Jan Harloff 4/17/95

MSE 430

Introduction to Polymer Science

Term Paper:

Application of Polymers for Surgical Sutures

Abstract:

Nowadays there is a wide variety of materials that are being used for surgical sutures. Nearly all of these materials are polymers, and most of those are synthetic products. The basic properties of those suture materials have to be compared in order to make the appropriate suture selection for a given type of wound closure, since there is not an ideal suture material that could be used under all circumstances in every operation. The principal division of the materials is into absorbable and nonabsorbable sutures, and each of these groups contains several materials with characteristic advantages and disadvantages.

Table of Contents:

Section 1: Introduction

There are several possibilities to close a wound, for example staples, skin tapes, or laser welding[1,2]. By far the most common technique is the use of sutures. In a clean incised wound, the fundamental purpose of suture placement is to appose the wound edges until healing has progressed sufficiently that normal tensile forces can be withstood[3].

The search for new and improved suture materials started fifty thousand years ago with ancient practitioners of the healing arts. The first documentation of sutures appears in an ancient Egyptian scroll dating back to 3000 B.C. that describes the use of linen to close wounds. Around A.D. 175 Galen, a physician to the Roman gladiators, experimented with catgut. Initially only natural materials were used. These included flax, hemp, horse and human hair, pig bristles, weeds, grasses, and the mouth parts of pincher ants. In the 1800's and early 1900's silk, cotton, and catgut were extensively used. In 1869 Lister introduced the practices of impregnating catgut with chromic acid and sterilizing suture material. In the early part of this century, Halsted promoted the advantages of silk over catgut, and silk soon became the most common suture material in surgical practice[4,5].

In the 1940's synthetic materials such as nylon and dacron, initially developed for other purposes, were used for suturing wounds. In the 1960's Frazza and Schmitt started the search for synthetic absorbable sutures. This led to the development of polyglycolic acid, polyglactin 910, and polydioxanone. With a wide array of suture materials to choose from, it is increasingly important to understand the basic properties of sutures materials in order to make the most appropriate suture selection for wound closure[4,5]. No one suture material is ideal. An ideal suture would be one that could be used under all circumstances in every operation. Such a suture should tie easily, form secure knots, have excellent tensile strength, produce no adverse effects on wound healing, not promote infection, and be easily visible. It should be able to stretch, accommodate wound edema and recoil to its original length with wound contraction. In addition, the ideal suture would be easily sterilized, readily available, and reasonably inexpensive[1,4]. In most applications surgical sutures are not permanently required. The longer a suture mass stays in the human body, the more likely it is to produce undesirable tissue reactions. Thus, an ideal suture should retain enough tensile strength during the wound healing period, and its mass should be absorbed as soon as possible without overloading the metabolic capacity of the surrounding tissues once the suture is no longer functional[8,9]. To date no one suture possesses all these attributes. Therefore compromises must be made in selecting a suture material[1].

Section 2: Properties of Suture Materials

Suture materials are evaluated in three main ways: (1) physical characteristics, (2) handling characteristics, and (3) tissue reaction characteristics. These broad areas of evaluation may influence one another. For instance the physical configuration of the suture material will help determine not only its handling characteristics but also possible tissue reactions to it[1)].

2.1. Physical Characteristics:

Physical characteristics are those that can be measured or visually determined away from the patient. The United States Pharmacopeia (USP) is the official compendium providing definitions and descriptions of the physical characteristics. The USP also serves as a guideline for manufacturing, packaging, sterilizing, and labeling sutures[1)].

Physical configuration of a suture refers to whether it is single-stranded (monofilamentous) or multistranded (multifilamentous). Multifilamentous materials may be braided or twisted. A braided suture usually ties more easily than a monofilamentous suture, but braiding increases the suture's ability to harbor organisms[1,4)].

Capillarity of a suture material refers to its ability to soak up fluid along the strand from the immersed wet end into the dry, nonimmersed portion. This is distinguished from the **fluid absorption ability**, which is the ability of a suture to take up fluid when totally immersed in it. Both capillarity and fluid absorption ability correlate with a suture's tendency to take up and retain bacteria. Braided suture material has greater capillarity than monofilamentous suture material and therefore has an increased ability to take up bacteria, resulting in an increased risk of infection[1,4)].

