Classic suturing materials overview

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ABSTRACT – REZUMAT

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Sutures are used in surgery to approximate wounds for the healing purpose after injury or elective interventions or for hemostasis ligation. During the millennial evolution of sutures, natural fibres have been almost completely replaced by synthetic materials. Experience from the last years has shown that silk and catgut chromium threads are natural fibres still used in surgical theatres, but they might have registered a decrease in preferences due to inflammatory response. Despite the continuous improvement in this field, there is not a perfect universal suture affordable and right for every patient. There are rare, but possible complications such as local irritation, foreign body response, granulomas or fistulas. Various studies conducted over time, some presented in this paper, have shown that actual surgical threads are safe and taking into account the indications, we should obtain maximum results with minimum adverse reactions. An ideal combination of delayed absorption and elasticity allows a tension-free closure and supports the healing process of most tissues and makes the surgical thread a preferred option for surgeons. The purpose of this article is to overview the suturing materials and to optimise surgical techniques by increasing the benefits of each suture material with minimal adverse reactions.

***Keywords**: natural fibres, synthetic sutures, absorption, monofilament, multifilament, tissular response*

Prezentare generală a materialelor de sutură clasice

Suturile sunt folosite în chirurgie pentru aproximarea rănilor în scopul vindecării după traumatisme sau intervenții chirurgicale elective sau pentru ligaturi hemostazice. Pe parcursul evoluției de-a lungul a mii de ani a suturilor, fibrele naturale au fost aproape complet înlocuite cu materiale sintetice. Experiența din ultimii ani a arătat că firele de mătase și crom catgut sunt fibre naturale încă folosite în blocurile operatorii, dar care par să înregistreze o scădere a preferințelor datorită răspunsului inflamator.
În ciuda îmbunătățirii continue în acest domeniu, nu există o sutură universală perfectă, accesibilă și potrivită pentru fiecare pacient. Există complicații rare, dar posibile, cum ar fi iritația locală, răspunsul la corp străin, granuloame sau fistule. Diverse studii efectuate de-a lungul timpului, unele prezentate în această lucrare, au arătat că firele chirurgicale efective sunt sigure și ținând cont de indicații, ar trebui să obținem rezultate maxime cu reacții adverse minime. O combinație ideală de absorbție întârziată și elasticitate permite o închidere fără tensiune și susține procesul de vindecare a majorității țesuturilor și transformă firul chirurgical într-o opțiune preferată pentru chirurgi. Scopul acestui articol este de a prezenta materialele de sutură și de a optimiza tehnicile chirurgicale prin sporirea beneficiilor fiecărui material de sutură cu reacții adverse minime.

***Cuvinte-cheie:** fibre naturale, suturi sintetice, absorbție, monofilament, multifilament, răspuns tisular*

INTRODUCTION

The first texts, that tell of the use of suture threads, were found in ancient China and Egypt and date back to 2000 B.C. the first dated needles are from 20.000 B.C. and were made of bone [1–6]. A Sanskrit text, called Charaka Samhita, described the use of ants to approximate the wound margins. These are the army ants (known also as driver ants), more precisely the “soldiers” were used because they possess large mandibles. After the ant bites its body is then twisted off leaving the head in place [1, 2].

Sushruta was an ancient Indian surgeon known today as the “Father of Surgery” described around 600 B.C., in Sushruta Samhita, a variety of operations in which he used horse hair, cotton, flax, hemp, tree fibres and animal ligaments as threads and different types of round or triangular and curved or straight needles [1, 2, 4].

The Edwin Smith papyrus that dates back to 1600 B.C. tells of linen strips coated with honey and flour their properties are similar to modern-day closure strips [6].

In the year 175, Galen describes the use of “catgut”. The thread was at first obtained from the submucosal tunic of sheep or goats’ intestines or the serous tunic of bovine intestines [1, 5].

In the 16th century Hieronimus Ab Aquapendante from Paduia introduced the use of gold threads and in the year 1857, J. M. Sims described the use of silver threads [1].

