



## Adhesion of surgical sealants used in cardiothoracic and vascular surgery



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### ABSTRACT

Surgical sealants are widely used in cardiothoracic and vascular surgery essentially for hemostasis and sealing. Their adhesive properties have mainly been studied by clinical experiments. The objective of this study is to measure adhesion of the three main types of surgical sealant used in cardiothoracic and vascular surgery under normalized realistic conditions.

The bulge-and-blister test was used to quantify adhesive performances of three types of surgical adhesives: cyanoacrylates, polyethylene glycol (PEG), and aldehydes. Samples were composed of two circular layers of equine pericardium glued by the surgical sealant studied. Comparative adhesion testing was carried out in eight samples bonded with a Dermabond<sup>®</sup> (cyanoacrylate), five samples with Bioglue<sup>®</sup> (aldehyde), four samples with Coseal<sup>®</sup> (PEG), and thirteen samples bonded with an industrial cyanoacrylate. Scanning electron microscope (SEM) observations of cross-sections of samples glued by Dermabond<sup>®</sup> and environmental scanning electron microscopy (ESEM) images of samples composed of equine pericardium glued by Bioglue<sup>®</sup> were also performed.

The average value of the adhesion energy is  $2.3 \pm 1.5 \text{ J.m}^{-2}$  for samples glued with Dermabond<sup>®</sup>,  $6.04 \pm 1.61 \text{ J.m}^{-2}$  with Bioglue<sup>®</sup>,  $2.37 \pm 1.25 \text{ J.m}^{-2}$  with Coseal<sup>®</sup>,  $3.74 \pm 1.33 \text{ J.m}^{-2}$  with the industrial cyanoacrylate glue in surgical conditions. SEM observations of cross-sections of samples glued by Dermabond<sup>®</sup> showed a failure at the interface between the glue and the pericardial layer. ESEM observations have revealed a majority of regions where the glue is not linked to the pericardium.

Adhesive performance measurements and microscopy observations in surgical conditions show that surgical sealants adhesion is weak and explain their poor efficacy in clinical practice. To improve adhesion in the surgical field, we need to focus on achieving a better cohesion between the adhesive and the substrate by modifying conditions adhesive bonding and consequently tend toward cohesive failure.

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### 1. Introduction

Sealants have been used in surgery for decades in many surgical indications. The class of surgical sealants comprises fibrin-based adhesives (Tissucol<sup>®</sup>, Tisseel<sup>®</sup>), cyanoacrylates tissue adhesives (Dermabond<sup>®</sup>, Omnex<sup>®</sup>), polyethylene glycols (PEG) (CoSeal<sup>®</sup>), and proteins polymers (Bioglue<sup>®</sup>, GRF<sup>®</sup>) (Fig. 1). In cardiothoracic and

vascular surgeries, tissue adhesives are mostly used for hemostasis and sealing [1,2]. Fibrin-based sealants have hemostatic properties but cannot be considered as adhesives as they do not adhere properly. They are not studied in this article. Table 1 indicates main characteristics and indications of the three main types of sealants used in cardiac, thoracic and vascular surgeries.

Surgical cyanoacrylate glues derived from industrial cyanoacrylate adhesives. Omnex<sup>®</sup> (Ethicon Surgical Sealant, Ethicon Inc., Somerville, NJ) is the only authorized cyanoacrylate in vascular surgery. There are few prospective randomized multicenter study on the efficacy of

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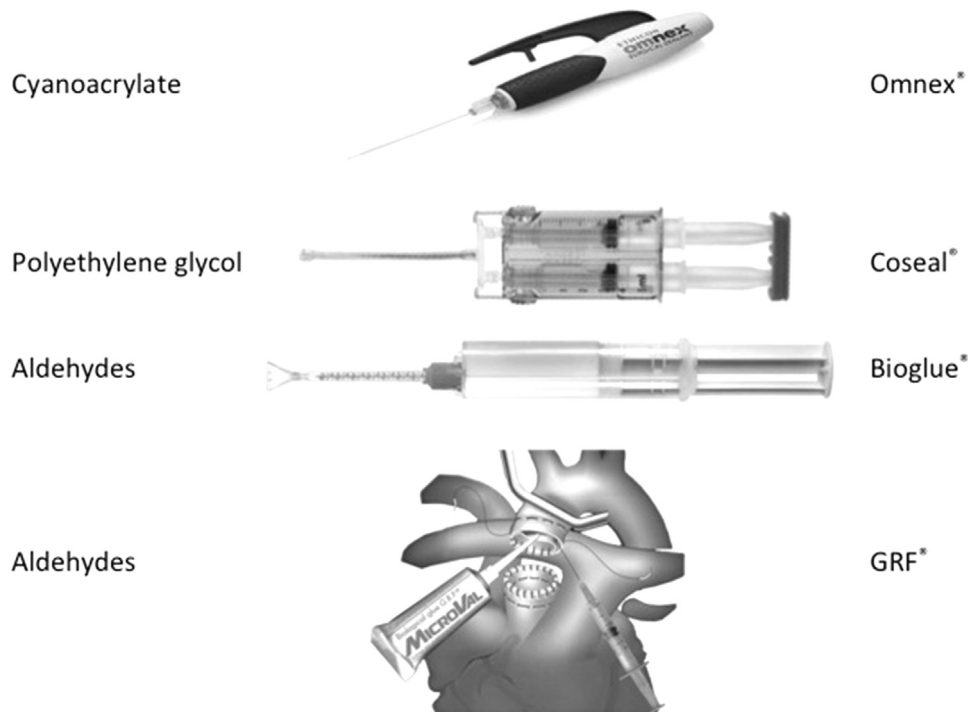