Diameter (caliber or gauge) of sutures is determined in millimeters and for most sutures is expressed in USP sizes, giving a descending sequence from size 5, 4, 3, 2, 1, 1-0, 2-0 through 11-0. Size 5 has the largest diameter while 11-0 has the smallest. Sutures in sizes of approximately 5-0 to 11-0 are smaller than the human hair. It should be noted that not all USP sizes correspond to the same diameters for all sutures materials. For example 4-0 catgut is larger than 4-0 nylon. This is because the USP size is related to a specific diameter range necessary to produce a certain tensile strength, but the diameter range varies slightly with different suture material categories[1,6)].

The **breaking strength** of the suture is the amount of force necessary to break the suture (breaking load). The **tensile strength** of the suture material is the breaking strength divided by the suture's cross-sectional area. A rank order for the straight pull tensile strength of commonly used suture materials is given in Table 1. Tensile strength may be measured in either dry or wet sutures, Table 1 is based on tensile strength measurements of dry sutures. Wet measurements more closely approximate the application situation of the suture, and can considerably deviate from the dry measurements. When wet, silk for example loses strength, while cotton gains strength. In addition to standard tensile strength measurements, suture may be evaluated by **effective tensile strength**. Effective tensile strength is tensile strength measured with the suture looped and knotted. A knotted suture has about one-third the tensile strength of an unknotted suture, although this varies with the suture material and the type of knot used[1,4,6)]. The strength of a suture material is important for a number of reasons, including the ability of the suture to withstand knotting and the imposed stress when used to bring soft tissues into apposition. Sutures of low strength will tend to break during surgery or, more seriously, postsurgery[24)].

Relative tensile strength	Nonabsorbable suture materials	Absorbable suture materials
high ↑	Steel	
	Polyester	Polyglycolic acid
	Nylon (monofilamentous)	Polyglactin 910
	Nylon (braided)	
	Polypropylene	Polydioxanone
	Silk	
low		Catgut

Table 1: Relative straight pull tensile strength of commonly used suture materials (taken from Ref. 1).

Knot strength is determined by calculating the force necessary to cause a given type of knot to slip, either partially or completely. Knot strength is dependent upon several factors, such as a suture's ability to stretch and its coefficient of friction. The knot is the least reliable part of any suture. The more slippery the suture material, the more likely a given knot will slip[1,6)].

Elasticity is a suture's inherent ability to regain its original form and length after having been stretched. A suture material with excellent elastic properties is for example polypropylene. This becomes important when there is swelling of a wound. A suture with a high degree of elasticity will be stretched and will not tend to cut into the swollen tissue. After wound swelling subsides it regains its original form and thus still apposes the wound edges[1,4).]

Memory is related to elasticity and refers to a suture's capacity to return to its former shape upon deformation such as tying. Thus knot security will be less in sutures with high memory. A suture material with a high memory, such as nylon, tends to untie as it tries to regain its former shape, whereas a suture material with a low memory, such as silk, rarely becomes untied. A greater number of knots have to be tied more securely in a suture material with high memory. Memory will also influence the handling characteristics of a suture material. Since a suture material with a high degree of memory is stiff, it handles less well[1,4)].

Sutures that are stiff or inelastic and of great tensile strength have a greater tendency to **cut through tissue** than others. Sutures may cut through tissue either at the time of implantation because of excessive tension during placement or after implantation because of wound swelling or sudden mechanical forces (such as coughing) acting on the wound. The tied suture loops may completely transect the tissue to the wound edge; this event is referred to as cutting out. Cutting through tissue is affected by suture size. The smaller the suture diameter the easier it is to cut through tissue. This is because a suture with a small diameter generates more force per unit area than a suture with a larger diameter[1)].

2.2. Handling Characteristics:

Handling characteristics of a suture material are related to its **pliability** as well as its **coefficient of friction**. Pliability is a subjective term that refers to how easily one can bend the suture. The most pliable sutures are those that are braided, such as silk; monofilamentous sutures are more difficult to handle. A suture material's coefficient of friction determines how easily the suture will slip through tissue and tie. In other words, its coefficient of friction is a measure of the slipperiness of a material. Suture materials with a high coefficient of friction tend to drag through tissue. These sutures are also difficult to tie because knots do not set easily. Some suture materials are especially coated to increase their slipperiness. A suture's coefficient of friction will also affect the force needed to remove it after the wound is sufficiently healed. Polypropylene for instance has a very low coefficient of friction and slides easily even after one or two weeks in tissue, making it especially ideal for use as a running intradermal suture[1,6)].

Knot tying and **knot slippage** are also affected by the coefficient of friction. The more slippery a suture material, the easier it is to slip a knot into place, i.e. set the knot. However, such a knot will be less secure because it may more easily slip undone. In general, braided, uncoated materials such as silk or polyester have good **knot security**, whereas monofilamentous materials have poor knot security[1,6)].

