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A REVIEW ON PROPERTIES OF SURGICAL SUTURES AND APPLICATIONS IN MEDICAL FIELD

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ABSTRACT

The purpose of the study was to provide detailed information on properties of suture materials in order to assist surgeons in their selection of adequate sutures for specific surgical applications. The essential requirements and characteristics of suturing materials effects on properties of surgical sutures. A wide range of stress-strain characteristics was observed in the tested sutures. Suture materials of similar nominal properties may behave quite differently in their stress-strain relationship. Sutures are classified into three classes according to its structural configuration and origin. These are classified by the Food and Drug Administration (FDA) with reference to Safe Medical Device Act (SMDA), and Food and Drug Administration Modernization Act (FDAMA) of USA. Absorbable suture is used to close the edges of a wound or incision and to repair damaged tissue. Non-absorbable sutures are designed to either be left permanently in the body or are to be removed after a certain healing period. This was true of sutures of the same chemical nature as well as of different geometric construction, such as Ethilon vs. Nurolon.

KEYWORDS: Fibre, Suture, Human Tissue, Synthetic, Bio-Degradable, Mono-Filament

INTRODUCTION

Suture is a generic term for all materials used to bring served body tissue together and to hold these tissues in their normal position until healing takes place. Sutures which are used in surgical purpose for field of medical textiles is now a most demand in joining of different type of tissues. Sutures are used to re-approximate the divided tissues and ligation of the cut end vessels. If the suture fails to perform the above said functions, the consequences may be disastrous. Massive bleeding may occur when the suture loop surrounding a vessel is disrupted [1]. Securing wounds is possible by knot or by recently developed barbed suture. Sutures require knots so as to ensure optimal tissue closure strength. The goal of wound closure is to bring the edges of the wound together not only with sufficient strength to prevent dehiscence, but also with a minimal residual tension and compression of the tissue [2]. The example of suturing which is help in joining of two tissues which are shown in Figure. This Figure shows wound before suturing and after suturing.

Figure 1: Wound before Suture

Figure 2: Wound after Suture

With the first wave of bioactive sutures already in the marketplace, research is ongoing in the development of future products. Such sutures could potentially have not only antimicrobial activity but also anesthetic and antineoplastic functions. Some clinical trials have already been completed in Russia. This technology is likely to become commonplace [3].

The suturing materials and techniques used to reconstruct the planes can thus have a direct and determinate influence on the phases of healing, making an indepth and detailed knowledge of the physical, chemical and technological properties of suturing materials an absolute necessity. The clinical choice that, on each individual occasion, leads us to prefer a synthetic or a natural thread, a single or a multiple filament, a resorbable or a non-resorbable suture, must be reasoned and never left to chance.

The thread is always used with a needle, the characteristics of which also contribute to differentiating its use in order to achieve the required results. A precise knowledge of these variables is part of the body of technical and theoretical expertise of every oral surgeon [4].

CHARACTERISTICS

Ideal Suture Characteristics

Suture material is a foreign body implanted into human tissues; it elicits a foreign body tissue reaction. During wound closure, a sterile field and meticulous aseptic technique are critical to minimize the risk of wound infection. Other complications of wound healing, such as hypertrophic scars, wide scars, and wound dehiscence, may result from patient factors (eg, nutritional status), incorrect suture selection, or a technique that results in excessive tension across the wound.

Skillful wound closure requires not only knowledge of proper surgical techniques but also knowledge of the physical characteristics and properties of the suture and needle.

The ideal suture has the following characteristics:

- Sterile
- All-purpose (composed of material that can be used in any surgical procedure)
- Causes minimal tissue injury or tissue reaction (ie, nonelectrolytic, noncapillary, nonallergenic, noncarcinogenic)
- Easy to handle
- Holds securely when knotted (ie, no fraying or cutting)
- High tensile strength
- Favorable absorption profile
- Resistant to infection

Unfortunately, at present, no single material can provide all of these characteristics. In different situations and with differences in tissue composition throughout the body, the requirements for adequate wound closure require different suture characteristics.