Most of the suture materials described did not withstand the test of time. After Joseph Lister introduced sterilization methods for the catgut threads, they became the main absorbable suture material in use in the 19th century and chromic catgut is still in use to this day [1, 5, 6].
Another type of thread that is still in use today is silk. It's used for surgical wound closure and was first described around 1050. E. Th. Kocher is responsible for its widespread usage, especially in Europe. Because of its qualities, softness, elasticity and durability, it was considered the "gold standard" [1, 6].
By the end of the First World War, George Merson manufactured eyeless needles sutures where one end of the suture material is attached to the base of the needle. In 1960, the introduction of sterilization by irradiation meant that the eyeless needle and the thread could be sealed in their package and then sterilized, reducing the risk of contaminating the needle or the thread [6].
This article aims to overview the suturing materials and their particularities to have a better understanding of how and when should each one be used, thus optimizing surgical techniques by maximizing the benefits of each suture material and minimizing the postoperatory complications.

GENERAL PRESENTATION AND CLASSIFICATION OF SUTURING MATERIALS

Surgical threads

The main factors used to classify actual surgical threads types are:
- Absorbable vs. non-absorbable
- Synthetic vs. natural
- Monofilament vs. multifilament.

A relevant scheme of this classification is presented in figure 1.
Sutures are considered absorbable if they lose most of their tensile strength over variable periods ranging from a few weeks to several months.
Absorbable threads are classified as natural and synthetic sutures. Natural fibres are derived from purified animal tissues and are sometimes made of the purified serosa of bovine intestines. Silk and catgut (made from sheep submucosa) are all types of natural sutures. Natural threads are different from synthetic sutures in that they degrade by proteolysis, while synthetic sutures degrade by hydrolysis. Hydrolysis causes less of an inflammatory reaction than proteolysis, which is why natural sutures can be known for causing more inflammation at the suture site. Usually, sutures have a smooth surface but there are newer sutures manufactured with barbs. These barbs do not require knots for security [7].
Other suture category is monofilament and multifilament. Monofilament sutures are single fibers with less capillarity and less surface area than a multifilament. Monofilament sutures demand more handling care, and more knots to provide security, but tend to fracture less than multifilament sutures, they pass