Sutures are available in **dyed** and **colorless** material. The dyed material is easier visible during surgery[1,6)].

2.3. Tissue Reaction Characteristic:

All suture material is a foreign substance to the body and will evoke a tissue reaction. As a general rule, the more suture material is implanted, the greater the tissue reaction. Therefore, as little suture material as possible should be used to close a wound. The initial tissue reaction to the suture is in part related to the injury inflicted by passage of the suture and needle. In addition, tissue reaction to the suture material itself occurs. This reaction of living tissue to injury or foreign bodies is called **inflammation**, and it usually peaks between 2 to 7 days after implantation. A prolonged inflammation due to sutures leads to delayed wound healing, infection, and possible reopening of the wound. Inflammatory reaction around a suture may lead to softening of sutured tissue. Cutting out of sutures will be more likely within such weakened tissues[1,7)].

The normal sequence of tissue reaction to suture material occurs in three stages. In the first 4 days, a cell infiltrate composed of special types of white blood cells (polymorphonuclear leukocytes, lymphocytes, and monocytes) occurs. During a second stage from the fourth to the seventh days, macrophages and fibroblasts appear. After the seventh day, fibrous tissue with chronic inflammation is seen. With nonabsorbable sutures that persist in the body, inflammatory reaction is minimal, and a thin fibrous capsule forms, usually by 28 days. With absorbable sutures, the inflammatory reaction is more marked and persists until the suture is either absorbed or extruded. In general, a greater tissue reaction occurs when multifilamentous rather than monofilamentous suture materials are used. A rank order for the relative **tissue reactivity** to commonly used suture materials is given in Table 2[1)].

Relative tissue reactivity	Nonabsorbable suture materials	Absorbable suture materials
high ↑		Catgut
	Silk, cotton	
	Coated polyester	Polyglactin 910
	Uncoated polyester	Polyglycolic acid
	Nylon	
low	Polypropylene	

Table 2: Relative tissue reactivity of commonly used suture materials (taken from Ref. 1).

Soon after placement of a suture through the cutaneous surface, a downgrowth of epidermis extends along the suture path and forms a perisutural cuff. This process is called **tissue ingrowth**, and it accounts for 70 to 85% of the work of withdrawal at the time of suture removal. In addition, the nonepidermal tissue around the suture may grow into the suture. Sutures with the greatest ingrowth and cuff formation will have the most resistance to removal. Silk in particular tends to be very difficult to withdraw after several days because of this tissue interaction with the braids of the material. In contrast, polypropylene requires little work of withdrawal even after weeks in tissue because such tissue interactions are minimal[1].

Some sutures are more likely to promote **wound infection** if significant bacterial contamination occurs at the time of surgery or soon afterwards. The physical configuration of suture material has been demonstrated to potentiate infection. In general, multifilamentous suture materials (whether braided or twisted) have been shown to enhance infection. Those that are monofilamentous are less likely to enhance infection. Apparently bacteria are drawn into the interstices of multifilamentous suture material. In the interstices, bacteria are relatively protected from the action of leukocytes and can induce and sustain infection by diffusion into surrounding tissue. The knots on a suture may also offer a haven for bacteria; therefore, the number of throws should be minimized on buried sutures. It is important to emphasize that any suture, regardless of composition or configuration, will enhance infection to some extent[1].

Allergy to suture material, particularly catgut, has been reported. Circulating antibodies to catgut have been found in patients subsequent to surgery in which catgut sutures were used. Chromic salts added to catgut to delay degradation may also provoke an allergic reaction in those who are chromate-sensitive[1].

2.4. Preparation of Sutures:

Modern surgical sutures are packaged with minimal handling and sterilized with either ethylene oxide or ionizing radiation, often cobalt 60. Each suture is placed in an inner foil suture packet that in turn is placed in an exterior half plastic, half foil packet, called the overwrap, to help ensure sterility[1,17].

Section 3: Degradation of Suture Material in the Human Body

3.1. Classification of Sutures as Absorbable or Nonabsorbable:

Absorption occurs with almost all permanently buried sutures except those made of stainless steel, polyester, or polypropylene. Therefore, division of sutures into absorbable and nonabsorbable is somewhat arbitrary. Absorbable sutures are usually defined as those that lose most of their tensile strength within 60 days after implantation. Polyglactin 910, polyglycolic acid, catgut, and polydioxanone are all classified as absorbable sutures by this definition. Silk and nylon, which are classified as nonabsorbable are actually also absorbed, but more slowly over many months. Therefore, these latter sutures should more properly be categorized as slowly absorbable sutures[1,4,5,6)].