Essential Suture Characteristics

All sutures should be manufactured to assure several fundamental characteristics, as follows:

- Sterility
- Uniform diameter and size
- Pliability for ease of handling and knot security
- Uniform tensile strength by suture type and size
- Freedom from irritants or impurities that would elicit tissue reaction

Other Suture Characteristics

The following terms describe various characteristics related to suture material:

- **Absorbable** - Progressive loss of mass and/or volume of suture material; does not correlate with initial tensile strength.
- **Breaking Strength** - Limit of tensile strength at which suture failure occurs.
- **Capillarity** - Extent to which absorbed fluid is transferred along the suture.
- **Elasticity** - Measure of the ability of the material to regain its original form and length after deformation.
- **Fluid Absorption** - Ability to take up fluid after immersion.
- **Knot-Pull Tensile Strength** - Breaking strength of knotted suture material (10-40% weaker after deformation by knot placement).
- **Knot Strength** - Amount of force necessary to cause a knot to slip (related to the coefficient of static friction and plasticity of a given material).
- **Memory** - Inherent capability of suture to return to or maintain its original gross shape (related to elasticity, plasticity, and diameter).
- **Non Absorbable** - Surgical suture material that is relatively unaffected by the biological activities of the body tissues and is therefore permanent unless removed.
- **Plasticity** - Measure of the ability to deform without breaking and to maintain a new form after relief of the deforming force.
- **Pliability** - Ease of handling of suture material; ability to adjust knot tension and to secure knots (related to suture material, filament type, and diameter).
- **Straight-Pull Tensile Strength** - Linear breaking strength of suture material.
- **Suture Pullout Value** - The application of force to a loop of suture located where tissue failure occurs, which measures the strength of a particular tissue; variable depending on anatomic site and histologic composition (fat, 0.2 kg; muscle, 1.27 kg; skin, 1.82 kg; fascia, 3.77 kg).

- **Tensile Strength** - Measure of a material or tissue's ability to resist deformation and breakage.
- **Wound Breaking Strength** - Limit of tensile strength of a healing wound at which separation of the wound edges occurs[6].

CLASSIFICATION OF SUTURES

Sutures are classified into three classes according to its structural configuration and origin[7]. These are classified by the Food and Drug Administration (FDA) with reference to Safe Medical Device Act (SMDA), and Food and Drug Administration Modernization Act (FDAMA) of USA. FDA classifies the medical devices which are used for the humans, with respect to their effectiveness and safety. All sutures are classified as Class I (General controls), Class II (Special controls), Class III (Pre market approval). These controls are specified by the Guide documents of FDA, SMDA and FDAMA [8]. Figure 3 gives us an idea about the classification of suture materials.

