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Effect of chemotherapy and heat on biomechanical properties of absorbable sutures

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ABSTRACT

Background: The quality of tissue repairs depends on tissue integrity, surgical technique, and material properties of the sutures used. Currently, there is no clear consensus on which is the best suture to use during cytoreductive surgery combined with hyperthermic intraperitoneal chemotherapy. The aim of this study was to evaluate the impact of heat and chemotherapy on sutures' biomechanical properties.

Methods: Six different 3.0 absorbable sutures (Biosyn, Dexon II, Maxon, Monocryl, PDS II, and Vicryl Plus) were tested. All suture strands were incubated for a 24-h period in saline, mitomycin-c, and oxaliplatin at 37 and 45°C. Suture loops were then loaded to failure using a servohydraulic testing machine. Data for tensile breaking force (TBF) and elongation rate were collected for all samples.

Results: Under basal condition, Maxon was the strongest of all sutures with a TBF of 59.6 ± 4.3 N ($P < 0.01$), and no significant difference in TBF was observed between other sutures. Heat alone had no impact on sutures' biomechanical parameters. Exposition to mitomycin-c at 45°C did not significantly affect sutures' basal tensile properties, with Maxon remaining the strongest suture. When incubated in oxaliplatin at 45°C, the six suture types had a similar TBF. In all experimental conditions, multifilament sutures had a significantly lower elongation rate than monofilament sutures, and no correlations were demonstrated between elongation rate and the TBF of sutures.

Conclusions: This study showed that exposition to heated chemotherapy did not significantly affect absorbable sutures biomechanical properties.

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1. Introduction

Cytoreductive surgery combined with hyperthermic intraperitoneal chemotherapy (HIPEC) is one of the best treatment options for several peritoneal malignancies. The morbidity and mortality rates associated with this procedure have decreased with improvement of surgical technology and increasing experience [1]. However, major surgical complications such as anastomotic leakage and bowel fistula do remain a main source of concern. Recent publications reported an overall incidence of gastrointestinal complication rate between 5 and 20% [2–4].

The bowel complications observed after HIPEC procedures have been associated with impaired wound healing induced by chemotherapy agents and/or hyperthermia. Nevertheless, the quality of tissue repair depends not only on tissue integrity but also on surgical technique and the material properties of the sutures used.

The perfect suture should have high tensile strength and induce minimal tissue reactivity. It should be easy to handle, resistant to infection, and have good knot security. Sutures can be divided in four categories; monofilament *versus* multifilament and absorbable *versus* nonabsorbable. Monofilament sutures have a high bending stiffness and elongation rate [5,6]. They have a less favorable handling profile, with a tendency to untie. Multifilament sutures consist of several filaments twisted and/or braided together. This offers better handling properties and flexibility comparatively with those of monofilament materials [7,8]. Their division into absorbable and nonabsorbable is based on their capacity of resorption within tissue. Absorbable suture materials will degrade *in vivo* via hydrolysis.

Chemical properties of absorbable sutures influence their absorption rate and, thus, their tensile properties. Many factors are known to affect the hydrolysis rate of glycolic and lactic acids polymers used in absorbable sutures composition. These include free radicals [9–11], enzymes [10,12,13], temperature [14], and pH [15–17]. Temperature is particularly important as most chemical reactions increase with temperature. Pietrzak *et al.* [14] reported that temperature variation as small as 2°C <37°C affected the degradation rate of polyglycolic/poly-L-lactic acid copolymer up to 30%.

To the best of our knowledge, no study has evaluated the impact of heated chemotherapy on biomechanical properties of the commonly used gastrointestinal sutures. Thus, the objective of this study was to compare tensile breaking force (TBF) and elongation rate of six different absorbable sutures when exposed to heat and cytotoxic drugs: oxaliplatin and mitomycin-c (MMC).

2. Materials and methods

2.1. Study design

Four types of monofilament and two types of multifilament absorbable sutures were tested in this study. United States Pharmacopeia (Chicago, IL) 3-0 thickness was selected as it is generally used for gastrointestinal anastomosis regardless of suture types. The monofilament sutures included Biosyn and Maxon (manufactured by Covidien, Mansfield, MA), Monocryl and PDS II (manufactured by Ethicon, Somerville, NJ). The multifilament sutures included Dexon II (Covidien) and Vicryl Plus (Ethicon). The characteristics of each suture material tested are detailed in Table 1.

To evaluate the impact of heat and chemotherapy (oxaliplatin and MMC) on suture properties, each suture material was immersed into 50 mL of saline (control), oxaliplatin (1 mg/mL), and MMC (0.1 mg/mL) solutions. All the aforementioned groups were incubated at 37 and 45°C for a 24-h period, respectively. Another group was kept under basal condition (dry at 37°C), resulting in seven different experimental conditions. Five samples ($n = 5$) of each suture type were tested per condition.

In this *in vitro* study, we have chosen to use 1 mg/mL of oxaliplatin and 0.1 mg/mL of MMC. This represents five times the maximum tolerated doses used during usual HIPEC procedure, which was calculated for an average body surface of 1.8 m^2 and perfusate volume of 2 L/m^2. The pH of each solution was measured at 0, 6, 12, and 24 h. After the 24-h incubation period, specimens were rinsed with 5% dextrose solution (D5%) at 37°C. Specimens were kept in that same solution before mechanical testing performed on the same day.

2.2. Biomechanical testing

Suture specimens were tied directly around the two vertically prealigned plastic pulleys fixed on the mechanical testing machine. A space of 0.5 mm was left between pulleys producing a standard 75-mm suture loop secured with six flat

Table 1 – Characteristics of absorbable sutures tested in this study.

Suture	Size U.S.P.	Material	Configuration	Batch number
Biosyn	3-0	Glycolide and p-dioxanone copolymer	Monofilament	A6G787
Maxon	3-0	Glycolide and trimethylene carbonate copolymer	Monofilament	R803585C
Monocryl	3-0	Glycolide and ε-caprolactone copolymer	Monofilament	XKZ147
PDS II	3-0	p-dioxanone monomer	Monofilament	XJ7853
Dexon II	3-0	Polyglycolic acid coated glycolide and ε-caprolactone copolymer	Braided multifilament	E7A0215C
Vicryl Plus	3-0	Glycolide and L-lactide copolymer coated with triclosan	Braided multifilament	XK7502

U.S.P. = United States Pharmacopoeia.
Monocryl, Maxon, and PDS II: Ethicon, Inc, Somerville, NJ.
Biosyn, Dexon II, and Maxon: Covidien, Mansfield, MA.