3.2. Absorption of Biological Suture Materials:

Biological suture materials (catgut and silk) are absorbed by cellular enzymes. This leads to a very unpredictable rate of absorption, especially for the very fast absorbing catgut. The absorption strongly depends on the location in the body and the healing process, since these two factors influence the cell population that is present around the suture[1,4,5,10,11)].

3.3. Absorption of Synthetic Suture Materials:

The synthetic suture materials are absorbed by hydrolysis due to water[1,4,5)]. For this hydrolysable linkages have to be present in the backbone of the polymer, in the case of suture materials these are the ester groups[12,13)]. Water molecules attack the ester linkages and break up the polymer backbone at that place to yield two chain ends, one carboxylic acid end, and one alcohol end[14)]:

$$R'-\overset{\overset{O}{\|}}{C}-O-R'' + H_2O \rightarrow R'-\overset{\overset{O}{\|}}{C}-OH + R''-OH$$

Fig. 1: Hydrolysis of an ester linkage. R’ and R” designate the further backbone of the polymer chain.

The amount of water absorption of the polymer is also crucial for the rate of the hydrolysis[13)]. The absorption rate of synthetic sutures is reproducible and, in contrast to biological sutures, only slightly influenced by such wound conditions as inflammation, infection, or body fluids[18,19).]

3.4. Phagocytosis:

In both cases, as well for biological as synthetic suture materials, the polymer chains are first being broken down into smaller fragments. The fragments are then phagocytized by the enzymatic action of special types of mononuclear and multinuclear white blood cells[15)]. In the process of phagocytosis the white blood cell first ingests the foreign body, e.g. a bacterium or a fragment of a suture. The lysosome granules inside of the cell then pour enzymes onto the foreign body, which are capable of further degrading it into even smaller pieces (see Fig. 2)[7)].

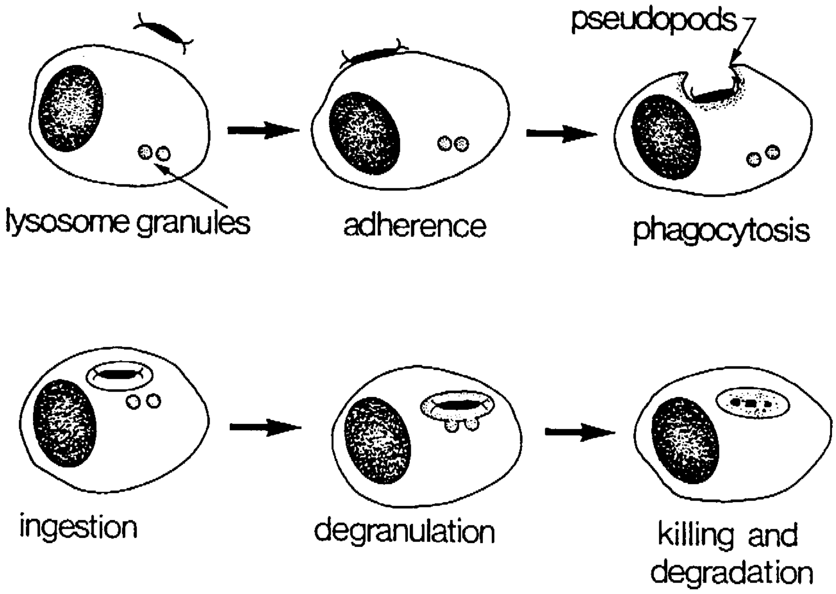


Fig. 2: Schematic illustration of phagocytosis (taken from Ref. 7).

The polymer is thus degraded to non-toxic, low molecular weight residues capable of being eliminated from the body by normal metabolic pathways[16)]. Urine and expired CO_2 seem to be the major excretary routes of these metabolites[15)].

3.5. Strength Loss and Total Mass Absorption:

It has been stated earlier that an ideal suture material should retain enough tensile strength as long as the wound still heals, but its mass should be absorbed as fast as possible without overloading the metabolic capacity of the surrounding tissues once the suture is no longer functional. However, this feature is being considerably obstructed by an inherent relationship between fiber structure and degradation mechanism. The hydrolytic degradation of synthetic absorbable sutures is partially affected by the ratio of crystalline to amorphous contents. The degradation will start in the amorphous regions, and then propagate further to the crystalline regions. Therefore, the total mass loss inherently requires much longer time than the total tensile strength loss for all synthetic absorbable sutures (see Table 3)[9)].

