Stitch by Stitch: Medical Aspects of Polymers in Surgical Suture Materials for Chemistry Education

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Abstract

Medical research and science progress over the last century made it possible for almost every wound to be treated by specialised doctors. In some cases, humans suffer from wounds inside their body, or they need an operation. In these cases, sections are mostly stitched with special sutures. On our body surface and skin, these sutures need to be removed two weeks after the operation but with healing processes inside the body, it wouldn’t be favourable to reopen a cut and to remove suture material. Therefore, there are different kinds of polymers used for sutures in different locations of our body, depending on environmental conditions and required strength of the stitches.

Because they show such a broad variety of characteristics and can be tailored to alter these, polymers as a chemical substance group are a perfect candidate to form different sutures for different applications. Not only can they be formed into threads, strings and filaments and be perfectly handled because of their flexibility. They also show different properties concerning their response to and degradation in acidic or basic environments [1] as well as their degradation behaviour with stimuli like gamma radiation or enzymes [2]. Hence, there are different sutures available for body regions like stomach or intestines compared to regions with physiological pH value. Furthermore, polymers are part of school curricula and their application in surgical suture materials links medical topics to organic chemistry and pH calculations. Thus, this topic presents linkage to everyday problems with great potential for chemistry education and offers motivating learning opportunities, especially for girls and young women [3]. It links school teaching to research findings and connects different scientific areas as well as it helps to develop networked thinking and experimental skill.

In this article, we present an experimental approach on how polymer characteristics can be made accessible for K-12 chemistry education and school laboratories through didactic reconstruction. For this purpose, PDS II™, MAXON™, VICRYL™ and PROLENE™ as well-known polymeric sutures are exposed to different acidic and basic environments and examined regarding their degradation behavior in a simplified tensile strength measurement experiment.

Keywords: *medicine, polymers, acidic and basic environments, polymer degradation*

1. Introduction

Medical topics surround us in our everyday life; we treat small wounds with a plaster, in case of infections we go to the doctor and in case of injuries to the hospital. Modern medicine can cure most diseases. Not only are medical aspects inevitably touching the life of adolescents, (young) people are often attracted by and interested in medicine [3]. Even if chemistry is not the first thing to come in mind when thinking of medicine, there are many overlaps between these disciplines.

Having surgery means closing incisions. Surely, sutures in our skin can be removed after two weeks, but what about sutures in internal tissues? There is no second operation needed to remove stitches inside our body since some sutures are absorbable and dissolve on their own [4]. Many sutures reaching from natural biomaterials to synthetic polymers emerged over the years [5]. Different materials show different characteristics, for example tensile strength or degradation behavior.

Not only are different surgical suture polymers a promising example to teach structure-property-relationships in chemistry classes. Further, connections to different pH values inside or body or reasons for biodegradability can be drawn. In this contribution, we present an experimental approach to study the characteristics of different polymeric sutures in a series of didactically reconstructed experiments. In this way we want to show why polymeric sutures are an interesting topic for teaching chemistry in a real-world context and offer a holistic way of learning.

2. Scientific Background: Surgical Suture Materials

Suffering injuries is an everyday problem of mankind. Some wounds heal on their own, some need to be tended to by medical experts. Natural materials have been used for wound closure for centuries - application of linen or animal sinew dates to ancient Egypt [4]. Defining a suture as a “biomaterial device, either natural or synthetic, used to ligate blood vessels and approximate tissues together” [5], it is obvious that sutures are used for closing different kinds of cuts on skin or tissues caused by injuries or due to surgery [4]. With an annual global market of $4.2 billion [5] sutures represent one of the largest groups of biomaterials, particularly polymers [4, 6]. For an application inside human bodies, sutures “should be easy to handle, […] and have a lasting tensile strength” [7]. Further, used materials should not support bacterial growth and elicit no allergic reaction or carcinogenic action [6]. Understanding their absorbability and other chemical properties [6] makes it possible to find the suitable material for different body regions with for example different pH levels influencing the degradation behavior of different sutures [1, 7]. Sutures vary in diameter and composition, and are classified in three groups: monofilament, pseudo monofilament, and multifilament [4]. Furthermore, one distinguishes between resorbable and non-resorbable sutures [4, 6]. Resorbable „sutures are based mostly on the lower α-hydroxycarboxylic acids and copolydioxanes” [6]. Three of the most used absorbable sutures are PDS II^{TM}, MAXON^{TM} and VICRYL^{TM}. They consist of poly-p-dioxanone, polyglyconate, and polylactide-co-glycolide (1:9) and are fully resorbed after 6-8 months, 6 months, and 70 days respectively (Fig. 1) [4, 7].

