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Review

Polymer sutures for simultaneous wound healing and drug delivery – A review

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ABSTRACT

Drug delivery using suitable polymeric devices has gathered momentum in the recent years due to their remarkable properties. The versatility of polymeric materials makes them reliable candidates for site targeted drug release. Among them biodegradable sutures has received considerable attention because they offer great promises in the realm of drug delivery. Sutures have been found to be an effective strategy for the delivery of antibacterial agents or anti-inflammatory drugs to the surgical site. Recent developments yielded sutures with improved mechanical properties, but designing sutures with all the desirable properties is still under investigation. This review is an attempt to analyze the recent developments pertaining to biologically active sutures emphasizing their potential as drug delivery vehicle.

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1. Introduction

Polymeric materials have dramatically influenced our day to day life. They find potential in various fields like food packaging, automobiles, water purification *etc.* (Baldino et al., 2017; Soyekwo et al., 2017; Evangelisti et al., 2017). Application of polymeric biomaterials in medicine has been a thrust area of research owing to the exceptional and superior properties they exhibit (Teo et al., 2016). The increased use of polymeric biomaterials in the form of surgical implants, sutures and scaffolds for biomedical applications can be attributed to the exceptional versatility that they offer when compared to metal or ceramic materials (Wong et al., 2012). Several drug delivery systems have been formulated such as controlled, slow and targeted delivery systems (Tiwari et al., 2012). While conventional drug delivery systems lack specificity, polymer drug delivery carriers offer tremendous control over the drug delivery process and can be tailored to meet specific needs (Rissanen et al., 2010). Polymers are conjugated with bioactive agents to achieve control over release kinetics and also to improve the targeting efficiency (Liechty et al., 2010). Polymeric materials can be fabricated with different functionalities and wide range of properties which make them desirable candidates for medical applications (Kulshrestha and Mahapatro, 2008). They can be engineered such that they act as site specific drug delivery systems and can also be fine-tuned to form stable biodegradable systems.

Polymer sutures are described as strands of materials, synthetic or natural, intended for closure of wounds (Dumitriu, 2001). Suture threads, have a prominent role among all other wound closure devices representing a market estimated to be currently around 1.3 billion annually (Champeau et al., 2017). Acharya Sushruta considered as a pioneer of ancient Indian surgery has described various surgical procedures including suturing techniques (Kansupada and Sassani, 1997). He suggested the use of horsehair, cotton and leather for wound closure (Santoni-Rugiu and Sykes, 2007). History says that some cultures witnessed the use of ants and beetles as wound closure agents. Egyptians used linen sutures along with natural adhesives to achieve proper healing (Ratner et al., 2004). Later on sutures made of silk and catgut were widely employed. Hippocrates the Father of Medicine developed plant based sutures. It is also reported that he used gold wires for sutures (Le May et al., 1975). Joseph Lister introduced the suture material, chromic catgut in 1881. He used carbolic acid for sterilizing sutures (Muffly et al., 2011). Sutures made of silk suffered from drawbacks such as poor tensile strength and undesirable tissue reaction (Tajirian and Goldberg, 2010). Natural sutures were replaced by synthetic sutures. Early 1970s witnessed the development of sutures based on poly glycolic acid (PGA) followed by poly (lactic-*co*-glycolic acid) (PLGA) sutures (Lee et al., 2014; Kaplan et al., 2014). Recently there has been a dramatic rise in the development of self-healing sutures that release drugs that enhance the healing process, without compromising the quality of suture. Sutures have been modified to improve tissue integrity, healing, and immune response (Gallo et al., 2016). Incorporating drugs in sutures becomes important when suturing is applied to internal organs or tissues where direct drug delivery is quite difficult (Wang et al., 2009). The delivery of anesthetics, analgesics, anti-inflammatory agents or antibiotics from the suture directly into the wound site provides a direct and efficient route for drug delivery (Padmakumar et al., 2016). In this regard, drug delivery suture also known as drug eluting suture has been developed by incorporating the active pharmaceutical ingredient (API) to the suture (Dennis et al., 2016).

The rationale behind using sutures for drug delivery is that controlled release systems create high local drug concentrations without excessive systemic levels. Sutures are utilized in almost all surgical procedures and hence delivering drugs using sutures eliminates the need for a foreign material to be placed in the wound bed, which might interfere with the healing process and or cause infection (Weldon et al., 2012).

It is noticeable that there has been stupendous progress in the development of sutures with improved materials but not much work has been done to improve the therapeutic value of sutures. The development of sutures with additional properties like release of antibiotics or other therapeutic agents to enhance wound healing has become an attractive research area of the medical fraternity. This review portrays different types of suture materials and their fabrication, emphasizing on their role as drug delivery vehicle. Different properties of suture materials are listed in Table 1.

2. Classification of sutures

2.1. Based on origin

Depending on the source of origin suture materials can be categorized as natural and synthetic. Long ago, natural materials like cotton, silk, linen *etc.* were used for stitching wounds. Prior to use, these materials were lubricated with oil and wine to reduce tissue drag and to provide a sterile coating (DattiloJr et al., 2002; Von Fraunhofer and Chu, 1997). Natural sutures are less preferred since they cause infection. Cotton sutures were recommended by Sushruta for abdominal wounds and wounds of the joint (Meade and Ochsner, 1939). Based on superior handling and knot security properties, silk is much preferred by many surgeons (Perret-Gentil, 2009). Their use is limited due to the acute inflammatory response elicited by this material (Tan et al., 2003). Greek physician and surgeon, Claudius Galen used material made from animal intestines, or "gut," as sutures (Taylor, 2017). Surgical catgut, prepared from the intestinal submucosa of sheep, have high tensile

Table 1
Terms describing suture characteristics (Dumitriu, 2001; Tajirian and Goldberg, 2010; Williams et al., 2010; Geiger et al., 2005; Harloff, 1995; Tjandra et al., 2006).

No	Characteristics	Description
1	Tensile strength	Ability of the suture to resist damage and deformation
2	Memory	Inherent ability of the material to return to or maintain its original shape
3	Capillarity	Extent to which the suture material allows the passage of absorbed fluid
4	Pliability	Ease of handling of the suture material
6	Knot Security	Sutures must be able to be tied effectively such that the knots do not slip
7	Coefficient of friction	Refers to the ease with which a suture passes through the skin