Comment

Surgical sealants and high strength adhesives

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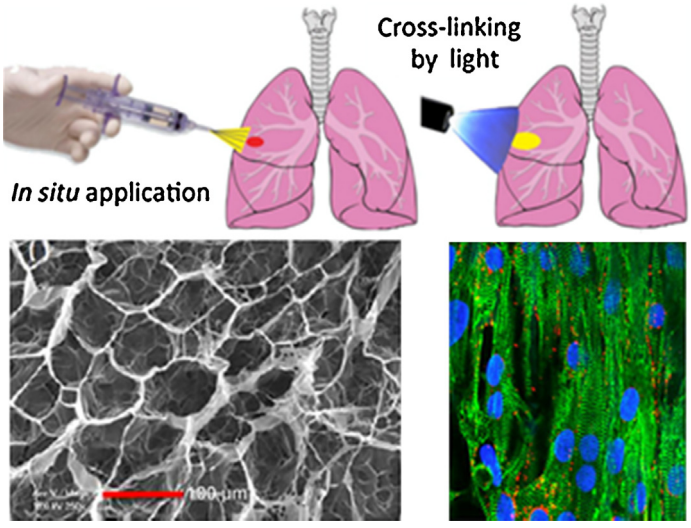
Advanced surgical adhesives based on naturally derived hydrogels

The closure of injured tissues during surgery is a critical step to restore tissue's structure and function. According to MedMarket Diligence report approximately 114 million surgical and procedure-based wounds occur per year worldwide and it is expected that the global wound closure market would reach $14 billion by 2018 [1].

Traditional methods for closing a surgical wound include the use of sutures, wires, and staples. However, despite their extensive use, these techniques have several limitations. For example, they are time-consuming, may cause further tissue trauma, increase the risk of infection and are difficult to use in some surgical locations. Moreover, none of these techniques create immediate and proper sealing. A promising alternative to the traditional closure techniques are surgical sealants. High strength surgical adhesives grow at over 15% compound annual growth rate (CAGR 2012–2017) in the U.S. [1]. Surgical sealants and adhesives can be used as adjuncts to sutures to prevent air and liquid leakages. They can also potentially replace sutures and staples for better closure, minimized blood loss, faster implementation, and easy and less painful operation without the need for removal.

Various biomaterials have been developed to attach tissues and seal the wounds, or to glue devices to tissues. The main challenge toward designing a surgical sealant/adhesive is to achieve sufficient adhesion strength to the tissues in the wet environment without impairing the biocompatibility and tissue function. In



A schematic of sealants/adhesives application in situ.

general, the compositions of current biomaterials used as surgical sealants/adhesives can be classified into three groups: natural polymer based sealants (such as fibrin-, collagen-, and albumin-based sealants), synthetic polymer based sealants (such as polyurethane-, polyethylene glycol-, and polyester-based adhesives), and cyanoacrylate sealants [2]. Despite the emergence of several surgical sealants/adhesives, the biomaterials used as sealants/adhesives often have some drawbacks that limit their applications, such as low elasticity, toxicity effects or toxic degradation products, and poor adhesive strength; therefore none of them meet all the necessary needs to replace sutures and staples. For example, fibrin-based sealants have high biocompatibility but lack adequate adhesion strength to the wet tissues. On the other hand, strong adhesives such as cyanoacrylate-based glues often have toxic agents in their formulation, or release toxic byproducts upon degradation. Moreover, some of the commercially available surgical sealants/adhesives are extremely expensive with fairly slow curing time. Therefore, despite the development of several sealants in the market, there is still a need for engineering cost effective surgical sealants with high

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mechanical properties and adhesion strength to the tissues. In addition, an ideal surgical sealant/adhesive is required to be highly elastic to be able to adapt with dynamic movement of native tissues, have excellent biocompatibility and controlled biodegradability, and provide high adhesive strength and burst pressure particularly in the presence of body fluids.

We have recently developed advanced surgical adhesives based on naturally derived hydrogels. These fast curing, biocompatible, antibacterial, and elastic adhesives are capable to encapsulate cells within a flexible 3D matrix and provide the essential adhesion strength to the tissues within the wet environments in the body. The physical properties and adhesion strength of these advanced surgical materials can be tuned by changing the compositions and chemistries used for the crosslinking of the biopolymer. The engineered hydrogel based surgical adhesives can be used alone or as an adjunct to standard surgical techniques to efficiently close the wound areas. Our studies have shown that the engineered adhesives have innate physiochemical properties after curing so that they remain in the form of a bulk continuum that will not dissolve during wound healing process, even when used in an aqueous or intravascular blood environment with physiologic pressure and flow. Despite their excellent burst resistance/adhesion properties and elasticity, we have also shown that the porous structure of the hydrogel constructs would allow the infiltration and growth of the cells into the adhesive which provides an excellent niche for accelerated wound healing [3,4]. The figure shows a schematic of the application of a photocrosslinkable hydrogel sealant on the wounded tissue (top image). The resulting adhesive is highly porous (left bottom image) and enables cellular growth on the adhesive to accelerate tissue healing (right bottom image) [3,4].

Due to the variations of properties in living tissues in human body, the characteristics of each sealant/adhesive should be carefully engineered and optimized for each indication. For this purpose, it is essential to understand the interactions between the adhesive biomaterials and that particular tissue by performing *in vivo* tests. Future surgical sealants/adhesives will not only provide a physically robust adhesion but also will actively encourage tissue growth and regeneration.

Further reading

[1] L. MedMarket Diligence, Report #S190, Worldwide Surgical Sealants, Glues, Wound Closure and Anti-adhesion Markets, 2010–2017.
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[4] N. Annabi, et al. Biomaterials 34 (2013) 5496–5505.