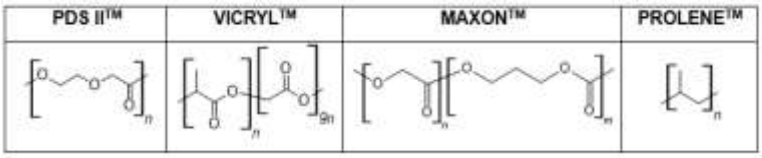


Fig. 1. Molecular formula of the sutures.

Degradation behavior varies with pH level and is generally faster in alkaline solutions. Most degradation characteristics can be explained regarding ester components in the polymers, especially fast degradation in alkaline solutions. Degradation equations are shown in Fig. 2. PROLENE^{TM} consists of polypropylene (Fig. 1) and is non-resorbable. Sutures from PROLENE^{TM} need to be removed after surgery and healing process. It remains stable without dependence on pH level [1].

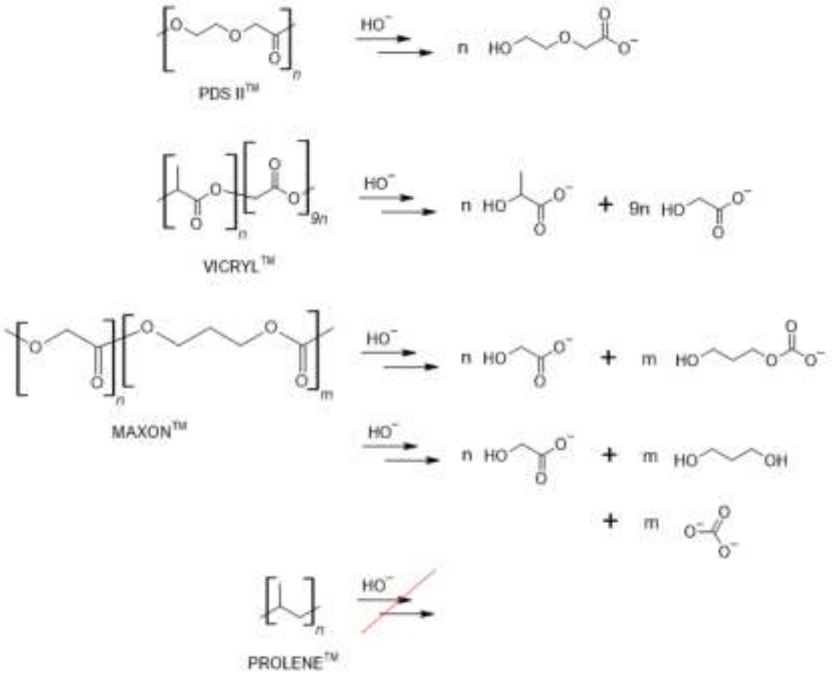


Fig. 2. Polyester degradation with base catalyst.

3. Didactic opportunities

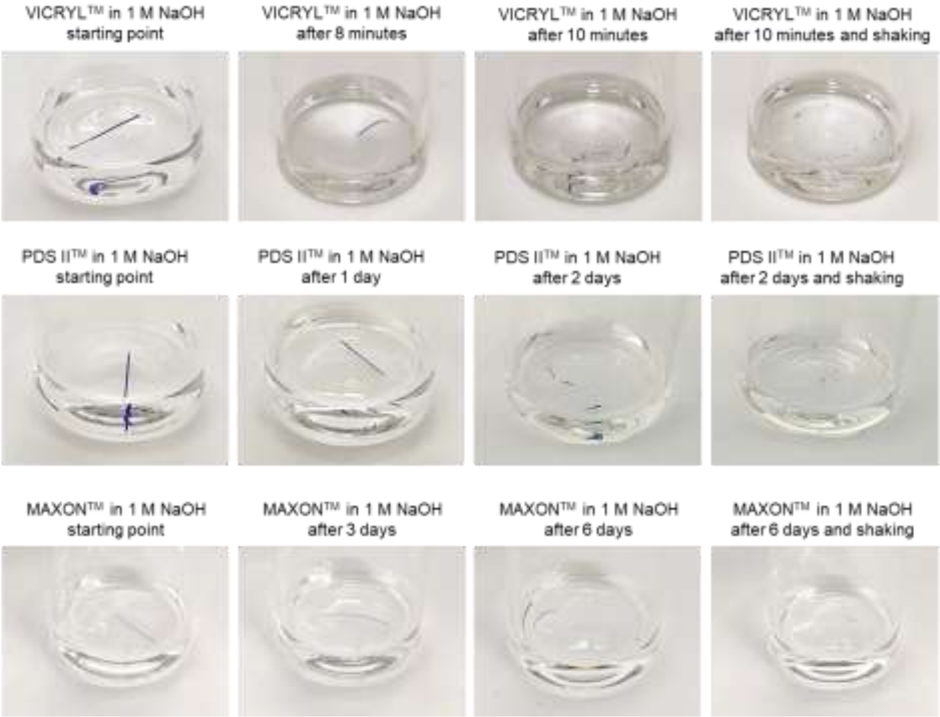
Because interest and curiosity are important pre-conditions for effective learning, medical topics at the interface of different natural sciences offer important possibilities to encourage students' interests in subjects like chemistry [8]. International studies like ROSE show that in many countries, sciences are less liked than other subjects, especially by girls [3]. But not only is it known that subjects like chemistry need a better standing. Studies show further that medicine is a field especially girls find interesting and promising for their later career [2, 9]. Further research shows that adolescents find science lessons interesting when experiments and real-life contexts are used [9, 10]. Reconstructing experiments with medical background for chemistry education is therefore a promising approach to wake interest in chemistry and to create effective learning opportunities. Using surgical sutures as a topic offers linkage to classical elements of the curriculum such as polymers, especially polyesters, ester cleavage, pH scale, and to basic concepts like structure-property-relationships.