Suture material	Days until total strength loss	Days until total mass loss
Polyglycolic acid	28	50-140
Polyglactin 910	28	90
Polydioxanone	63	180-240
Polyglyconate	56	210

Table 3: Strength and mass loss of four commonly used suture materials (taken from Ref. 9).

Section 4: Absorbable Sutures

4.1. Catgut:

Although catgut is rarely used today in surgery with the wide availability of synthetic absorbable sutures, it is worthwhile discussing because it represents a standard against which modern suture materials are frequently compared. The origin of the name catgut, which is also called surgical gut, is obscure. Gut sutures in general consist of processed strands of highly purified collagen from the small intestines of sheep or cattle[1,4,5].

Collagen is a fibrous protein. The arrangement of amino acids in the collagen molecule is shown schematically in Fig. 3. Every third residue is glycine. Proline and hydroxyproline follow each other relatively frequently, and the gly-pro-hyp sequence makes up about 10% of the molecule. This triple helical structure generates a symmetrical pattern of three left-handed helical chains that are, in turn, slightly displaced to the right, superimposing an additional “supercoil”[20].

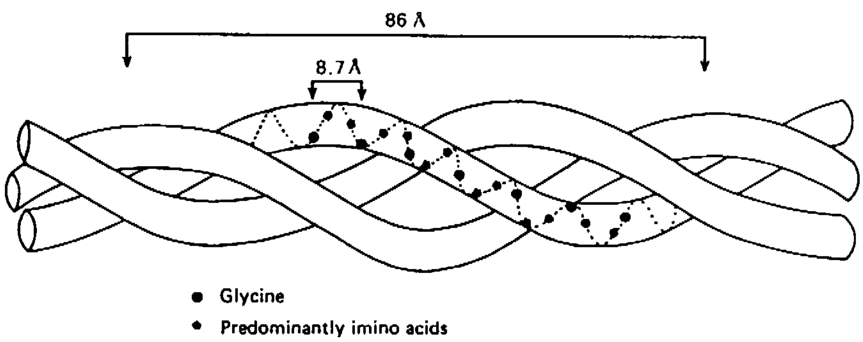


Fig. 3: Schematic drawing showing the collagen triple helix (taken from Ref. 20).

Catgut may be treated with chromium salts, which react with the collagen in a process similar to the tanning of leather. This produces a tougher, harder substance known as chromic catgut that is stronger and more resistant to tissue degradation than plain catgut. Both plain and chromic gut are difficult to manipulate and tie and the knot-holding properties are poor in the presence of body fluids. Knots tend to become hard and can traumatize adjacent tissue. The rate of absorption is unpredictable since body enzymes and macrophages can break them down. Plain gut does not remain intact for more than 5 to 7 days, but chromic gut can last approximately twice as long. Of the commonly used sutures, surgical gut causes the highest degree of tissue reaction, which often impedes healing[1,4,5].

4.2. Polyglycolic Acid:

In 1971 Dexon was introduced as a synthetic homopolymer processed from glycolic acid to give polyglycolic acid[14,15]:

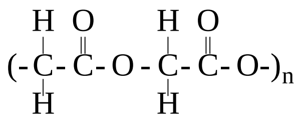


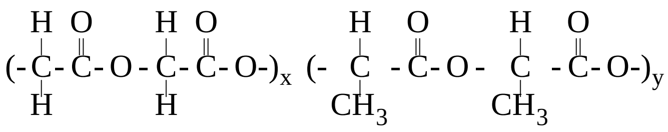
Fig. 4: Monomer of polyglycolic acid.

The polymer is extruded into thin filaments, heat stretched, and braided into sutures. This suture is biologically and physically superior to gut, and was a major advance in absorbable suture materials. Absorption occurs by slow hydrolysis in the presence of tissue fluids and the low pH of an infection minimally increases the rate of suture absorption. By 15 days Dexon has lost more than 80% of its original strength. By 28 days, this material retains only 5% of its original tensile strength, and it is completely dissolved by 90 to 120 days. Dexon causes much less tissue reaction and inflammation than natural collagen; however, bacteria can pass through its multifilament structure into a wound more easily than through monofilament sutures, if used for cutaneous surgery, i.e. to suture the outer skin. Absorbing polyglycolic acid sutures inhibit bacterial growth causing less tissue reaction[1,4,5].

In 1977 Dexon S became available. Its finer filaments and tighter, smoother braid provided optimal handling characteristics, similar to silk. A third generation of polyglycolic acid sutures is Dexon Plus, which contains a surface coating of Polaxamer 188. The coating is used to lubricate the surface of the suture to improve its handling characteristics. The non-toxic Polaxamer 188 is very soluble in aqueous solutions and is therefore rapidly absorbed in tissue resulting in an uncoated suture that has increased knot security as compared with that of the coated surface[5,21].

