A COMPARATIVE STUDY OF TISSUE REACTION TO FOUR DIFFERENT SUTURE MATERIALS

by

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INTRODUCTION

Suture materials currently used for ventral abdominal wound closure in the horse do not offer sufficient strength without secondary adverse effects. Veterinary surgeons continue to search for a suture material which, provides good holding strength until tissue healing is achieved, produces minimal tissue reaction, resists bacterial contamination or infection, and is well tolerated throughout the life span.

Suture material may act as a foreign body, thus eliciting variable degree of tissue reaction which in turn, might have influence on the final outcome of tissue healing.[39,49,53,54] A common reaction to suture material is inflammation which is one factor involved in the reduction of the efficiency of the microcirculation in affected tissues.[40] It has been suggested that the degree of enhancement of infection by a suture material roughly corresponds to the inflammatory reaction elicited when it is buried.[49,54]

Suture materials are generally classified as a absorbable and non-absorbable. Sutures presently used for ventral abdominal wound closure in the horse include: #4 Extra Chromic Gut,[a] #4 Medium

[a]Chromic Gut. Absorbable Suture. Ethicon, Inc. Somerville, N.J. 08876

Chromic Gut, 18 Gauge Stainless Steel,[b] Extra Heavy Vetafil,[c] #2 Dexon,[d] and #1 Vicryl.[e]

Each suture has certain disadvantages. Number 4 Extra Chromic Gut[R] is manufactured on special order; therefore, it has the disadvantage of delayed availability which becomes difficult for equine surgeons. Number 4 Medium Chromic Gut[R] may disintegrate very quickly thus allowing ventral hernia to occur. The knots of 18 Gauge Stainless Steel[R] can cause irritation in the skin and in this may predispose to infection or drainage. On occasions the steel sutures will break allowing a piece to migrate through the tissues acting as a foreign body. Vetafil[R] has been used by many surgeons although it creates a definite tissue reaction and can predispose to formation of permanent sinuses. Number 2 Dexon[R] doubled will cut through the abdominal tunic. Vicryl[R] is an absorbable suture which may be absorbed before tissue strength is achieved as well as cutting through tissues.

The purpose of this research was to study the soft tissue

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[b] 18 Gauge Stainless Steel Surgical Wire. Steri-Spool, P.O. Box 7114, Los Angeles, CA. 90022.

[c] Vetafil, a synthetic, polyamide, non-absorbable, polyfilament, class II, surgical suture. Made in West Germany. Processed in U.S.A. by Jackson INC. Washington, D.C. 20014.

[d] Dexon Polyglycolic Acid. Davis & Geck American Cyanamid Company, Pearl River, New York 10965.

[e] Vicryl, Polyglactin 910 synthetic absorbable suture. Ethicon Inc. Somerville, N.J. 08876.

reaction to various suture materials buried in the ventral abdomen and biceps femoris muscles of the horse. Sutures used in this investigation were: #5 Ethibond[f], a braided polyester (polyethylene or mersilene) non-absorbable suture coated with polybutilate, #3 Extra Heavy Vetafil[R] a synthetic polyamide, polyfilament, class II non-absorbable suture, #1 Vicryl[R] polyglactin 910, and #1 Prolene[g] a polypropylene non-absorbable monofilament suture.

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[f]Ethibond, a braided polyester (polyethylene or mersilene) non-absorbable suture coated with polybutilate. Ethicon Inc. Somerville, N.J. 08876.

[g]Prolene Blue Monofilament Polypropylene, non-absorbable suture. Ethicon Inc. Somerville, N.J. 08876.

LITERATURE REVIEW

GENERAL CONSIDERATION FOR THE SELECTION OF A SUTURE MATERIAL

The selection of a suture material should not be based on guess work or habit of the surgeon. The surgeon should be aware of the physical, chemical and biological characteristics of the wide variety of suture materials currently available.

In vivo measurements of material degradation place sutures into two classifications, absorbable and non-absorbable. Sutures which undergo rapid degradation in tissue and loose tensile strength within 60 days are considered absorbable. Sutures maintaining tensile strength for longer than 60 days are referred to as non-absorbable.[16,17,49,53]

Among the physical charactertistics which should be considered in the selection of a suture material include the tensile strength of the suture versus tensile strength of the tissues. The relation between these two values is particularly important since there is no advantage in using a larger or stronger material with tensile strength exceeding that of the tissues.[49,53] Fiber arrangement within the tissue has been proven to affect the holding power of sutures. Different tissues vary in strength and this is a fact that should be considered.[53] Durability of a suture materials should be considered. Durability is dictated by the suture line tension, healing rates of the tissue where the suture is being implanted and local factors affecting the suture and tissue environment eg:, inflammation, infection etc. A third characteristic to consider is the knot security of the suture material. A suture should be easy to handle. Important factors are stiffness, and twisting or kinking which weakens the suture or shreds its coating material.[29,35,49,53] Good knot security is of primary importance on every suture since slippage or untying of the knot may predispose to death by hemorrage or evisceration depending on the case.[29,53] Knot security may be influenced by the quality of the knot tied, coefficient of friction and gauge of the suture material.[49,53] It has been proven that excessive knot throws will weaken the material at the knot and this additional material further handicaps the host's defenses, thereby extending an invitation to infection.[35] A suture must have capability of withstanding sterilization, in case that further sterilization is needed. The three most common methods of sterilization are gamma irradiation, ethylene oxide and steam sterilization.[49,53]

The physical and chemical configuration of a suture material should always be taken into account.[17,49,53] The physical configuration of a suture may present some hazards. General agreement exists in that the ability of a suture to harbor microorganisms may be related to its configuration.[17,36,49,13,54] Studies have shown that braided and twisted sutures, whether coated or uncoated, will pick up 10 times more organisms per unit length than monofilament sutures. Treatment of braided multifilament suture material, to produce a closer weave has decreased the incidence and severity of infection.[17,35,36,39,49,53,54] The chemical composition of a suture appears to be an important determinant of early infection because its degradation can act as an anti-bacterial agent. In vitro studies have demonstrated that the incubation of Staphylococcus aureus with varying concentration of glycolic acid, 1,6 hexanediamine and adipic acid resulted in a marked reduction of the bacterial count.[16,17]

The biological characteristics of a suture material are important factors in the selection of a suture. The biological interaction of a suture material and tissue can alter the mechanical properties of the suture and the physical properties of the wound. Both physical and chemical configuration of sutures are known to contribute to post-surgical complications.[16,17,35,49,53]

It is well known that inflammation is an unavoidable and essential part of the wound healing process.[49,53] The degree of the inflammatory response directly influences the efficiency of local circulation, thus influencing healing.[39,49,53] The presence of sutures in surgical wounds increases the tissue susceptibility to infection.[16,49,54]

Ideally for a suture material to have good biological qualities it should have minimum suture-tissue interaction, lack of allergenic and carcinogenic properties, and have a minimal effect on wound in the presence of infection.

