration nets were well tolerated by the body with minimal early postoperative complications. PVC filtration nets were found to be relatively better than nylon based on gross and histopathological findings, however, nylon nets were more readily available and relatively cheaper than the PVC net, though the PVC nets had higher tensile strength than nylon and standard ethicon® mesh.

Therefore, based on this research nylon and PVC coated glass fibre filtration nets are good and relatively cheaper substitutes for standard meshes. PVC net is better than nylon and closely resembles the standard ethicon mesh used in surgical repair of hernia in goats.

6.2 RECOMMENDATIONS

From this work it was recommended that sterilized nylon filtration nets and polyvinyl chloride coated fibre nets could be used as a cheap and relatively safe substitute for commercial meshes for the correction of hernias with large rings.

It is recommended that both nylon and Polyvinylchloride coated glass fibre filtration nets may be employed for hernioplasty not only in animals but also in humans as the commercial meshes are very expensive.

The increased intraabdominal pressure at advanced stage of pregnancy observed in pregnant does in both the control and experimental groups and straining during the process

of parturition did not rupture the nets. Therefore, these nets could also be used for hernia repairs in pregnant subjects since this study observed that pregnant does successfully carried their pregnancy to term and kidded.

It is also recommended that different types of cheap filtration nets that are inert should be evaluated for hernia repair and longer period of study on this filtration nets should be conducted to evaluate the possibility of tissue rejection on long term basis.

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Appendix 4.1 Mean presurgical and post surgical vital parameters of the experimental and control groups of goats

Group	Mean presurgical vital parameter values			Mean postsurgical vital parameter values		
	Temp (^{o} C)	Pulse rate (beats/min)	Resp. rate (cycles/min)	Temp. (^{o} C)	Pulse rate (beats/min)	Resp. rate (cycles/min)

Nylon	39.3± 0.06	96.0± 24.11	28.0± 2.31	39.2± 0.05^{d}	75.0± 1.8^{ab}	27.0± 1.03^{a}
PVC	39.5± 0.21	86.7± 5.81	28.0± 2.31	39.2± 0.07^{e}	83.0± 1.7	30.0± 0.8
Ethicon®	39.5± 0.21	84.0± 4.62	30.0±1.16	39.6± 0.07^{de}	84± 1.5^{b}	31.0± 0.8^{a}

Note: Values with the same superscripts are significantly different (P□0.05).
Key: Temp. =Temperature, Resp. =Respiratory, PVC=Polyvinyl Chloride coated fibreglass nets, all data are mean± sem = standard error of mean.

Appendix 4.2: Postsurgical temperature (^{o}c) of the experimental and control groups of goats

Prosthetic Material	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Overall Mean**
Nylon	39.17±0.12^{a}	39.13±0.03^{b}	39.33±0.13	39.10±0.12	39.0±0.12	39.15±0.05
PVC	39.37±0.03	39.27±0.12	39.30±0.06	39.03±0.13	38.83±0.13^{c}	39.16±0.07
Ethicon®	39.77±0.12^{a}	39.57±0.09^{b}	39.73±0.23	39.50±0.21	39.37±0.07^{c}	39.59±0.07

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.3: Postsurgical pulse rate (beats/minute) of the experimental and control groups of goats

Prosthetic Material	Day 1	Day 2	Day 3	Day 4	Day 5	Overall Mean
Nylon	68.67±1.8	76.67±3.7	77.33±5.5	76.00±4.2	78.00±4.2	75.33±1.8[ab]
PVC	83.33±2.9	82.67±5.2	83.33±4.1	82.01±5.3	82.67±4.1	82.80±1.7[a]
Ethicon®	79.33±6.7	83.33±2.9	88.67±1.8	86.0±1.2	84.67±0.7	84±1.5[b]

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.4: Postsurgical respiratory rate (cycles/minute) of the experimental and control groups of goats

Prosthetic	Day 1	Day 2	Day 3	Day 4	Day 5	Overall

Material						Mean
Nylon	28.67±4.1	26.67±3.7	28.67±0.7	26.67±1.3	26.12±1.2	27.33±1.03[a]
PVC	32.20±0.0	30.00±1.2	27.33±0.7	28.67±1.3	29.33±3.5	29.47±0.8
Ethicon®	30.67±2.7	30.67±2.7	31.33±1.8	30.67±1.3	29.33±0.7	30.53±0.8[a]

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.5: Postsurgical packed cell volume (%) of the experimental and control groups of goats

Prosthetic Material	Day 3	Day 8	Day 28	Day 56	Overall Mean
Nylon	35.33±1.5	36.67±1.5[a]	33.33±1.9	38.00±3.6	35.83±1.1[b]
PVC	32.33±1.2	32.33±1.5	33.67±1.8	35.67±0.9	33.50±0.7
Ethicon®	28.00±3.5	30.00±0.58	33.00±4.04	34.67±3.2	31.42±1.5[b]