4. Experimental: Degradation studies and tensile strength measurement

Based on extensive research concerning degradation behavior and tensile strength of suture materials [1, 2, 4-7], we present a series of experiments using PDS II^{TM}, MAXON^{TM}, VICRYL^{TM}, and PROLENE^{TM} suitable for K-12 chemistry education. One inspiration for didactic implementation is given by KNUTSON in connection with polymerization [10]. Beside the necessity to buy surgical material or get it sponsored by local clinics, the experiments use common school equipment, non-toxic and inexpensive chemicals, and can be easily conducted by students.

4.1 Degradation studies in basic environment

The aim of the experiments is to show differences in the degradation behavior of the sutures in a simple way. To achieve this, suture pieces (1 cm) were incubated in 1 M NaOH, 0.1 M NaOH, and water at 50 °C as well as at room temperature. In 1 M NaOH, VICRYL^{TM} was to degrade the fastest (minutes to hours), followed by PDS II^{TM} (1-3 days). MAXON^{TM} took 1 week to degrade. PROLENE^{TM} did not show any signs of degradation. Degradation could be observed for VICRYL^{TM} as disintegration into pieces with dissolvement, for PDS II^{TM} as disintegration, and for MAXON^{TM} as thinning out. At 50 °C, degradation of VICRYL^{TM} in 1 M NaOH could be observed within 10 minutes, leaving visible only dye crumbles. At room temperature, degradation in 1 M NaOH took about 1 hour and was characterized by smaller pieces. The process was significantly slowed down with 0.1 M NaOH. No degradation was observed in water. Higher temperature did not alter the behavior of PDS II^{TM}, MAXON^{TM}, and PROLENE^{TM}. Fig. 3 shows the degradation behavior in comparison.



VICRYL^{TM} in 1 M NaOH starting point

VICRYL^{TM} in 1 M NaOH after 8 minutes

VICRYL^{TM} in 1 M NaOH after 10 minutes

VICRYL^{TM} in 1 M NaOH after 10 minutes and shaking

PDS II^{TM} in 1 M NaOH starting point

PDS II^{TM} in 1 M NaOH after 1 day

PDS II^{TM} in 1 M NaOH after 2 days

PDS II^{TM} in 1 M NaOH after 2 days and shaking

MAXON^{TM} in 1 M NaOH starting point

MAXON^{TM} in 1 M NaOH after 3 days

MAXON^{TM} in 1 M NaOH after 6 days

MAXON^{TM} in 1 M NaOH after 6 days and shaking

Fig. 3. Degradation behavior with relevant changes over time.

4.2 Simplified tensile strength measurement

To support the understanding of polymer degradation mechanisms and the fact of sutures keeping their form while losing strength, we conducted a simple tensile strength test with spring force meters (1 N, 5 N, 20 N, 50 N) referring to the point of rupture. Pieces with a length of 4 cm of fresh strings and after incubating them in 1 M NaOH for one hour were measured. Fig. 4 shows the experiment. Table 1 shows relevant data.

Fig. 1. Tensile strength measurement with a spring force meter.

Table 1. Tensile strength before and after incubation in 1 M NaOH.

Suture	**strength [N]**	**strength after incubation [N]**
VICRYL^{TM}	30	- (degradation)
PDS II^{TM}	50	30
MAXON^{TM}	20	6
PROLENE^{TM}	30	30

5. Outlook

The experiments will be embedded in a learning arrangement for a series of chemistry lessons. Therefore, it will be expanded by other medical aspects of polymers, *e.g.*, nanocarriers for targeted drug delivery [11] or alginates for wound supply. After piloting, evaluating, and optimizing it will be connected to other arrangements with medical topics.

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