ETHIBOND^R

Polyester sutures have been widely used in soft tissue surgery. They are among the strongest sutures noted for retaining their strength in tissue for indefinite periods of time. One of the disadvantages of the polyester sutures has been its tendency to "drag" when passed through the tissues exerting a tearing force on the tissue. Many attempts have been made to improve the quality of polyesters. These attempts have been designed to lower the coefficient of friction by coating the suture material with polytetrafluoroethylene (Teflon) or silicon lubricants. Unfortunately, these coatings do not have an affinity for the polyester filaments. Thus, the lubricant is usually bonded to the suture filaments with an adhesive resin or is mechanically trapped within the braid.[6,17, 35, 46, 49] It has been demonstrated that these coating materials provide a less "dragging" effect when the treated suture is passed through the tissue. Since these materials do not bond well to the suture, minute amounts of the coating become dislodged and scattered through tissues.[46] These fragments are engulfed by macrophages. Because they are insoluble and resistant to enzymes, a chronic microscopic granuloma can be produced.[6,46]

Ethibond^R is a synthetic non-absorbable braided polyester (polyethylene terephtalate or mersilene^R polyester) which has been coated with a new material. This new coating material is polybutilate (poly - (oxy-1, 4-butomediyloxy (1.6-Dioxo-1.6

Hexanediyl), which bonds strongly to the polyester fibers. As a result the quantity of coating per unit length is less as compared to other coatings. Polybutilate coated suture is less reactive than noncoated polyesters.[6,46]

The physical characteristics of coated polybutilate suture material are: good handling quality with no twisting, good pliability, does not drag when pulled through the tissues, a high tensile strength, provides easy tying of the knots and the knots are secure.[6,17,46]

Histopathological studies of polybutilate-coated polyester in perivascular and gluteal muscle surgery on rats have demonstrated slight tissue reaction. Findings in these studies varied from slight tissue response with presence of macrophages and giant cells from the seventh post-surgical day to a minimal response with few cells and a well organized fibrous capsule at 180th post-surgical day.[6,46]

VETAFIL^R

Vetafil^R is a synthetic fiber non-absorbable suture derived from the polyamides. It is classified as a polyfilament, class II surgical suture.

Vetafil^R is produced in Hannover, West Germany and is processed in U.S.A. It is sold in non-sterile packages containing 164 ft. of the suture material. There are different sizes and diameters of this suture material but the most commonly used are: Size 3

Extra Heavy, 0.6 mm in diameter and size 00 Medium 0.3 mm diameter. This suture material can be sterilized by saturated steams at 121°C for 30 minutes or by ethylene oxide gas.

The use of Vetafil^{R} by veterinary surgeons has been particularly wide spread in bovine practice. The material has been used for surgical procedures in several different tissues as rumen, intestine, uterus, diaphragm, ventral abdominal musculature, tendons and skin.[14,26,29,30,55,56]

The physical characteristics of Vetafil^{R} are similar to those offered by braided polyester. The suture material has a good holding strength, its friction coefficient is better when compared to coated polyester, it has good knot security and provides easy methods of sterilization.[14,26,29,30,55]

Biological tests done on Vetafil^{R} differ in the results because of the wide use in different types of tissue. Most authors agree that Vetafil^{R} has some degree of "dragging" when pulled through the tissues as compared to braided coated or monofilament non-absorbable sutures. Other observations are that it produces an early moderate inflammatory response after implantation, and that adhesions and tissue scaring are more evident when compared to other polyfilament non-absorbable suture.[14,26,29,30,55]

Several disadvantages have been reported. Care should be taken when handling and tying since coating of this suture material may be shredded by rubbing one strand against the other, thus minute amounts of the coating dislodged and become scattered through the tissues. These fragments may become engulfed by macrophages or giant cells and since they are insoluble and resistant to enzymes, they may predispose to the formation of chronic microscopic granulomas.[55] Flaking of the coating material may alter the characteristics of the suture specially in regard to resistance to infection or tissue reaction. It has been proven that flaking enhances adhesion formation in the tissue where the suture has been implanted. Vetafil[R] suture subjected to steam sterilization more than three times will be weakened.

Histopathological studies have been conducted involving the use of Vetafil[R] in different structures of the body. The most common findings are: tissue reaction between the 7th and 15th day post-implantation characterized by a moderate inflammatory reaction and degenerative changes with cellular infiltration of polymorphonuclear leukocytes, neutrophils, mononuclear cells and giant cells. Tissue reaction between the 15th and 45th day post-implantation characterized by increased numbers of fibroblasts, fibroplasia around the sutures, and infiltration of macrophages and lymphocytes. The most noted problem from the 45th day to 60th day, is moderate fibroplasia and necrotic exudate.[14,29,30,55]

PROLENE[R]

Monofilament polypropylene was introduced in 1961.[48,49] Initially most surgeons found the suture difficult to handle and tie because of its slippery characteristics; however, repeated experience with monofilament polypropylene material increased the surgeons ability to handle and tie this type of suture.[21,49]

Monofilament polypropylene is a synthetic non-absorbable suture material which is produced by closely controlled polymerization of propylene. Propylene, the basic molecule of polypropylene, is an unsaturated hydrocarbon with a double bond between two of its three carbon atoms.[16,38] Monofilament polypropylene is an isotatic crystalline steroisomer of a linear hydrocarbon. It is colored with copper phthalocyanine blue (pigment blue 15). The plastic is extruded as monofilament fiber using a special melting extruder where pellets are converted into uniform sutures.[38,40] Sterilization is done with ethylene oxide.[38] Its softening point is 300°F and its melting point is 340°F.

Monofilament polypropylene has a high tensile strength, low specific gravity and it is resistant to most acids or bases.[16,38,40] This suture material has been shown to be resistant to the action of tissue enzymes and to have great ability to withstand infection.[36,38] The smooth surface allows easy passage through tissues, thus minimizing trauma.[40,48] Other positive characteristics of monofilament polypropylene are that its knot holding ability is superior to other suture materials, that there is no softening of the suture material after four years of implantation in the patient,[36,40] that it does not kink when handled,[40] and that its brilliant blue color has good tinctorial property and is very stable to light, chemical action or heat.[4,38]

Monofilament polypropylene offers several biological advantages when implanted in tissues. It has a special advantage when it is used to close contaminated wounds, although it is not completely biologically inert.[9,21,36,38,40,42] It is well tolerated by the patient for years after implantation.[9,48] It does not produce excessive scar tissue.[8] It is significantly less thrombogenic than other materials such as braided non-absorbable sutures.[34] Polypropylene does not cause malignant new growths.[38]

Histopathological studies of tissue containing monofilament polypropylene have shown that there is an acute inflammatory reaction, limited in degree, in the early stages following implantation. This early inflammatory reaction is characterized by the presence of polymorphic neutrophilic leukocytes.[38,40] The reaction is followed by a rapid proliferation of connective tissue with encapsulation of the suture occurring several days later.[9,36,38,40] After two years the tissue reaction to this suture material is limited to a narrow fibrous capsule around the suture.[36]

Several disadvantages have been noted. Monofilament polypropylene has a low coefficient of friction[9,42] and because of this three to five throws must be placed when tying the knots.[9,38,42,48] The material can be shredded or weakened by rubbing one strand against the other, crushing or crimping, thus care should be taken especially when tying the knots under tension.[48,49] The stiffness of polypropylene has been reported to make its handling difficult.[9,38,40,49] Breakage of the suture material has been reported; however, this might have been a result of damage when tying the knots. It is recommended that the surgeon use the index finger to carefully set the knot down and thereby reduce the abrasive contact between the strands.[48]

VICRYL[R]

Vicryl,[R] polyglactin 910, is a synthetic suture material which was designed to improve the qualities of absorbable sutures, by having a higher tensile strength and more rapid absorption.[8]

Polyglactin 910 is a synthetic absorbable suture synthesized by the copolymerization of a mixture of purified lactide and glycolide, cyclic intermediates derived from the lactic and glycolic acids. The extruded filaments are strengthened by stretching until the molecules are properly aligned. The filaments are braided to allow better handling properties and the braid is restretched to further increase its tensile strength.[7,8,24]

The sutures are packaged dry in a laminated aluminum foil and sterilized using ethylene oxide. To improve visualization during a surgical procedure a colored polymer is produced by adding Drug and Cosmetic Violet No. 2 dye during polymerization of the lactide and glycolide. The resulting fiber is violet in color.[8]

Polyglactin 910 absorption is accomplished by controlled hydrolysis (presumably by esterase[49]) of the polymers from which it is derived. There are few leukocytes around the suture but there is no evidence to substantiate a cell-mediated absorption mechanism.[8,24] Intramuscular implantation of polyglactin 910 in rats, has shown that the absorption of this suture material is minimal until the 40th day post-implantation. Absorption is complete between the 60th to 90th day post-implantation[7,8] and no remnants are found after the 90th day.[49]

Polyglactin 910 provides higher tensile strength than other synthetic absorbable suture materials. It is known that the tensile strength loss rate of this polymer is sensitive to changes in temperature and pH. Both heat and alkaline conditions hasten the decline of strength.

