Progress in Polymer Science 37 (2012) 1031–1050

Contents lists available at SciVerse ScienceDirect

Progress in Polymer Science

journal homepage: www.elsevier.com/locate/ppolysci

Surgical adhesives: Systematic review of the main types and development forecast

A.P. Duarte[a,b,c,*], J.F. Coelho[a,1], J.C. Bordado[b,2], M.T. Cidade[c,3], M.H. Gil[a,4]

[a] *Centro de Investigação em Engenharia dos Processos Químicos e dos Produtos da Floresta (CIEPQPF), Departamento de Engenharia Química, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Pólo II, Rua Silvio Lima, 3030-790 Coimbra, Portugal*

[b] *Instituto de Biotecnologia e Bioengenharia, Departamento de Engenharia Química e Biológica, Torre Sul, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa, Portugal*

[c] *Departamento de Ciência dos Materiais e Centro de Investigação de Materiais, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus da Caparica, 2829-516 Caparica, Portugal*

ARTICLE INFO

Article history:
Received 7 June 2011
Received in revised form
29 November 2011
Accepted 7 December 2011
Available online 14 December 2011

Keywords:
Surgical adhesives
Types and applications
Biomimetic adhesives
Commercial products

ABSTRACT

Due to several advantages over traditional approaches (*e.g.* sutures and staples), surgical adhesives are excellent materials for wound closure. For several decades intensive research activities have been carried out to enhance the efficiency of the adhesives in different tissues and application conditions. This article provides a concise literature review of different types of adhesives in order to understand their structure–properties relationship. Some of the most important commercial adhesives available are presented and discussed in terms of limitations and applications. The recent advances reported in the literature that could provide new avenues to the development of more efficient adhesives inspired in nature strategies are also discussed.

Contents

Abbreviations: ASTM, American Society for Testing Materials; CSF, cerebrospinal fluid; DIN, standards and the Deutsches Institut Für Normung; DOPA, 3,4-dihydroxyphenyl-L-alanine; DNA, deoxyribonucleic acid; FDA, food and drug administration; GAG, glycosaminoglycan; GRF, gelatine–resorcinol–formaldeyde; GRFG, gelatine–resorcinol–formaldeyde–glutaraldehyde; HAV, hepatitis A virus; HBV, hepatitis B virus; HCV, hepatitis C virus; HIV, immunodeficiency virus; HDI, hexamethylene diisocyanate; IEMA, 2-isocyanatoethylmethacrylate; IPDI, isophorone diisocyanate; mTG, microbial transglutaminase; PBS, phosphate buffered saline; PCL, polycaprolactone diol; PEG, poly(ethylene glycol); PGSA, poly(glycerol sebacate acrylate); PP, polypropylene; SEM, scanning electron microscope; US, United States; UV, ultraviolet radiation; vCJD, variant form of Creutzfeldt–Jakob disease.

* Corresponding author at: Centro de Investigação em Engenharia dos Processos Químicos e dos Produtos da Floresta (CIEPQPF), Departamento de Engenharia Química, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Pólo II, Rua Silvio Lima, 3030-790 Coimbra, Portugal.
Fax: +351 218418101.

E-mail addresses: aluapana@yahoo.com, anapduarte@ist.utl.pt (A.P. Duarte), jcoelho3@gmail.com (J.F. Coelho), jcbordado@ist.utl.pt (J.C. Bordado), mtc@fct.unl.pt (M.T. Cidade), hgil@eq.uc.pt (M.H. Gil).

[1] Fax number: + 351 239798703.
[2] Fax number: +351 218418101.
[3] Fax number: +351 212957810.
[4] Fax number: +351 239798703.

0079-6700/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.progpolymsci.2011.12.003

1. Introduction

The application of surgical adhesives appears as an extremely convenient method for wound closing. This fact is based on their main known characteristics, such as: fast application, less traumatic closure, less pain, no suture removal, excellent cosmetic result and localised drug release. In spite of the enormous efforts of the scientific community during the last decades, the currently available tissue adhesives still have significant limitations and drawbacks.

Surgical reconnection of injured tissues is essential for restoration of their structure and function. For many years, the mechanical fasteners such as sutures, staples and wires have been the most widely used methods for joining tissues. A useful fastener must hold the joined tissues in close proximity to allow adequate healing and stop the leakage of biological fluids while being able to resist tensile loads. Despite their common use in the clinic, these mechanical methods have some disadvantages. Besides the application of sutures being inherently traumatic to the surrounding tissue they are not suitable for inherently complicated procedures, such as stopping leaks of bodily fluids and air in blood vessels and tissues with rather low cohesion energy such as lung, liver, spleen and kidney. Also, the accuracy of positioning of the mechanical union may be extremely difficult when working in regions of the body not easily accessible. Therefore surgical adhesives, including tissue adhesives, have emerged because they provide attractive alternatives to suturing or stapling since they exhibit some advantageous features, such as haemostasis sealing of air leakages, elimination of the risk of needlestick injury to the surgeon, reduction of surgery time, tissue handling and blood loss by the patient, mitigation of surgical complications (*e.g.* infection), easy application, quality and strength of seal and no removal requirements [1–3].

Besides this, they really become an asset in situations where mechanical fastening is undesirable [2].

Tissue adhesive can be broadly defined as any substance with characteristics that allow for *in situ* polymerization to cause adherence of tissue to tissue or tissue to non-tissue surfaces, as for prostheses, to control bleeding (haemostats) and to serve as a barrier to gas and liquids (sealants) [3,5]. Many different tissue adhesives and haemostats have been developed over the past 30 years based on different materials.

In general, the adhesive must be easy to use, safe and, above all, it must have good adhesion properties, however the required properties are strongly dependent on the surgical specialty and procedure, in which the adhesive will be used. For example, to control a small oozing in a facial reconstruction, a more slowly polymerized adhesive that in a reconstruction of a portion of the aorta [6], is required.

The surgical adhesives should have, however, some common essential requirements. They must hold the two sides of the tissue together until it has enough mechanical strength to properly support wound healing and they should be biodegradable. In addition they must also polymerize in a moist environment, be gradually metabolised by the surrounding tissue without foreign-body response [7], be inexpensive and prevent tissue deformation [8].

Currently there are several types of commercially available tissue adhesives, which are traditionally classified into three categories: natural or biological, synthetic and semi-synthetic and biomimetic adhesives.

The biological tissue adhesives (*e.g.* fibrin glues, collagen adhesives) are really effective in some applications, but since they are derived from autologous tissue they are rather expensive and of limited availability.

Fibrin glue presents relatively weak tensile and adhesion strengths and requires a labour-intensive preparation just prior to application. Furthermore, thrombin and fibrinogen, which are the main components of the fibrin glues, obtained from human blood can, if not properly screened, cause viral infections such as immunodeficiency virus (HIV) and hepatitis and/or immune deficiency syndrome [1,9]. Concluding, biological glues are expensive, often exhibit