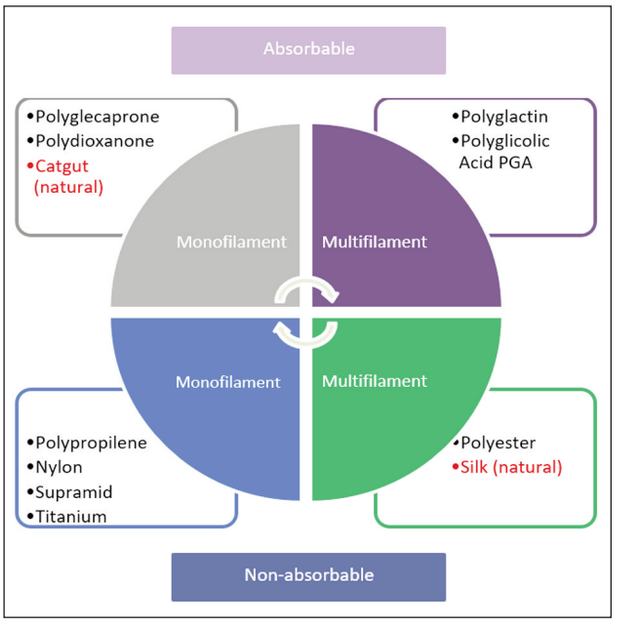

Fig. 1. Surgical threads general classification

through tissues more easily and cause a less inflammatory reaction than their multifilament counterparts. Multifilament sutures are more malleable; they tie knots more securely and they are easier to handle by the surgeon. However, multifilament sutures also cause more friction through tissue and have increased capillarity and surface area, increasing their predilection to inflammation and infection. Multifilament sutures can be coated to make them slide through tissues more easily and have properties more similar to a monofilament suture. They can also be coated with antibiotics to make them more infection-resistant. However, they are more expensive than traditional sutures [8]. Table 1 presents mainly surgical threads with an individualized period of absorption, indications and broken-down mechanism.
From the surgical thread size point of view (transversal section), there is used the United States Pharmacopeia (USP) scale from 11-0 (the thinnest) to 5 (the thickest able to tow a car). In the USP scale, 1-0 is not included. Depending on these dimensions the wires are adapted to various tissues as presented in table 2.
For high infection risk, one should use monofilament absorbable sutures. For suturing the skin, the smallest suture for the area is preferable.
Regarding absorbable sutures, if more strength is required, slowly absorbable sutures are the best choice. For fascia and tendons low absorbable or non-absorbable sutures should be used while the stomach bladder or colon requires absorbable material [8, 9].

Surgical needles

The needle is composed of three main segments – the base, body and point. The base could include the needle eye where the thread attaches manually to the needle (this type is mentioned for historical reasons, not in routine use), or a point where the suture

Table 1

ABSORPTION TIME, INDICATIONS AND BROKEN-DOWN MECHANISM OF SUTURES			
Material	**Total absorption time**	**Indication**	**Broken-down mechanism**
Polyglactin	50–70 days	Soft tissue closing and ligation	Hydrolysis
Polyglycolic acid	60–90 days	Soft tissue closing and ligation	Hydrolysis
Polyglycolic acid – rapid absorption	Approximately 42 days	Superficial tissue and mucosa only	Hydrolysis
Poliglecaprone	90–110 days	Superficial tissue and ligation	Hydrolysis
Polydioxanone	180-210	General soft tissue closing	Hydrolysis
Plain catgut	63 days	General soft tissue closing and ligation	Phagocytosis
Catgut chromium	90 days	General soft tissue closing and ligation	Phagocytosis

Table 2

UNITED STATES PHARMACOPEIA (USP) SCALE FOR THREADS AND USING DEPENDING ON TISSUE		
USP scale	**Actual size (mm)**	**Tissue**
11-0 & 10-0	0.01 & 0.02	Ophthalmology, microsurgical repair
9-0 & 8-0	0.03 & 0.04	Ophthalmology, microsurgical repair
7-0 & 6-0	0.05 & 0.07	Small vessel repair/grafting for hand and face
5-0 & 4-0	0.1 & 0.15	Larger vessel repair, hand and face skin, tendon repair
3-0 & 2-0	0.2 & 0.3	Thick skin, fascia, muscle, tendon repair
0 & 1	0.35 & 0.4	Fascia, drains stitches
2 & >2	>0.5	Large tendon repairs, thick fascia closure, orthopaedic surgery

thread gets crimped onto the needle. The body is the most considerable segment of the needle and connects the base to the point and determines the shape of the needle. The needle can be straight or mainly curved in surgery. The circle of a curved needle comes in different lengths, but most curves are 1/4, 1/2, 3/8, or 1/3 of a circle. The curve is crucial in helping the surgeon know where the tip of the needle is at all times. Most skin closure sutures are curved, and usually 3/8 of a circle [7, 9].

There are different types of needles categorized by the appearance of the needle tip, mainly cutting or taper needles. Cutting needles have a tip with three sharp edges, with a regular cutting needle having the cutting surface inside the needle and a reverse cutting needle having it on the outside of the needle. Reverse-cutting needles are commonly used for sewing skin.

Taper needles are rounded and can be either sharp or blunt. They work by piercing the tissue without cutting it, and spreading the tissue as it passes through it. These are used for soft tissues. A useful needlepoint section classification is pictured in figure 2.