4.3. Polyglactin 910:

In 1974 Vicryl was introduced as a synthetic copolymer of glycolic and lactic acid, which are present in a ratio of 90 to 10, giving polyglactin 910[14,22]:



(a) (b)

Fig. 5: Monomers constituting the copolymer polyglactin 910: (a) is the polyglycolic acid monomer and (b) is the polylactic acid monomer. The ratio of x to y is 90 to 10.

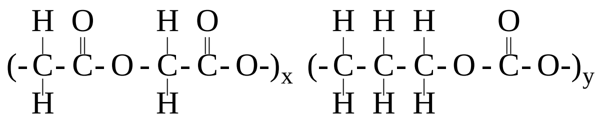
The suture is braided to enhance its surgical handling quality. The loss in strength of Vicryl is very similar to that of Dexon, the material retains only 8% of its original tensile strength by 28 days. However, complete absorption time of Vicryl suture is less than that of Dexon (60 to 90 days) because the bulky lactide group holds the polymer chains apart, which creates a rapid water hydrolysis. Coated Vicryl is treated with polyglactin 370 and calcium stearate for lubrication to improve its passage through tissue, knot placement, and tie down. The tissue reaction, handling qualities, tensile strength, and knot security of coated Vicryl are almost identical to those of Dexon Plus[1,4,5)].

4.4. Polydioxanone:

A relatively new absorbable suture is PDS. It is a homopolymer made from paradioxanone to give polydioxanone, a polyester. Unlike Vicryl or Dexon, PDS is manufactured as a monofilamentous suture. PDS takes more time to be completely absorbed than either Vicryl or Dexon, it takes approximately 180 days. It also retains significant breaking strength after 28 days, 58% of the original value. Tissue reaction to the suture is minimal. Since it is a monofilament its affinity for microorganisms is less than is the case for Vicryl or Dexon. PDS is stiffer than the braided synthetics and more difficult to handle[1,4,5)].

4.5. Polyglyconate:

Maxon is the newest synthetic absorbable suture on the market. It is a copolymer consisting of glycolic acid and trimethylene carbonate combined in a 2 to 1 ratio to give polyglyconate[15,22)]:



(a) (b)

Fig. 6: Monomers constituting the copolymer polyglyconate: (a) is the polyglycolic acid monomer and (b) is the trimethylene carbonate monomer. The ratio of x to y is 2 to 1.

It is a monofilament that was designed to combine the excellent tensile-strength retention properties of PDS with improved handling characteristics. Maxon has an average strength retention of 59% after 28 days, complete absorption occurs between 180 and 210 days, with minimal tissue reaction. Moreover, Maxon is much more supple and easier to handle than PDS, with 60% less rigidity[4,22)].

Section 5: Nonabsorbable Sutures

5.1. Silk:

Surgical silk is made from the protein-rich thread spun by silk-worm larvae when making cocoons. The raw silk is degummed, scoured and bleached, braided, stretched, and dyed. The silk strands are treated with silicone or waxes to improve handling characteristics and to reduce capillary action. Although silk is classed by the USP as a nonabsorbable suture the material loses most of its tensile strength in 90 to 120 days, and is usually completely absorbed after 2 years. Thus it is rather a slowly absorbed suture. Silk is not as strong as the synthetic sutures, but it is exceptionally workable, soft, has little memory, and is easy to knot. Silk and its fragments elicit an inflammatory response. The braided nature of silk gives it a tendency to draw fluid into the tissue if used cutaneous. These qualities can retard healing. Furthermore silk should not be used in areas of infection or contamination. Nevertheless silk has been a favorite suture material for years, primarily because of its exceptional handling properties and ease of knot tying. It has therefore set the standard against which other sutures are judged[1,4,5)].

5.2. Surgical Cotton:

Surgical cotton, a natural, cellulose fiber, comes from the long, silky material covering the seeds of the Egyptian cotton plant. Cotton remains encapsulated in body tissues, where it loses 50% of its strength in 6 to 9 months. It handles well but is the weakest suture material described in this paper. The permeability of this multifilament suture to bacteria is similar to silk and is the major factor affecting tissue reaction. The fibers also have a tendency to separate[6)].