Fig. 1. The three classes of surgical adhesives used in cardiothoracic and vascular surgery.

Table 1

Main characteristics and indications of the three principal types of sealants used in cardiac, thoracic, and vascular surgeries.

Types	Company	Company	Composition	Caution	Polymer-ization(s)	Degradation	Surgical indications and uses
<b>Cyanoacrylates</b>	OMNEX <sup>®</sup>	Ethicon (J & J)	2-Octyl Cyanoacrylate		120	75% at 2 years	Hemostasis by sealing area of leakage Vascular: + Cardiac: – Pulmonary: –
<b>PEG</b>	COSEAL <sup>®</sup>	Cohesion Technologies Baxter	PEG Polymer	Swelling (risk of compression)	60	1 month	Hemostasis by sealing area of leakage Vascular: + Cardiac: – Pulmonary: –
<b>Aldéhydes</b>	GRF <sup>®</sup>	Cardial	Formaldehyde-Gelatin-Resorcinol	Release of formaldehyde (cytotoxicity)	120	Un-known	Aortic dissection
	BIOGLUE <sup>®</sup>	Cryolife	Bovine Serum Albumin Glutaraldéhyde	Rigid (risk of compression) Release of Glutaraldéhyde (cytotoxicity)	120	Never	Aortic dissection

cyanoacrylate for hemostasis of a vascular anastomosis (femoral bypass or arteriovenous fistula) [3]. Their effectiveness in this clinical indication is not clearly validated. Cyanoacrylate adhesives are not used in cardiac and thoracic surgery. A previous study demonstrated that the average value of the adhesion energy of this type of surgical sealant is  $2.3 \text{ J m}^{-2}$  with a standard deviation of  $1.5 \text{ J m}^{-2}$ , which is very low in terms of adhesion [4].

PEGs are bicomponent polyethylene glycols adhesives. CoSeal<sup>®</sup> (Cohesion Technologies Inc./Baxter Healthcare International, Palo Alto) is the most widely PEG sealant used in vascular surgery for primary prevention of bleeding. The effectiveness of the product is described by two randomized comparative trials. The first trial compared the efficiency of CoSeal<sup>®</sup> to the one of Gelfoam<sup>®</sup> to obtain hemostasis on infra-inguinal bypass surgery and PTFE arteriovenous shunts for dialysis in 148 patients. CoSeal<sup>®</sup> allows more frequent immediate

hemostasis but is not beneficial for hemostasis at 10 min [5]. The second study compares the efficacy of CoSeal<sup>®</sup> to the one of Gelfoam<sup>®</sup> to obtain hemostasis on Dacron aortic grafts for unruptured aneurysms. CoSeal<sup>®</sup> also allows better immediate hemostasis immediately after unclamping [6]. CoSeal<sup>®</sup> is used in thoracic surgery in the treatment of air leaks. Clinical results for this indication are contradictory in the duration of air leaks and hospitalization [7,8]. CoSeal swells in the presence of moisture and expands to quadruple in volume within 24 h after application and additional swelling may occur as the gel is resorbed. It is therefore necessary to consider the maximum amount of swelling and its possible effects on surrounding anatomic structures that could be damaged by compression.

Aldehyde based surgical glues such as Bioglue<sup>®</sup> (CryoLife Inc, Atlanta, GA) and GRF<sup>®</sup> (Cardial, Saint-Etienne) are two-component adhesives known for their affinity for water. They are polymerized by

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