Polyglactin 910 provides good handling ability since the material is pliable. The positive features are that it does not drag when pulled through the tissues, does not twist or fray when tied or cut and that slippage or breakage of knots is not a problem.[7,24]

The biological advantages of polyglactin 910 implanted in tissues include acceleration of absorption after fulfilling its function and tensile strength, and good visibility of the suture material in the surgical field due to its violet color. The material does not predispose to premature absorption. Acid pepsin does not change the absorption rate as usually happens with other absorable sutures.[7,8,24]

Histopathological studies in rats and rabbits have shown a minimal tendency of polyglactin 910 to elicit foreign body reaction.[8]

Cell response to implantation of polyglactin 910 is characterized by a minimal inflammatory reaction and the presence of mononuclear, eosinophilic, giant cell and fibroblasts from the fifth day to the 10th day post-implantation. The tissue reaction at 30 days post-implantation is characterized by a minimum necrotic exudate, decreased giant cell reaction, and decreased infiltration of mononuclear and eosinophilic cells. Good healing with minimal or no tissue reaction is noted from 60 to 120 days.[7,8,24]

Tensile strength loss is sensitive to changes in temperature and pH. Heat or alkaline conditions hasten the decline of strength.[8] Adverse reactions are reported* to be minimal. Reported adverse reactions vary from redness, induration and abscessation.

*Ethicon Inc., Somerville, N.J. 08876

MATERIALS AND METHODS

Six horses were used in this research. Four horses were male and two were females. The age of the animals ranged between 1 to 15 years.

The horses were divided in two groups consisting of three horses each. Six incisional sites were selected for burying different types of suture materials in the soft tissues of each horse. Two sites selected were on the ventral abdomen. Two incisions 17.5 cm. long were created. One in the linea alba and the second was paramedian; 15 cm. to the right. Four incisions were made on the right and left biceps femoris muscles. The incisions consisted of two parallel vertical 7.5 cm. long, 5 cm. apart from each other created on each side.

In the three Group I horses, #5 Ethibond[R] a braided polyester, polyethylene or mersilene, non-absorbable suture coated with polybutilate and dyed with color D&C green No. 6, was used for closure of the incisions in the linea alba. The right paramedian incision was closed with size 3 Extra Heavy Vetafil[R] (0.6 mm diameter) a synthetic, polyamide, non-absorbable, polyfilament class II surgical suture. In both closures the sutures were double stranded. The four incisions in the biceps femoris muscles were closed with #1 Ethibond[R], size 00 Medium Vetafil[R], #1 Vicryl[R], and #1 Prolene[R].

In the three Group II horses, the incision in the linea alba was closed with size 3 Extra Heavy Vetafil[R] and the right paramedian incision was closed with #5 Ethibond.[R]

The incisions in the right and left biceps femoris muscles were closed with the same suture materials used in the Group I horses.

The distribution of the suture materials implanted in each horse is summarized in Tables I and II.

On the day prior to surgery the hair of the ventral abdomen was removed using a #40 clipper blade. Care was taken to avoid trauma to the skin since this could predispose to the formation of microabcesses. An area 30 cm. long by 30 cm. wide was clipped on each leg over the biceps femoris muscle.

All feed was withheld during a period of 12 hours prior to surgery. Water was not restricted. Thirty minutes before surgery the horse's mouth was washed with water. The feet were picked out and cleaned of debris, and the hair coat brushed.

Acepromazine,[h] 3.0 mg/45.40 kg of body weight, was given intravenously 10 minutes prior to the induction of the anesthetic. Following tranquilization a combination of Surital[i] 3 grams in 500 cc. of Glycodex[j] was given intravenously. The horse was

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[h]Acepromazine (Acetylpromazine Maleate injectable) 10mg/ml. Ayerst Laboratories Incorporated, New York, N.Y. 10017.

[i]Surital (Thyamilal Sodium N.F.) Parke Davis & Co., Detroit, Mi. 48232 U.S.A.

[j]Glycodex (Guaifenesin 50mg/ml) Burns-Biotec Laboratory Division, Omaha, Nebraska 68103 U.S.A.

intubated and anesthesia was maintained with Halothane[k] and oxygen in a closed system.

The horse was transported to the surgery table and positioned in dorsal recumbency. Pads were used to avoid pressure myositis. The prepuce of the male horses was cleaned. A purse string pattern with #1 Nylon was used to close the preputial opening in order to avoid contamination of the surgical field. The area over the linea alba, the right paramedian abdominal, the right and left biceps femoris, was shaved using a blade. The area of the shaved sites was 30 cm. cranio-caudal and 10 cm. to each lateral side from the selected incisional lines in the ventral abdomen. The area of the shaved sites of the right and left biceps femoris muscles was 20 cm. long by 20 cm. wide.

A four step surgical scrub was done on the ventral abdomen with Prepodyne scrub[l] followed by Betadine[m] spray solution.

The surgeons prepared themselves using a seven minute mechanical scrub, sterile gowns and doubled gloved. A 225 cm. by 240 cm. long sterile drape was placed on the cranial aspect of the surgical field covering the thoracic cavity, thoracic limbs,

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[k]Halothane U.S.P. inhalation anesthetic, nonflammable and non-explosive. Halocarbon Laboratories, Inc. 82 Burlews Court, Hackensack, N.J. 07601.

[l]Prepodyne Scrub ("Tamed Iodine") West Chemical Product Inc. New York, N.Y. 11101.

[m]Betadine Solution (Povidone Iodine 10%) Purdue Frederick Company, Norwalk, Conn. 06856.

neck and head. A second 225 cm. wide by 240 cm. long sterile drape was placed on the most caudal part of the surgical field and extended caudally covering the pelvic limbs. Two sterile cloth drapes, 180 cm. wide by 112 cm. long, were placed longitudinally, one on either side of the horse. Towel clamps were applied at the points of intersection. A shroud with a 2.5 cm. wide by 20 cm. long apperture opening, was placed over the selected incisional site and towel clamps were applied.

The outer pair of gloves, used to drape the patient, were removed with care taken not to contaminate the inner pair. The talcum left by the first pair of gloves was removed from the surgical gloves by use of gauze sponges and saline.

A standard equine surgical pack, a 30 cm. stainless steel rule and the suture materials described in Table I and II, were used throughout the surgical procedure.