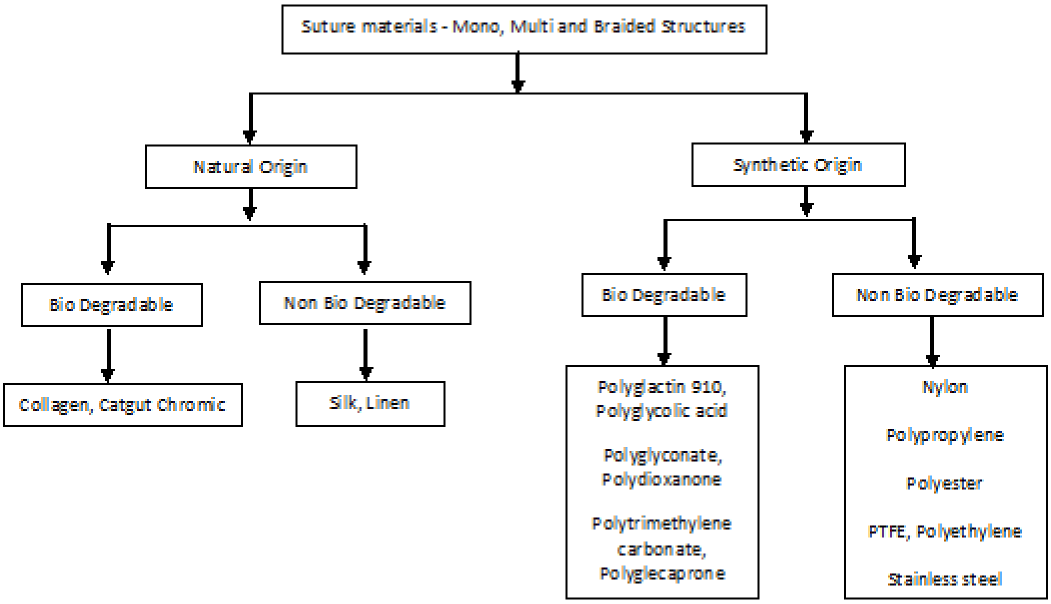

Figure 3: Classification of Suture Materials

- Absorbable and Non-Absorbable
- Natural and synthetic
- Monofilament and multi-filament

Absorbable Suture

A surgical suture is used to close the edges of a wound or incision and to repair damaged tissue. There are many kinds of sutures, with different properties suitable for various uses. Sutures can be divided into two main groups [9]. Namely, absorbable. An absorbable suture decomposes in the body. It degrades as a wound or incision heals.

These are constructed from the materials which are broken down in tissue after a given period of time usually from ten days to four weeks depending on the suture composition. They are therefore applied in many inner tissues of the body. In most of the cases, three weeks are sufficient for the wound to recover firmly. The suture is disappeared gradually and not needed any more to be removed, as there is no foreign material left inside the body. Absorbable sutures were originally made from intestines of sheep, the so called catgut. The manufacturing process was similar to that of natural musical strings for violins and guitars, and also of natural strings for tennis racquets. The major part of the absorbable sutures used are now made of synthetic polymer fibres, which may be braided or monofilament; these offer numerous advantages over gut sutures, notably ease of handling, low cost, low tissue reaction, consistent performance and guaranteed nontoxicity [10].

Absorbable sutures provide temporary wound support, until the wound heals well enough to withstand normal stress. Absorption occurs by enzymatic degradation in natural materials and by hydrolysis in synthetic materials. Hydrolysis causes less tissue reaction than enzymatic degradation. The first stage of absorption has a linear rate, lasting for several days to weeks. The second stage is characterized by loss of suture mass and overlaps the first stage. Loss of suture mass occurs as a result of leukocytic cellular responses that remove cellular debris and suture material from the line of tissue approximation.

Chemical treatments, such as chromic salts, lengthen the absorption time. Importantly, note that loss of tensile strength and the rate of absorption are separate phenomena. The surgeon must recognize that accelerated absorption may occur in patients with fever, infection, or protein deficiency and may lead to an excessively rapid decline in tensile strength. Accelerated absorption may also occur in a body cavity that is moist or filled with fluid or if sutures become wet or moist during handling prior to implantation. Examples: Catgut, Chromic, Vicryl, PDS[11].

Non-Absorbable Suture

Non-absorbable sutures are designed to either be left permanently in the body or are to be removed after a certain healing period. Permanently placed, non-absorbable sutures are generally used in tissue where even though healing may occur; the new tissue may never have the needed strength to support itself. The effective tensile strength of such sutures remains high over time. When used to close skin, non-absorbable sutures are usually removed in 10-14 days, but this may vary by location and situation[12]. Sutures are made from materials which are not metabolized by the body, and used either on skin wound closure, where the sutures can be removed after a few weeks, or in some inner tissues in which absorbable sutures are in adequate. This is applied in the heart and blood vessels, whose rhythmic movement requires a suture which stays longer than three weeks, to provide the wound enough time to recover[13]. Other organs, like the bladder, contain fluids which make absorbable sutures disappear within a few days, too early for the wound to heal. Inflammation caused by the foreign protein in absorbable sutures can amplify scarring, so if removable sutures are less antigenic it would represent a way to reduce scarring. Examples: Nylon (Ethicon), Prolene, silk.