Key: The values with the same superscripts are significantly different (P□0.05),
PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.6: Postsurgical haemoglobin value (Hb) (g/dL) of the experimental and control groups of goats

Prosthetic Material	Day 3	Day 8	Day 28	Day 56	Overall Mean
Nylon	11.73±0.5	12.23±0.5 [a]	11.07±0.5	12.673±1.5	11.73±0.5[b]
PVC	10.77±0.4	10.77±0.5 [a]	11.2±0.6	11.87±0.3	11.15±0.23
Ethicon®	9.30±1.2	9.96±0.2[a]	10.97±1.3	11.50±1.1	10.43±0.5[a]

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.7: Postsurgical white blood cells (WBC) ($X10^9$/L) of the experimental and control groups of goats

Prosthetic Material	Day 3	Day 8	Day 28	Day 56	Overall Mean
Nylon	7.8±0.5	7.63±0.61	8.3±0.7	9.3±0.7	8.3±0.3
PVC	7.43±0.2	7.37±0.3	7.8±0.2	8.7±0.6	7.8±0.2
Ethicon®	10.03±2.0	7.4±0.6	8.1±0.8	8.7±0.4	8.6±0.6

Key: PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.8: Postsurgical neutrophils (%) of the experimental and control groups of goats

Prosthetic Material	Day 3	Day 8	Day 28	Day 56	Overall Mean
Nylon	39.67±0.6	39.67±5.6	55.33±7.3	41.67±4.4	44.08±3.2
PVC	29.00±2.1	29.0±2.1	56.33±3.2	41.67±2.8	39.00±3.6
Ethicon®	39.67±10.2	39.67±10.2	52.00±3.1	39.33±4.8	42.67±3.7

Key: PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.9: Postsurgical lymphocytes (%) of the experimental and control groups of goats

Prosthetic Material	Day 3	Day 8	Day 28	Day 56	Overall Mean
Nylon	63.0±0.6	52.67±3.7	58.67±4.1	54.67±6.1	57.25±2.5
PVC	62.67±3.2	56.0±0.6	56.33±3.2	53.33±2.4	57.08±1.7
Ethicon®	56.33±10.2	57.0±1.5	52.0±3.1	55.33±4.2	55.17±2.5

Key: PVC= Polyvinyl chloride coated fibreglass net, all data are mean± sem = standard error of mean.

Appendix 4.10: Postsurgical monocytes (%) of the experimental and control groups of goats

Prosthetic Material	Day 3	Day 8	Day 28	Day 56	Overall Mean
Nylon	1.33±0.7	0.33±0.3	2.33±1.5	1.0±0.6	1.25±0.4
PVC	2.33±0.3	1.67±0.9	0.67±6.7	0.0±0.0	1.17±0.37
Ethicon®	0.33±0.3	0.67±0.7	1.33±0.3	1.33±0.33	0.92±0.23

Key: PVC= Polyvinyl chloride coated fibreglass net**,** all data are mean± sem = standard error of mean.

Appendix 4.11: Postsurgical eosinophils (%) of the experimental and control groups of goats

Prosthetic Material	DAY 3	DAY 8	DAY 28	DAY 56	Overall Mean

Nylon	0.0±0.0[ab]	2.67±0.33	2.0±1.2	3.33±0.3	2.0±0.46
PVC	4.3±0.9[a]	2.0±1.2	3.67±3.0	2.3±1.2	3.08±0.5
Ethicon®	3.67±0.9[b]	3.3±1.3	2.67±0.67	4.0±0.6	3.4±0.4

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass net**,** all data are mean± sem = standard error of mean.

Appendix 4.12: Postsurgical band neutrophils (%) of the experimental and control groups of goats

Prosthetic Material	**DAY 3**	**DAY 8**	**DAY 28**	**DAY 56**	**Overall Mean**
Nylon	0.0±0.0[a]	0.33±0.3	0.67±0.67	0.67±0.33	0.42±0.2[a]
PVC	1.67±0.3[ab]	1.33±0.9	1.67±0.9	0.33±0.3	1.25±0.3[ab]
Ethicon®	0.0±0.0[b]	0.67±0.67	0.67±0.67	0.33±0.3	0.42±0.2[b]

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass nets, all data are mean± sem = standard error of mean.

Appendix 4.13: Postsurgical total proteins (g/dL) of the experimental and control groups of goats

Prosthetic Material	DAY 3	DAY 8	DAY 28	DAY 56	Overall Mean
Nylon	6.8±0.3[a]	7.3±0.26[c]	7.07±0.2	7.6±0.6	7.2±0.2
PVC	8.0±0.3[ab]	7.3±0.24[c]	6.9±0.5	7.1±0.7	7.3±0.2
Ethicon®	6.73±0.2[b]	8.6±0.3[c]	6.7±0.3	7.1±0.6	7.3±0.3

Key: The values with the same superscripts are significantly different (P□0.05), PVC= Polyvinyl chloride coated fibreglass nets, all data are mean± sem = standard error of mean.