5.3. Nylon:

Nylon is a synthetic polyamide polymer[23)]:

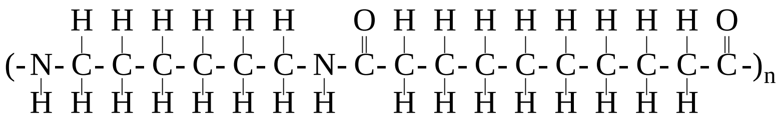


Fig. 7: Monomer of nylon.

It is classed by the USP as a nonabsorbable suture, yet it loses strength and is absorbed by hydrolysis at a rate of 15% to 20% per year. It is therefore really rather a slowly absorbed suture. The polyamide material is either extruded into monofilamentous strands (Ethilon and Dermalon) or it is twisted into a yarn, braided into multifilaments, and treated with silicone (Nurolon and Surgilon). Little tissue reaction or fragmentation occurs from this material, and it does not support bacterial growth. The monofilament strand is smooth with no capillary action. When monofilament nylon is moistened, it is more pliable and handles like the multifilaments, but it has a rather high memory and therefore a decreased knot security. The multifilament nylon feels and handles similar to silk, and at the time time has the inertness and strength of a synthetic material[1,4,5)].

5.4. Polypropylene:

Surgilene and Prolene are relatively new synthetic monofilament sutures made from the linear hydrocarbon polymer polypropylene[23)]:

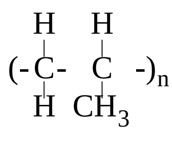


Fig. 8: Monomer of polypropylene.

This suture maintains its above-average strength indefinitely, it remains encapsulated in body tissues. Polypropylene has extremely low tissue reactivity. Because of its lack of adherence to tissue, it is and excellent “pull-out” suture. This suture is smooth and resists flexural fatigue. The material is elastic, allowing elongation under tension and recovering its original form as the tension decreases[1,4,6)].

5.5. Polyethylene:

Dermalene is a synthetic monofilament suture made from polyethylene[23]:

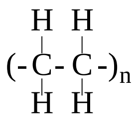


Fig. 9: Monomer of polyethylene.

It is similar to polypropylene but has less knot security and tensile strength in tissue and can eventually break[6].

5.6. Polyester:

Polyester fibers are polymers formed, like nylon, by condensation polymerization[23]:

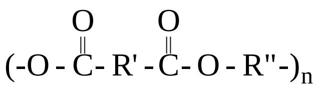


Fig. 10: Monomer of polyester. R' and R" designate a variable number of CH_2 groups in the chain.

The polyester sutures handle well because they are multifilamentous and braided. These sutures have extremely high tensile strength, second only to that of metal suture. Polyester sutures are either uncoated or coated. One disadvantage of the uncoated polyester sutures (Mersilene and Dacron) is that they have a relatively rough surface that produces drag when brought through tissues and when knots are set. Therefore lubricant coatings have been developed for polyester sutures to produce a smooth surface that is less grabby, for example polybutilate (Ethibond). Polyester sutures, like polypropylene sutures, will maintain their tensile strength indefinitely and will not resorb[1,4].

5.7. Polybutester:

The newest of the nonabsorbable suture materials is a special type of polyester called polybutester (Novafil). It is a copolymer composed of polyglycol terephthate and polybutylene terephthate. Novafil is a monofilamentous suture that possesses many of the advantages of both polypropylene and polyester. For example, it is slippery and elastic like polypropylene, but ties easily like polyester. Being monofilamentous, Novafil induces little inflammatory reaction[1,4,6].

5.8. Stainless steel:

Stainless steel is the only nonpolymeric material used for medical sutures and is included here for completeness. It is relatively inert, has extremely high tensile strength, and provides excellent knot security. Stainless steel is produced either as monofilamentous or multifilamentous suture (twisted or braided). The drawbacks in its usage are that it is difficult to handle, and kinks can occur[1)].

Section 6: Conclusion

Within the past 25 years a variety of synthetic products have entered the market of surgical sutures, competing with the traditional materials. This gives a wide array of suture materials to choose from, and the basic properties of sutures materials have to be compared in order to make the appropriate suture selection for a given type of wound closure. The characteristics of the suture materials are compared to each other in Appendix 1 and 2. To date there is not an ideal suture material that could be used under all circumstances in every operation. Therefore compromises must be made in selecting a suture material. A factor that should not be forgotten is the price of a suture. Usually surgeons and physicians tend to use the least expensive suture that is appropriate for the given situation, especially for routine operations[1,4,5)].