Natural Suture

Natural sutures are made from animal or plant materials. Their protein composition can elicit the most pronounced tissue reaction (inflammation) of any suture material. Their useful strength in tissue varies from a few days with Plain Catgut to several months for Silk, and can vary with the individual.

- **Collagen:** The collagen sutures are derived from the submucosal layer of ovine small intestine or the serosal layer bovine small intestine "gut." This collagenous tissue is treated with an aldehyde solution, which cross-links and strengthens the suture and makes it more resistant to enzymatic degradation. Suture materials treated in this way are called plain gut.

- **Surgical Gut, Plain:** Tensile strength is maintained for 7-10 days post implantation (variable with individual patient characteristics), and absorption is complete within 70 days. This type of suture is used for repairing rapidly healing tissues that require minimal support and ligating superficial blood vessels. Surgical gut, fast-absorbing: This type of suture is indicated for epidermal use (required only for 5-7 d) and is not recommended for internal use.
- **Surgical Gut, Chromic (Treated with Chromium Salt):**
  - Tensile strength is maintained for 10-14 days. The absorption rate is slowed by chromium salt (90 d). Tissue reaction is due to the noncollagenous material present in these sutures. Also, patient factors affect rates of absorption and make tensile strength somewhat unpredictable.
  - Salthouse and colleagues demonstrated that the mechanism by which gut reabsorbs is the result of sequential attacks by lysosomal enzymes. Natural fiber absorbable sutures have several distinct disadvantages. First, these natural fiber absorbable sutures have a tendency to fray during knot construction. Second, there is considerably more variability in their retention of tensile strength than is found with the synthetic absorbable sutures. A search for a synthetic substitute for collagen sutures began in the 1960s. Soon, procedures were perfected for the synthesis of high molecular weight polyglycolic acid, which led to the development of the polyglycolic acid sutures.
- **Surgical Silk:** This suture is made of raw silk spun by silkworms. The suture may be coated with beeswax or silicone. Many surgeons consider silk suture the standard of performance (superior handling characteristics). Although classified as a nonabsorbable material, silk suture becomes absorbed by proteolysis and is often undetectable in the wound site by 2 years. Tensile strength decreases with moisture absorption and is lost by 1 year. The problem with silk suture is the acute inflammatory reaction triggered by this material. Host reaction leads to encapsulation by fibrous connective tissue.
- **Surgical Cotton:** This is made of twisted, long, staple cotton fibers. Tensile strength is 50% in 6 months and 30-40% by 2 years. Surgical cotton is nonabsorbable and becomes encapsulated within body tissues.

Synthetic Suture

Sutures are also classified according to their form. Some are monofilaments, that is, consisting of only one thread-like structure. Others consist of several filaments braided or twisted together. The type of suture is chosen depending on the operation. A monofilament has low tissue drag, which indicates that it passes smoothly through the tissue. Braided or twisted sutures may have higher tissue drag, but are easier to knot and have greater knot strength[14]. Braided sutures are usually coated to improve tissue drag. Other sutures may have a braided or twisted core within a smooth sleeve of extruded material. These are known as pseudo monofilaments. Sutures are designed to meet different needs. Sutures for abdominal surgery, for example, are different from sutures applied for cataract surgery. Since no one type of suture is ideal for every operation, surgeons and medical designers have come up with sutures with different qualities. One may be more absorbable but less flexible, while another is exceedingly strong but perhaps somewhat difficult to knot. This gives surgeons many options. Designers of a new suture have to take into account many factors. The rate of which the suture degrades is important, not only along the length of the suture but also at the knot[15] Some sutures need to be elastic, so that they will stretch and not break. One of that type of special suture is barbed structured sutures. There are both one directional and bi directional barbed sutures, shown in Figure 4 and Figure 5.