The first incisional site selected was the right paramedian incision which was created 15 cm. to the right of the linea alba. A #21 scalpel blade was used to make the 17.5 cm cranio-caudal incision. The initial incision was extended through the subcutanous tissues. A #10 scalpel blade, was used to extend the incision through the aponeurosis and muscles of the obliquus externus abdominis and obliquus internus abdominis. Bleeding vessels were clamped and ligated with #00 Chromic Gut.[R] The rectus abdominis muscle, transversus abdominis muscle and peritoneum were then incised using the sharp edges of a Mayo curved scissors, thus exposing the abdominal cavity.

In the three Group I horses, closure was accomplished in the following manner. Size 00 Medium Vetafil[R] in a half-circle taper point needle and a simple continuous suture pattern was used on the peritoneum and transversus abdominis muscle. The rectus abdominis muscle, obliquus internus abdominis muscle and obliquus externus abdominis muscle were sutured using a double stranded size 3 Extra Heavy Vetafil[R], a half-circle martin uterine needle, a simple interrupted pattern, and tied with a surgeons knot followed by a square knot. The first suture was placed at the most cranial part of the incision line, 2 cm. abaxial to the cut edge on either side. The sutures were spaced 1.25 cm. apart and the same suture pattern was followed until complete closure of the incision line was achieved. The subcutaneous tissue was closed with size 00 Medium Vetafil[R], a conventional cutting needle, and a simple continuous pattern. The skin incision was sutured with #0 Nylon, a conventional cutting needle, and with an interrupted horizontal mattress pattern.

On completion of closure of the right paramedian incision, the apperture opening drape was moved to the incisional site of the linea alba, and clamped in place. A cranio-caudal skin incision 17.5 cm. long was created using a #21 scalpel blade. The incision was continued through the subcutaneous tissue until good visualization of the median fibrous raphe of the linea alba was achieved. A 4 cm. incision was created into the fibrous raphe of the linea alba, using a #10 scalpel blade. The incision was continued using the sharp edges of a Mayo curved scissors, and the abdominal cavity exposed.

In the three Group I horses the incision line was sutured starting at the most cranial aspect of the incision and 2 cm. abaxial in either side of the cut edges. A simple interrupted pattern, double stranded #5 Ethibond[R], on a half-circle martin uterine needle, was utilized. The suture tie was a surgeons knot followed by a square knot. The sutures were placed at 1.25 cm. intervals until complete closure of the incision line was achieved. The subcutaneous tissue was closed with #1 Ethibond[R], a conventional cutting needle, and using a simple continuous suture pattern. The skin was sutured with #0 Nylon, a conventional cutting needle and using an interrupted horizontal mattress pattern.

Following closure of the incisions in the ventral abdomen, the drapes were removed and the horse positioned on right lateral recumbency exposing the left biceps femoris muscle area. The surgical field, already clipped and shaved, was scrubbed and sprayed with Prepodyne[R] scrub and Betadine[R] solution respectively. An incisional plastic shroud was applied over the surgical area, and towel clamps were used to clamp it in place. Two parallel dorso-ventral skin incisions 7.5 cm. long, and 5 cm. apart were created with a #21 scalpel blade. The subcutaneous tissue and deep fascia were incised, using a #10 scalpel blade. The biceps femoris muscle were thus exposed.

A single strand of suture with a conventional cutting needle was used for closure of these incisions. A simple interrupted suture pattern taking 2.5 cm. deep bites into the muscle and thus apposing the fascia edges was applied. The tie was a surgeons knot followed by a square knot. The first simple interrupted suture was placed at the most dorsal aspect of the incision line. A second simple interrupted suture was placed so as to allow 1 cm. between the sutures. The same suture pattern was continued until complete closure was achieved. The subcutaneous tissue was approximated using the same suture material and a simple continuous suture pattern. The skin incision was closed with #0 Nylon, a conventional cutting needle, and an interrupted horizontal mattress pattern.

A sterile towel was then placed and sutured over the incisional sites using a cruciate pattern of #0 Nylon placed 2 cm. abaxial to each incision line.

The patient was rolled over and placed in left lateral recumbency. Preparation of the surgical field and the surgical techniques described above, were performed in like manner. The distribution of the suture materials is described in Table II.

Following completion of the surgical procedures, the patient was transported to the recovery room. Observation of the horse was mantained until recovery from anesthesia was complete. A compress bandage was applied around the ventral abdomen using an Army Navy[n] bandage on the incision lines and stretch gauze 15 cm. wide. Elastikon[o] tape 15 cm. wide was used to hold the bandage in place.

The three Group II horses, were treated in the same manner except that the suture materials for both abdominal incisions were exchanged as described in the materials and methods.

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[n]Army Navy bandage. Compress and Bandage Field, Johnson & Johnson Dallas, Texas.

[o]Elastikon, Johnson & Johnson, Brunswick, N.J. 08903.

TABLE I

SUTURE MATERIALS USED IN THE VENTRAL ABDOMEN OF THE HORSE

	Linea* alba	Subcutaneous tissue	Skin	Right Paramedian* incision	Subcutaneous tissue	Skin
Group I	#5 Ethibond^{R}	#1 Ethibond^{R}	#0 Nylon	Size 3 Extra Heavy Vetafil^{R}	Size 00 Medium Vetafil^{R}	#0 Nylon
Group II	Size 3 Extra Heavy Vetafil^{R}	Size 00 Medium Vetafil^{R}	#0 Nylon	#5 Ethibond^{R}	#1 Ethibond^{R}	#0 Nylon

*Double strand implantation.

TABLE II

SUTURES MATERIALS USED IN THE BICEPS FEMORIS

MUSCLES OF THE HORSE*

Patient No.	Right Biceps Femoris Muscle		Left Biceps Femoris Muscle	
	Cranial incision	Caudal incision	Cranial incision	Caudal incision
1	#1 Prolene[R]	Size 00 Medium Vetafil[R]	#1 Vicryl[R]	#1 Prolene[R]
2	#1 Ethibond[R]	#1 Vicryl[R]	#1 Vicryl[R]	#1 Ethibond[R]
3	Size 00 Medium Vetafil[R]	#1 Ethibond[R]	#1 Ethibond[R]	#1 Prolene[R]

*This table applies for both: Group I and Group II horses.

Daily observations were made and recorded of the gross tissue reaction to the suture materials. The horses were euthanized 60 days post-surgery using T-61[p] Euthanasia Solution intravenously at a dose of 6 ml/50 kg of body weight.

Necropsy was performed. The abdominal surgical sites were examined grossly, and an "en block" of tissue, 5 cm. cranio-caudal and 5 cm. to each lateral side from the suture line was removed. Gross examination of tissue healing and photography were accomplished. Five transverse cuts with a sharp blade were made and measurements of tissue recorded between a point 3 cm. cranial to the first suture line to 3 cm. caudal to the last suture line. Care was taken not to damage the buried suture material. The soft tissues were tacked or nailed to a plywood board. The epidermal side was placed facing the plywood board thus exposing the subcutaneous tissue and musculature. The soft tissues, nailed to the plywood board, were immersed in a five gallon plastic container filled with 10% neutral buffered formalin solution. The formalin fixation was routine.

The formalin fixed tissues were sliced and examined grossly. Three tissue samples were cut and placed into a tissue container

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[p]T-61 Euthanasia Solution. National Laboratory Corp. Somerville, N.J. 08876.

with a number for identification. The tissue samples were processed routinely in the auto-technicon. Parafin sections were prepared from the samples and stained with hematoxilin and eosin stain (H&E).