Usually absorbable sutures do not have a particular advantage if used for cutaneous surgery. In most of these cases the suture is later on removed clinically. In some cases, when the later extramedical or paramedical care is unwanted fast absorption suture material can be used. The suture material weakens and comes loose by itself in 3 to 4 days in the case of fast absorption chromic gut1) or in 8 to 10 days in the case of fast absorption polyglactic acid[25)].

In some cases of surgery inside of the body absorbable sutures may have a distinct advantage over nonabsorbable sutures. For example in the case of microsurgical reconstruction after an injury of nerves the results have been unsatisfactory due to the fact that the used nonabsorbable sutures inhibit the sprouting of axis cylinders. The use of absorbable sutures could lead to progress in this field[26)].

A second very important field for absorbable sutures is the surgery that includes blood vessels of children. Since children still grow the use of nonabsorbable sutures can lead to problems at the suture sites that do not dilate according to the growth. The use of absorbable sutures significantly improves the results[27,28,29)].

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Appendix 1:

Comparison of Absorbable Sutures (Data taken from References 1, 4, 5, and 6)

Suture	Trade Name	Raw Material	Configu-ration	Absorption	Strength	Tissue Reaction	Knot Security	Ease of Handling	Uses	Cost
Plain Catgut		Small intestines of sheep or cattle	Twisted	Body enzymes and macrophages 70 d	+ 4 to 10 d	++++	Least +	+	Rapidly healing mucosa, avoids suture removal	in-expensive
Chromic Catgut		As above, treated with chromic salts	Twisted	As above 90 d	+ 10 to 14 d	+++	+	+	As above, slower absorption	in-expensive
Poly-glycolic Acid	Dexon	Homopolymer of glycolic acid	Braided	Slow water hydrolysis 60 to 120 d	+++ 14 to 21 d	++	+++	+++	Subepithelial sutures, mucosal surfaces, vessel ligation	medium
	Dexon S	As above, tighter braids						++++		
	Dexon Plus	As above, coated with Polaxamer 188						++++		
Coated Poly-glactin 910	Coated Vicryl	Copolymer of lactide and glycolide coated with Polyglactin 370 and calcium stearate	Braided	Slow water hydrolysis 60 to 90 d	+++ 20 to 30 d	++	+++	++++	Subepithelial sutures, mucosal surfaces, vessel ligation	medium
Poly-dioxanone	PDS	Polyester polymer	Mono-filament	Slow water hydrolysis 210 d	+++ 40 to 60 d	+	++	++	Absorbable suture with extended support	medium
Poly-glyconate	Maxon	Copolymer of polyglycolic acid and trimethylene carbonate	Mono-filament	Slow water hydrolysis 180 to 210 d	+++ 40 to 60 d	+	++	+++	New product, limited experience	expensive

Appendix 2:

Comparison of Nonabsorbable Sutures (Data taken from References 1, 4, 5, and 6)

Suture	Trade Name	Raw Material	Configu-ration	Absorption	Strength	Tissue Reaction	Knot Security	Ease of Handling	Uses	Cost
Silk		Natural protein fiber of silkworm treated with silicone or wax	Braided	Local inflamma-tory response 2 years	++ 90 to 120 d	++++	+	++++	Mucosal surfaces	medium
Surgical Cotton		Natural cellulose fiber of the seeds of Egyptian cotton plant	Twisted	Not absorbed	Least + (270 d)	++	+	++++	Mucosal surfaces	medium
Nylon	Ethilon, Dermalon	Polyamide polymer	Mono-filament	Very slow water hydrolysis 15 to 20 % loss per year	+++ 15 to 20 % loss per year	Low +	++	++	Skin closure	medium
	Nurolon, Dermalon	As above, braided and silicon treated	Braided			+	+++	++++	Skin closure, mucosal surfaces	
Poly-propylene	Prolene, Surgilene	Polymer of propylene	Mono-filament	Not absorbed	+++ indefinite	Low +	+++	+++	Skin closure, vascular surgery	expensive
Poly-ethylene	Dermalene	Polymer of ethylene	Mono-filament	Not absorbed	++ weakens and breaks	+	++	++	Skin closure	medium
Polyester	Dacron, Mersilene	Polyester polymer	Braided	Not absorbed	+++ indefinite	+	++	+++	Skin closure	expensive
	Ethibond	As above, coated with polybutilate					+			
Poly-butester	Novafil	Copolymer of polyglycol terephthate and polybutylene terephthate	Mono-filament	Not absorbed	+++ indefinite	+	+	+++	Elastic suture when tissue swells	mode-rately expensive
Stainless steel	Ethicon	Stainless steel	Mono-filament, twisted, or braided	Not absorbed	++++	+	+++	+	Skin closure	expensive