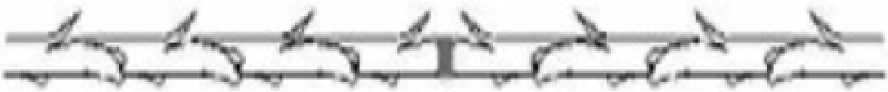

Figure 4: Bi Directional Barbed Suture

Figure 5: One Directional Barbed Suture

which results improved knot ability and security. In the year 1967 A R McKenzie published an article about an experimental multiple barbed suture. He stated that during insertion the barbed suture minimized tissue damage and his study shows that barbed nylon sutures could be used successfully in tendon repair[16].

Monofilament and Multifilament

Monofilament suture is made of a single strand. This structure is relatively more resistant to harboring microorganisms. The monofilament sutures exhibit less resistance to passage through tissue than multifilament suture. Great care must be taken in handling and tying monofilament suture because crushing or crimping of this suture can nick or weaken the suture and lead to undesirable and premature suture failure. Multifilament suture is composed of several filaments twisted or braided together. These materials are less stiff but have a higher coefficient of friction. Multifilament suture generally has greater tensile strength and better pliability and flexibility than monofilament suture. This type of suture handles and ties well. Because multifilament materials have increased capillarity, the increased absorption of fluid may act as a tract for the introduction of pathogens.

Mono filaments are stiffer and creates problem during knotting. Braided multi filaments sutures cause trauma during surgery due its rough surface. This surface roughness results greater tendency to break. Multi filaments and braided structures possess high capillary phenomena. Suture material with a high capillarity could cause body fluids coming out of wound or infection penetrating the wound [17].

Table 1: Functional Requirements of Suture with Respect to its Structure

Requirements	Design		
	Mono	Multi	Braided
Knot security	Low	Moderate	High
Handling properties	Moderate	Good	Good
Frictional resistance to advance knot	Less	Moderate	More
Tissue drag	Low	High	Higher
Capillarity	Nil	More	More due to Interstices
Tissue reaction	Low	High	High

Multifilament sutures are very good in handling, but have a small risk of infection and significant friction with the tissue in contact. On the contrary, monofilament sutures are easy in knot throw-down and less risky in infection. However, attention has been paid in the development of multifilament sutures in this decade[18].

Fiber Used on Suture

Material composition of sutures is very important in the development of suture material for different applications. Table 2 shows the performance of different suture materials.

Table 2: Performance of Different Suture Materials

Material Name	Tensile Strength	Tissue Reaction	Handling	Knot Security
Absorbable Suture Materials				
Cotton, twisted	Good	High	Good	Good
Silk, braided	Good	High	Poor	Good
Nylon, monofilament	High	Low	Good	Poor
Nylon, braided	High	Moderate	Poor	Fair
Polypropylene(mono)	Fair	Low	Fair	Poor
Polybusteter,(mono)	High	Low	Good	Poor
Polyester, braided	High	Moderate	Poor	Good
Stainless steel, (mono/multi)	High	Low	------	Good
Non Absorbable Sutures				
Collagen, plain & Chromic gut	Poor	Moderate	Fair	Poor
Coated vicryl	Good	Low	Good	Fair
Polydioxanone	Good	Low	Poor	Poor
Poly glycolic Acid	High Hydrolysis at 90-120 days	Low-moderate	Fair-good	Fair-good
Polyglactin	High Hydrolysis at 60-90 days	Low-moderate	Good	Fair
Polytrimethylene Carbonate	High Hydrolysis at 180-210 days	Low	Good	Good
Polyglecaprone	High Hydrolysis at 90-210 days	Low	Excellent	Good

In many fields of application, the strength of the surgical sutures is an important aspect. The mechanical properties of resorbable polyesters are similar to other polymers but considerably lower than the strength of bone or metal. Metallic implants in the reconstructive surgery of the shoulder joint can lead to certain complications. Therefore, a small bioresorbable dowel made of PLA has been developed for arthroscopic refixation of the glenoid labrum along with a reliable fixation of sutures by the implant in clinical situations can be widely guaranteed from the experimental studies.

During selection of material surgeon must have idea about the biodegradable properties of the suture material. The following graph shows the relative reaction rate of different material. The situation where catgut shows high reaction rate compared with other and PDS shows relatively less reaction rate[19].