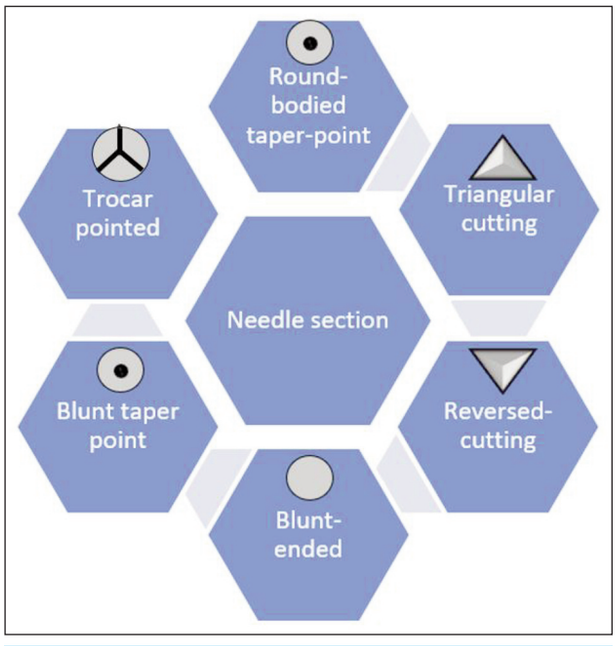

Fig. 2. Needlepoint section classification

INDICATIONS AND COMPLICATIONS OF SURGICAL THREADS

Absorbable materials

Monofilament

- **Polydioxanone** (PDS) – is generally used for soft tissue closing in General Surgery, Gastrointestinal Surgery, Orthopedics, Gynecology, Plastic surgery, Urology and Ophthalmic Surgery. This is not suitable for cardiovascular tissues, neurological tissues and microsurgery.
- **Plain surgical gut** – is generally used for soft tissue closing and ligation in General Surgery, Gastrointestinal surgery, Gynecology, Urology and Ophthalmic surgery. This is not suitable for Cardiovascular surgery and Neurosurgery. As an

absorbable material with quick absorption, it is contraindicated when extended wound support is needed with special precautions in patients with delayed wound healing and infected wounds.

- **Poliglecaprone** – is generally used for soft tissue closing and ligation in General Surgery, Gastric Surgery, Gynecology, Plastic Surgery and Urology. This material it is contraindicated in patients with allergies and known sensitivity of its components and for when wounds support is required for longer periods.
- **Polytrimethylene carbonate** – is generally used for soft tissue closing and ligation in General Surgery, Gastrointestinal Surgery, Gynecology, Urology, Plastic Surgery and peripheral Vascular Surgery. It is not intended for use in adult cardiovascular tissue, ophthalmic surgery and neurological surgery.
- **Glycomer** – is generally used for soft tissue closing and ligation in General Surgery, abdominal closure and Ophthalmic Surgery. It is contraindicated for use in cardiovascular and neurological surgery.

Multifilament

- **Polyglactin** – is generally used for soft tissue closing and ligation in General Surgery, Gastrointestinal surgery, Plastic Surgery, Gynecology, Orthopedics, Urology and skin closure. This material is not intended for cardiovascular and neurological surgery.
- **Polyglycolic acid** (PGA) – is generally used for soft tissue closing and ligation in General Surgery, Gastrointestinal surgery, Plastic Surgery, Gynecology, Orthopedics, Urology and skin closure. This material is not intended for cardiovascular and neurological surgery.

Non-absorbable materials

Monofilament

- **Polypropylene** – is generally used for soft tissue closing and ligation in Cardiovascular surgery, Neurosurgery, Ophthalmic surgery, Microsurgery, Plastic Surgery, skin surgery, Orthopedics, Gynecology, General Surgery, Gastrointestinal surgery and in abdominal wall surgery.
- **Polyamide** – is generally used for soft tissue closing and ligation in General Surgery, Plastic surgery, Gastrointestinal surgery, Gynecology, Orthopedics, Ophthalmic surgery and skin closure.
- **Steel** – is generally used for closure of the sternum, abdominal wall closure, hernia repair and Orthopedics.