Histopathologic studies and photography were accomplished using a light microscope and a Leitz microscopy with polarizing filters.

RESULTS AND DISCUSSION

ETHIBOND[R]

Gross evaluation of the polybutilate-coated polyester suture revealed the implant to be essentially inert with little or no gross inflammatory reaction in five of the abdominal incisions. On one paramedian abdominal incision, horse #4, an inflammatory reaction was presented on the 25th post-surgical day. Pain was present when pressure was applied on the incision line. Redness and heat were evident abaxial to the incision line. Two days later a purulent drainage developed on the most cranial aspect of the surgical site. Heavy growth of Staphylococcus aureus was isolated from the draining tract. Treatment of the infected area was accomplished by local infusion with Nitrofurazone Solution.[q] Purulent drainage was not present at the fifth post-treatment day; however, healing was not achieved. Gross evaluation of the infected area at necropsy revealed sinus tracts throughout the suture line.

Gross morphological changes were not noted following implantation of the suture material in the biceps femoris muscles.

The handling qualities of polybutilate-coated polyester showed the implant to have good pliability and good holding power which provided excellent apposition of tissues. No evidence of a drag was noted when pulled through the tissues. Knot security was adequate; however, its friction coefficient was low during the tying process. Due

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[q]Nitrofurazone Solution. Hanover Drug Products Inc. Hanover, N.J. 07936

to this reason it is advisable to place four to five throws when tying the knots. Visibility of the suture material in the surgical field was excellent.

The histopathological reaction of tissue when polybutilate-coated polyester was implanted in the linea alba of the three Group I horses revealed good healing and minimal tissue reaction. The reaction was characterized by the presence of mature fibrous connective tissue, few mononuclear cells, few lymphocytes, giant cells and small blood vessels.

Microscope examination with polarized filters revealed the presence of minute particles of the polybutilate coating material scattered throughout the adjacent tissues and the formation of several chronic microscopic granulomas circumscribing the coating particles.

Histopathological evaluation of polybutilate-coated polyester buried in the right paramedian incision of the three Group II horses revealed a minimal fibrous connective tissue reaction in two of the horses. Cell reaction was minimal; however, on horse #4 a heavy infiltration of polymorphonuclear cells, mononuclear cells and lymphocytes was evident. The presence of botryomycosis and chronic microscopic granulomas characterized the tissue reaction to the infection of Staphylococcus aureus in this particular tissue.

The histopathological findings of the tissue reaction to the implantation of polybutilate-coated polyester buried in the biceps femoris muscles of both Groups of horses revealed that the suture material provided excellent healing with the presence of a thin rim of fibrous connective tissue around the suture. There was also the presence of few lymphocyte, macrophages and giant cells.

VETAFIL[R]

Evaluation of the Vetafil[R] suture material revealed several characteristics. The suture material buried in the ventral abdomen in four of the incision sites, caused marked inflammatory reaction of the tissue and pain was elicited when pressure was applied. Heat and redness were evident in two cases. Horse #1 developed a purulent drainage at the cranial aspect of the right paramedian incision on the 20th post-surgical day. A beta hemolytic Streptococcus was isolated on culture. Horse #3 developed a purulent drainage at the cranial aspect of the right paramedian incision on the 28th post-surgical day. Staphylococcus aureus was isolated on culture. On both cases the organisms were sensitive to Nitrofurazone[R]. Seven days after the first treatment, the sinus tracts were no longer draining frank pus and healing was not achieved. At the 40th post-operative day the skin area where drainage had occurred changed to a granulomatous appearance which persisted until euthanasia. Gross morphological findings at necropsy on both horses, demonstrated infected tracts with necrotic exudates. Sinus tracts were well defined from the most caudal aspect of the suture line to the most cranial aspect where ventral drainage had occurred.

Gross morphological findings of the tissue where Vetafil[R] was implanted in the biceps femoris muscles revealed a slight inflammatory reaction early. The reaction was no longer evident after the 12th post-operative day on three of the incisions. The fourth incision developed an infected tract on the 20th post-surgical day. Staphylococcus aureus was isolated on culture. Nitrofurazone[R] infusions were used in treatment of this incision. Healing was uneventful.

The size 3 Extra Heavy Vetafil[R] was found to be markedly stiff and its pliability was of poor quality. The handling ability of this suture material was inferior when compared to polybutilate-coated polyester; nevertheless, the knot security and coefficient of friction when placing a knot were superior than polybutilate-coated polyester. Vetafil[R] had a high degree of drag when pulled through the tissues and its high tensile strength provided good apposition of the tissues.

The histopathological findings of the tissue response to the implantation of Vetafil[R] in the right paramedian incision of the three Group I horses revealed an inflammatory reaction and evidence of infection. Tissue reaction was characterized by heavy infiltration of mononuclear cells, polymorphonuclear cells, macrophages and plasma cells. Several sinus tracts were noted around the suture line. The areas were surrounded by collagen borders with capillaries arranged in a perpendicular manner.

Microscopic examination with polarized filters of the tissues where Vetafil[R] was buried revealed the presence of minute filament particles which were dislodged and scattered through the adjacent tissues. Several granulomatous reactions were found circumscribing the scattered minute particles.

The histopathological studies of the tissue reaction to the implantation of Vetafil[R] in the linea alba of the three Group II horses were characterized by the presence of mature fibrous connective tissue with a marked cellular reaction of lymphocytes, macrophages, plasma cells and giant cells; however, there was no evidence of dislodged suture material.

The histopathological findings of the tissue reaction where Vetafil[R] was implanted in the biceps femoris muscles revealed a slight cell reaction characterized by mature connective tissue, a few macrophages filled with hemosiderin, lymphocytes and few giant cells. Generally, good healing was evident.

PROLENE[R]

Monofilament polypropylene was evaluated in six incisions involving the biceps femoris muscles. No gross morphological findings were appreciable. The suture was essentially inert and the retrived specimens appeared the same as at the time of implantation. No softening or breakage of the material was observed.

The handling ability of monofilament polypropylene revealed that its tensile strength allowed excellent apposition of the tissues. Knot security was adequate although five throws were required when tying the knots due to its low coefficient of friction. The smooth surface of the monofilament polypropylene allowed easy passage through the muscles, thus minimizing trauma to the tissues. No dragging or pulling was experienced. The blue color of the suture provided excellent visibility in the surgical field.

On histopathological examination a minimal tissue reaction and muscle damage were present. The cell reaction was characterized by a few macrophages, lymphocytes and vascular proliferation. Encapsulation by connective tissue and a thin rim of fibrous tissue around the suture were evident.

VICRYL[R]

Polyglactin 910 absorbable suture was placed in six incisions involving the biceps femoris muscles. No appreciable difference of tissue was detected on gross morphological evaluation.

The high tensile strength of polyglactin 910 provided a good holding power when placed. No twisting was experienced. The suture material presented good pliability and minimum drag effect when pulled through the tissues. Slippage or breakage of knots did not occur. The violet color of the suture facilitated its visibility in the surgical field.

Histopathological examination of the tissue reaction elicited by Polyglactin 910 revealed it to have a minimal cell response characterized by moderate connective tissue, fibrous tissue, a few macrophages and lymphocytes. Excellent healing was evident and absorption of the suture material was in process at 60 days post-implantation.