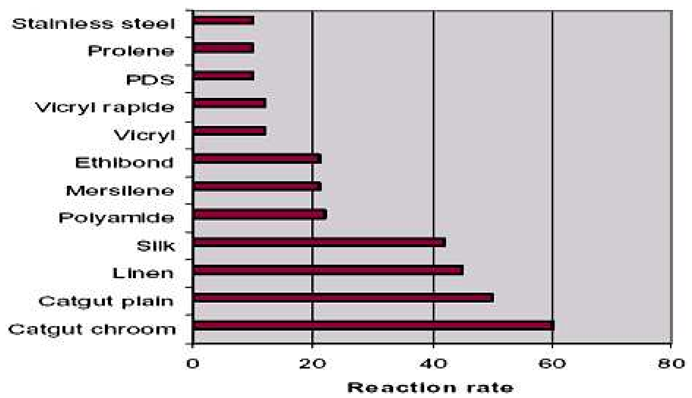

Figure 6: Reaction of Different Suture [20]

Surgical materials should be free from microorganisms. Sterilization is an important process for suture material. The bacteria and spores are destroyed in this process. Sterilization may be achieved by the use of dry heat, moist heat, irradiation (or) chemical agents. Suture materials should be stable during sterilization. After sterilization, thread must retain its functional requirement. Sterilization for coated suture is complicated. In case of coated suture thread must retain its coating along with its functional properties [131]. In dry heat sterilization pathogens are killed at temperature between 160˚C and 190˚C. Moist heat sterilization is performed in autoclave with pressurized steam, 15 min exposure to 120˚C at a pressure of 0.1 bar. In the case of chemical sterilization chlorine dioxide and ethylene dioxide are used.

One requirement for surgical suture materials is stability in sterilization: after sterilization, the thread must retain the maximum useful properties. Selecting the method of sterilization for coated suture thread is complicated, since in addition to the properties of the thread, the properties of the coating must also be preserved. In a study on stability of polycaproamide suture thread with coatings in radiation sterilization, it was observed that the sterilizing dose of 2.5 Mrad recommended by the State Pharmacopeia does not cause destructive processes thread modifiers and has almost no effect on the physicomechanical properties and capillarity of the modified thread. This is the optimum sterilizing dose for suture thread with BF-6 phenol--polyvinylacetal adhesive coatings, SKTN-G dimethylsiloxane rubber; and a composite with addition of an antimicrobial – Decametoxin[21].

CONCLUSIONS

The suturing technique is a complex operation involving a surgeon-specific mix of cognitive and technical components. Notwithstanding the surgeon importance, the choice of the correct suture is fundamental for tissue healing and patient recovery. Usually, this choice takes into account the patient, the type of wound and tissue characteristics and also the anatomic region. An inelastic suture cannot be placed to the area where the tissues or incision subjected to stretch often.

Proper designing of sutures make it possible to sharply reduce the percentage of postoperative complications and correspondingly to reduce the number of repeated operations. Simultaneously, the time for treating surgical patients will be shortened and expenses for treatment will be reduced. The physical characteristics of a suture comprise the diameter and configuration, capillarity and hygroscopicity, friction, tensile strength, knot strength, elasticity and creep. In certain cases fulfilling the suture characteristics is quite difficult for contradictory requirement. For instance, high friction is needed for better knot security, but on the other hand it increases the tissue drag.

Critical requirement of suture materials are knot security, bio compatibility, degradability etc, and depending on application suture needs high elongation, and recovery, fatigue resistance etc. However, strength and diameter of the suture are the only physical Properties available to surgeon. For proper choice of material other specific properties like extensibility, creep, relaxation behavior of material, biodegradability should be known for specified application. Today a lot of biomaterials are available to make sutures, but it is more important to adjudge its biocompatibility.

Research in material science and polymer engineering fields results new developments in surgical suture materials. Research focuses now on the drug delivery surgical suture materials [39].

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