Multifilament

- **Polyester** – is generally used for soft tissue closing and ligation in Cardiovascular surgery, General Surgery, Ophthalmic surgery, Oral surgery, Gastrointestinal surgery, Gynecology and skin closure
- **Silk** – is generally used for soft tissue closing and ligation in General Surgery, Ophthalmic surgery, Oral surgery, Gastrointestinal surgery, Gynecology and skin closure. This material is not intended for urinary tract tissue, biliary tract tissue and known allergies and sensitivities.

Complications and adverse reactions of suture materials might be:

- Local irritation
- Transitory inflammatory foreign body response
- Erythema
- Induration during the absorption process of subcuticular sutures
- Suture materials may enhance an existing infection
- Wound dehiscence
- Granulomas
- Fistula formation.

LITERATURE OVERVIEW

The probability of a complication to occur is low as demonstrated in a study in which a long period without any complications was presented data from 12 patients (1 in 2004 and 11 in 2005) who developed mild to moderate inflammation or fistula/infection (inflammation, granuloma, extrusion, fistula, abscess) after 3 to 8 weeks after clean operations (varicose vein, hernia, benign soft tissue tumour) in which they used Vicryl (Polyglactin 910) [10].

In a study in which were included 1000 plastic surgery outpatients it was demonstrated that there are no substantial differences between the different suture materials and suturing techniques, making the association of different suture materials, individual patient characteristics, surgeon skills and wound site and length with postoperative wound complications (tissue reactivity, infection rate and wound dehiscence). A moderate increase in the risk of tissue reactivity for silk and polyglactin 910 and a protective effect of thinner internal sutures were observed [11].

In a study in which polyglactin 910 and polyglycolic sutures were compared after layer closure of laparotomy wounds after 306 acute or elective operations. The total incidence of wound dehiscence and herniation was 0.65% with no significant difference between polyglycolic acid (0.6%) and polyglactin 910 (0.7%). The incidence of abscess, granuloma or sinus formation was 6.5% for polyglycolic acid and 11.3% for polyglactin 910, with the difference not being statistically significant [12].

In recent years, the minimally invasive approach to abdominal surgery has become increasingly established, but open surgery is still practised. Numerous studies addressed the question of the ideal suture material and the optimal suture technique for primary elective abdominal wall closure [13–18].

Based on current meta-analyses, the application of a monofilament, late-absorbable suture using a continuous suture technique with a suture-to-wound length ratio of at least 4:1 is the method of choice [19] A recommendation for this combination can also be found in the recently published European Hernia Society guidelines [20].

In 2009, a new monofilament, ultra-late-absorbable suture with high elasticity was developed for abdom-

inal wall closure and introduced into the market [21]. The combination of delayed absorption and elasticity allows a tension-free closure and supports the healing process of the fascia.

One of the studies that evaluated the performance of Monomax suture was MULTIMAC study. The objective of this international, multi-centric, prospective, observational, single-arm cohort study was to analyse the performance of Monomax suture material under daily clinical routine in a non-selected patient population. The study followed a total of 200 patients undergoing a primary elective laparotomy using either a midline or transverse incision that were examined regarding the frequency of short-term complications (reintervention due to burst abdomen, wound infection, wound healing disorders)

The results of the MULTIMAC study indicate that the ultra-long-term absorbable, elastic monofilament suture is safe and efficient for abdominal wall closure performed under daily clinical routine.

CONCLUSIONS

Surgical suturing materials were needed from ancient times and during technology evolution, the manufactures improved their characteristics. The perfect universal surgical thread doesn't exist, but there is a variety of sutures to choose from, depending on each patient, type of intervention or tissue. Regardless of threads' actual improved performances, there are possible complications such as local irritation, foreign body response, granulomas or fistulas. The multitude of studies conducted in the last 20–30 years established the indications and contraindications for each type of thread or needle, but there are expected new materials to be developed to improve the range of suturing materials or even replace the existing ones.

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