SUMMARY

The objective of this study was to compare the soft tissue reaction to four different suture materials buried in the ventral abdomen and biceps femoris muscles of the horse. The suture materials selected for this purpose were #5 Ethibond[R] and size 3 Extra Heavy Vetafil[R] which were implanted in the ventral abdomen. The suture materials implanted in the biceps femoris muscles were #1 Prolene[R], #1 Ethibond[R], size 00 Medium Vetafil[R] and #1 Vicryl[R]. The horses were euthanized on the 60th, post-surgical day. Clinical examination gross morphological evaluation and histopathological studies of the sutures implanted in the ventral abdomen revealed the Ethibond[R] to be superior than the Vetafil[R]. Evaluation of the suture materials implanted in the biceps femoris muscles revealed the Ethibond[R], Prolene[R] and Vicryl[R] implants to be relatively inert evoking a minimal tissue reaction. No appreciable differences were detected among these sutures; however, the Vetafil[R] implant presented an early inflammatory response and a higher degree of cell reaction.

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PICTURES

HISTOPATHOLOGICAL EVALUATION OF THE TISSUE REACTION TO THE IMPLANTATION OF ETHIBOND^{R} IN THE VENTRAL ABDOMEN

Picture 1

Linea alba. Clean stitch canal surrounded by a thin rim of mature connective and fibrous tissue. Cell reaction characterized by minimal infiltration of mononuclear cells and lymphocytes.

Picture 2

Linea alba. Microscopic examination under polarized filters revealed birefringence of the suture material.

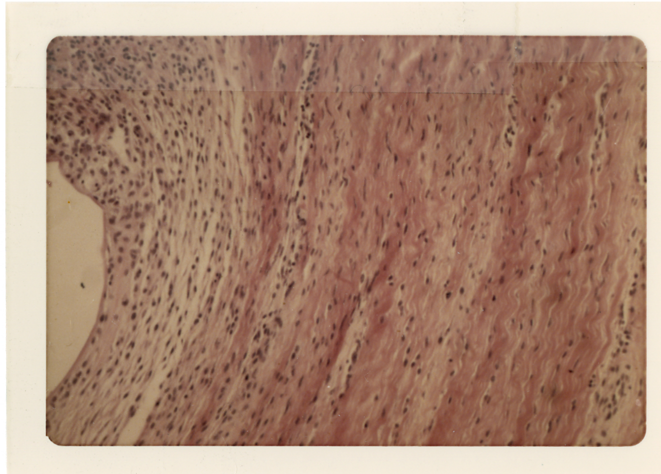
Picture 3

Linea alba. Microscopic examination under polarized filters revealed the presence of birefringent material scattered throughout the adjacent tissue; however, the material evoked minimal tissue reaction.

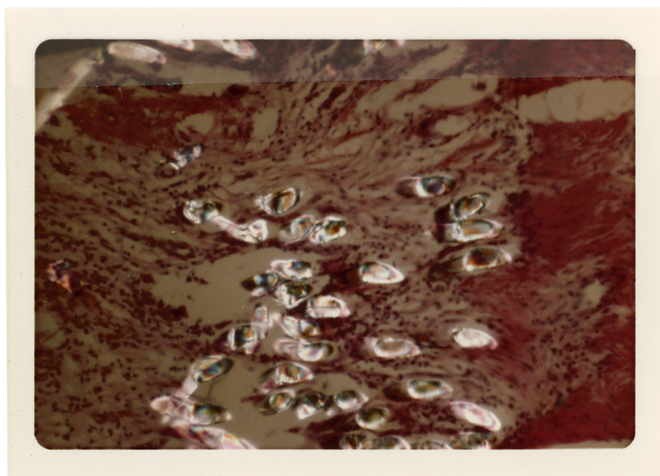
THIS BOOK CONTAINS NUMEROUS PICTURES THAT ARE ATTACHED TO DOCUMENTS CROOKED.

THIS IS AS RECEIVED FROM CUSTOMER.

Picture 1



Picture 2



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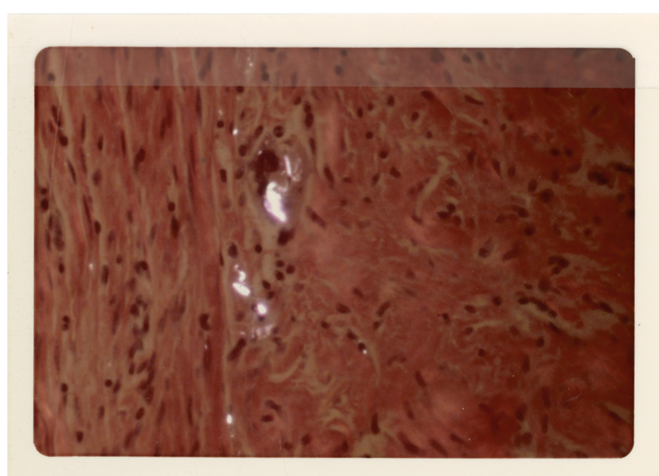
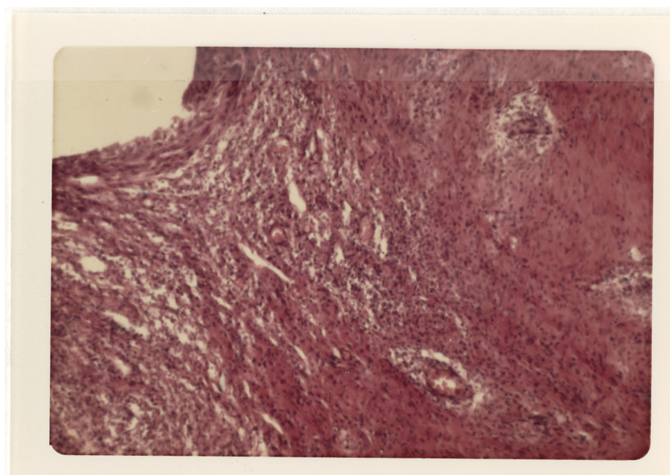


GROSS MORPHOLOGICAL EXAMINATION AND HISTOPATHOLOGICAL EVALUATION OF THE TISSUE REACTION TO THE IMPLANTATION OF VETAFIL[R] IN THE VENTRAL ABDOMEN

Picture 4	Gross morphological appearance of the tissue of the right paramedian abdominal incision at necropsy revealed the presence of sinus tracts throughout the suture line.
Picture 5	Histopathology of the right paramedian incision. Clean stitch canal surrounded by mature connective tissue. Cell reaction characterized by heavy infiltration of polymorphonuclear leukocytes lymphocytes and mononuclear cells.
Picture 6	Linea alba. Clean stitch canal. Cell reaction characterized by the presence of moderate infiltration of lymphocytes, polymorphonuclear cells and a few giant cells.

Picture 4

Picture 5



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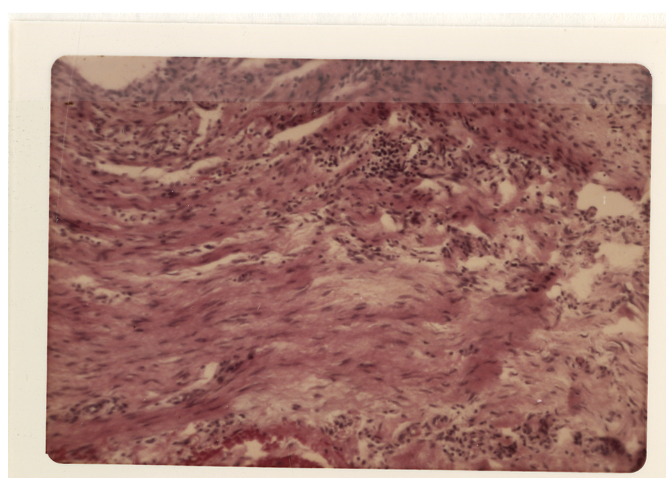
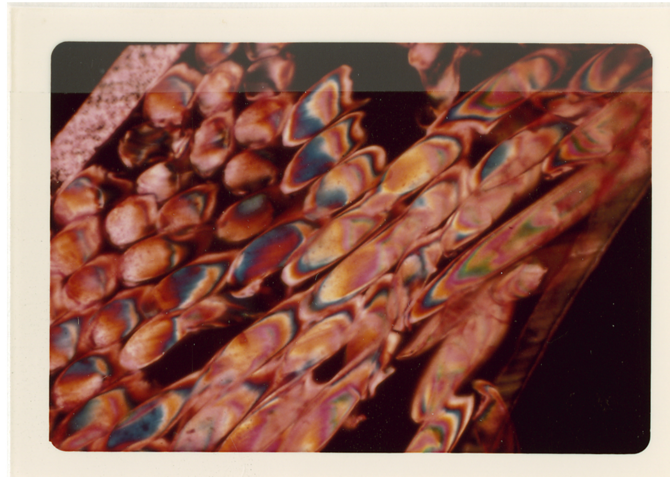


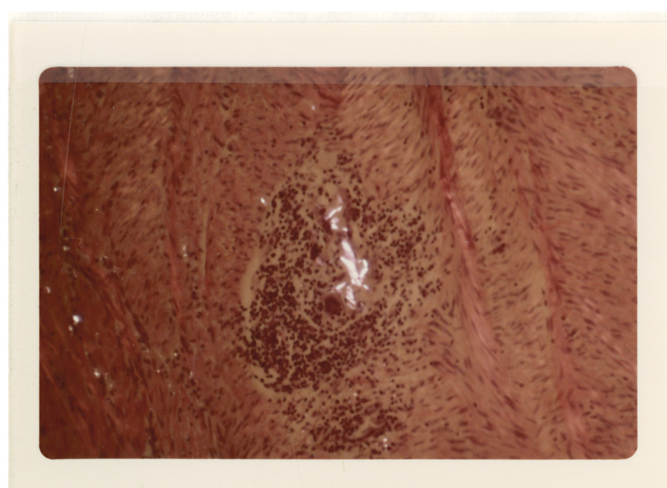
Picture 7	Examination of Vetafil^R under polarized filters. The filaments (center) are contained within the coating material (upper left corner).
Picture 8	Right paramedian incision. Evaluation of Vetafil^R under polarized filters revealed disruption of the coating material.
Picture 9	Right paramedian incision. Microscopic examination under polarized filters revealed the presence of birefringent material scattered throughout the adjacent tissues. Cell reaction characterized by heavy infiltration of polymorphonuclear cells and lymphocytes.

Picture 7



Picture 8

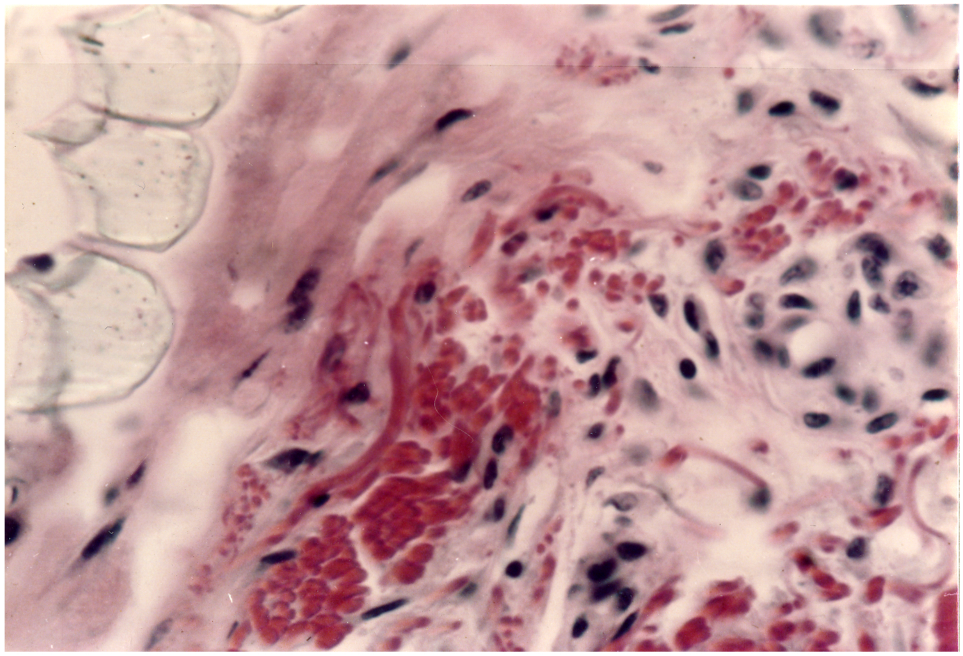
Picture 9



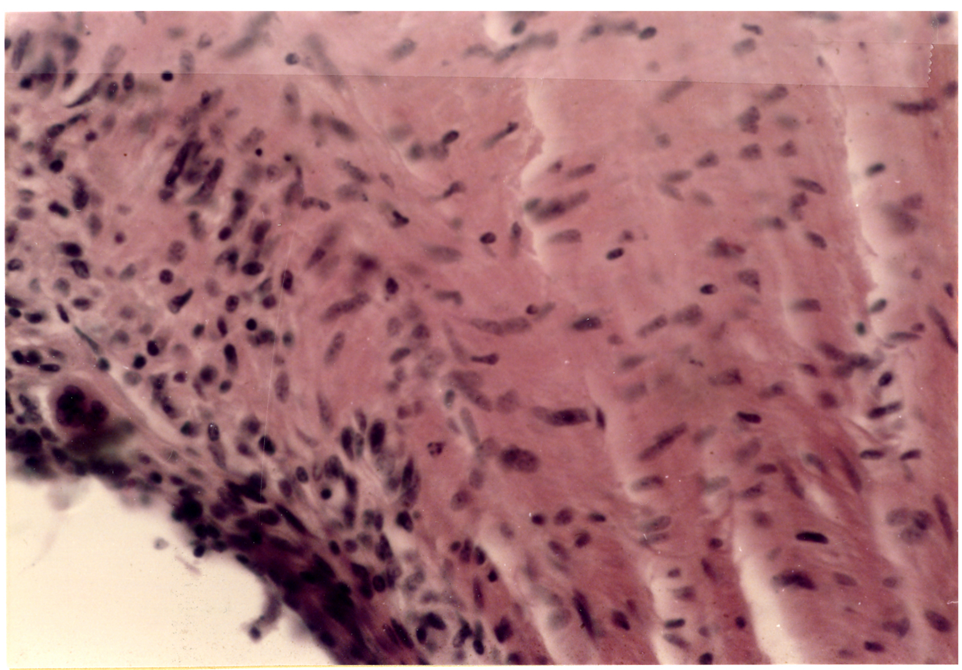
HISTOPATHOLOGICAL EVALUATION OF THE TISSUE REACTION TO DIFFERENT SUTURE MATERIALS IMPLANTED IN THE BICEPS FEMORIS MUSCLES

Picture 1	ETHIBOND[R]. Microscopic examination under polarized filters revealed the presence of birefringent material (upper left corner). Suture material surrounded by mature connective tissue. Minimal cell reaction characterized by a few lymphocytes. Vascular proliferation is evident.
Picture 2	VETAFIL[R]. Microscopic examination revealed a clean stitch canal surrounded by mature connective tissue. Cell reaction characterized by moderate infiltration of lymphocytes a few giant cells and plasma cells.

Picture 1



Picture 2



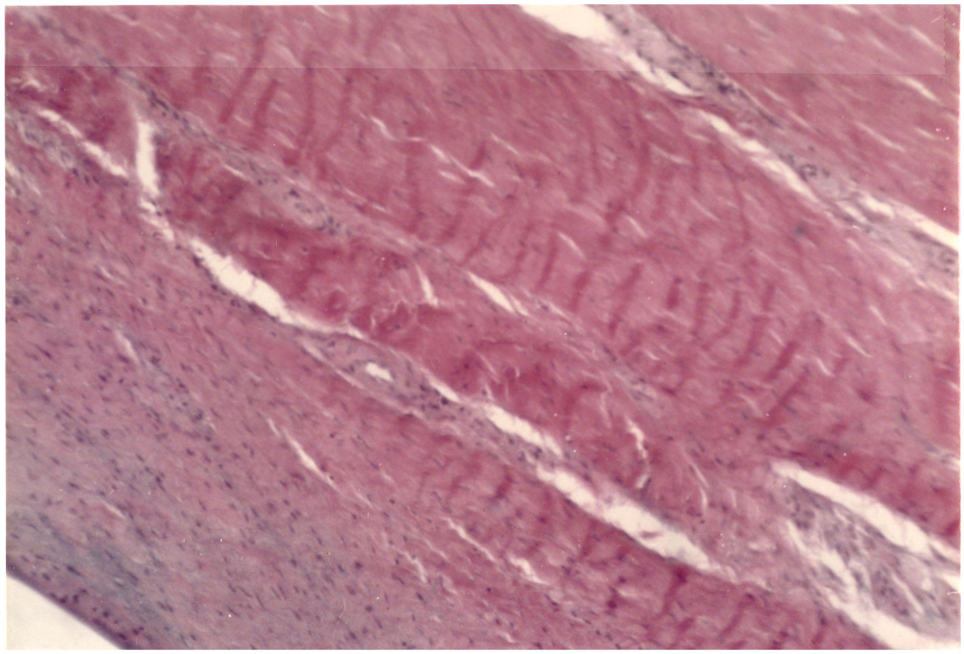
Picture 3

PROLENE[R]. Microscopic examination revealed a clean stitch canal (lower left corner) surrounded by connective tissue. Cell reaction is minimal.

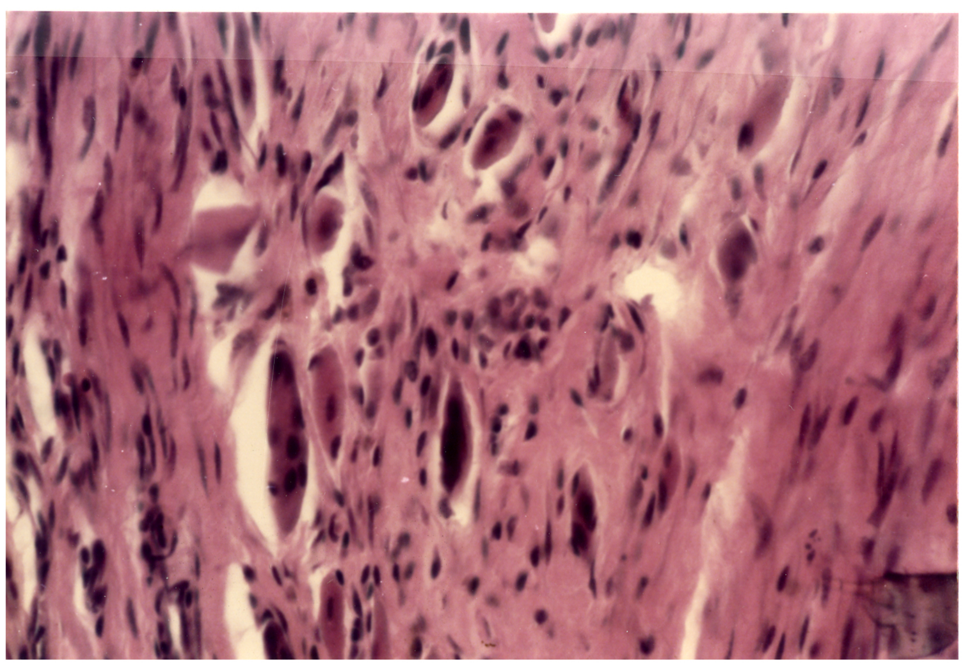
Picture 4

VICRYL[R]. Microscopic examination revealed the stitch canal (center) being replaced by mature connective and fibrous tissue. Muscle regeneration is evident. Cell reaction characterized by a few lymphocytes. No suture remnants were present.

Picture 3



Picture 4



A COMPARATIVE STUDY OF TISSUE REACTION TO FOUR DIFFERENT SUTURE MATERIALS

by

JUAN A. CANTU

M.V.Z. Centro De Estudios Universitarios, 1976

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

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Manhattan, Kansas

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ABSTRACT

Suture material currently used for ventral abdominal wound closure in the horse do not offer sufficient strength without secondary adverse effects. Veterinary surgeons continue to search for a suture material which provides good holding strength until tissue healing is achieved, produces minimal tissue reaction, resists bacterial contamination or infection and is well tolerated throughout the life span.

Suture materials may act as a foreign body, thus stimulating varying degrees of tissue reaction which in turn, might have influence on the final outcome of tissue healing.

The purpose of this research was to study the soft tissue reaction to four different suture materials buried in the ventral abdomen and biceps femoris muscles of the horse.

In this study six horses were used. The horses were divided in two groups consisting of three horses in each group. Two incisions were created in the ventral abdomen of each horse. On the three Group I horses, #5 Ethibond[R] a braided polyester (polyethylene or mersilene) non-absorable suture coated with polybutilate was implanted in the linea alba and size 3 Extra Heavy Vetafil[R] a synthetic polyamide polyfilament class II non-absorbable suture was implanted in the right paramedian incision. In both closures the sutures were double stranded. Four incisions were created on the biceps femoris muscles. The incisions were closed with #1

Ethibond^{R}, size 00 Medium Vetafil^{R}, #1 Vicryl^{R} (polyglactin 910) and #1 Prolene^{R} (monofilament polypropylene).

In the three Group II horses, the incisions created in the linea alba were closed with size 3 Extra Heavy Vetafil^{R} and the right paramedian incision was closed with #5 Ethibond^{R}. The incisions in the right and left biceps femoris muscles were closed with the same suture materials used in Group I horses.

The distribution of the suture materials implanted in the biceps femoris muscles of both groups of horses is summarized in Table II.

The horses were euthanized and necropsied on the 60th post-surgical day. Clinical evaluation, gross morphological examination and histopathological studies of the suture materials implanted in the ventral abdomen revealed the Ethibond^{R} to be superior to Vetafil^{R}. In general, the Ethibond^{R} implant provided good healing and minimal tissue reaction characterized by the presence of a few lymphocytes, macrophages and a few giant cells.

Evaluation of the Ethibond^{R}, Prolene^{R} and Vicryl^{R} implanted in the biceps femoris muscles revealed these suture materials to be relatively inert evoking a minimal inflammatory and cell reaction; however, the Vetafil^{R} implant showed a higher degree of inflammation and cell reaction. Over all, good healing was achieved.