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Interpenetrating polymer network (Ipn) – hydrogels

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Abstract
Interpenetrating polymer network (IPN) is regarded as one of the most useful novel biomaterial. The invention of IPN can be rendered biocompatible and biodegradable has far reaching and profound long-term implications for the pharmaceutical industry and indeed medicine as a whole. The excellent biocompatibility and safety due to its physical characteristics such as impart stability of the drug in the formulations, improves solubility of hydrophobic drugs, excellent swelling capacity and its biological characteristics, like biodegradability, impart bioavailability, drug targeting in a specific tissue and very weak antigenicity, made IPN the primary resource in both pharmaceutical and medical applications. The potential applications of IPN as drug delivery systems specially for the controlled release drug delivery systems. It was also used for tissue engineering including bone substitutes, stationary phase and cartilage scaffolds. This article reviews focused on the entire features of IPN in both as a drug delivery matrix system and a system for tissue engineering as well as its potential therapeutic applications. Finally it can be concluded that IPN offers novel way to address hydrophobic and low bioavailable drugs and are being applied in a wide range of healthcare settings.

Keywords: Interpenetrating polymer network, Biomaterials, Drug Delivery, Tissue engineering.

1. Introduction
Over the past decades, blends have been investigated to satisfy the need of specific sectors of polymer industry. Such polymeric blends showed superior performances over the conventional individual polymers and consequently, the range of applications have grown rapidly for such class of materials. In the recent years, carbohydrate and biodegradable polymers have been extensively used to develop the controlled release formulations of drugs having short plasma life [1]. Among the various polymers employed, hydrophilic biopolymers are quite suitable in oral applications due to their inherent advantages over the synthetic polymers [2]. The importance of biocompatible and biodegradable polymers is continuously increasing in pharmaceutical applications because of their propensity to form cross-linked three-dimensional network hydrogels that tend to swell in water or biological fluids[3]. Such systems have been considered as the potential candidate to deliver bioactive molecules, particularly in controlled release applications [4-6].
The chemical and physical combination methods and properties of multi-polymers have been of great practical and academic interest for the controlled release of drugs because they provide a convenient route for the modification of properties to meet specific needs. Among these methods, considerable interest has been given to the development of IPN based drug delivery systems. This would open up new avenues to use IPN in designing the novel controlled release drug release systems [7, 8]. A combination of judicially selected natural and synthetic polymers has been found to be useful in enhancing the release of short half-lived drugs under physiological conditions. In order achieve this, the properties of natural and synthetic polymers have been modified by grafting, blending and other means. Grafting of vinyl monomers onto natural polymers such as cellulose has been widely accepted [9-11].
The purpose of this article is to review entire features of IPN including as a controlled release drug delivery systems of a large variety of drugs, for assessment of tissue engineering and biomedical applications. This IPN matrix system further serves as the substrate in the evaluation process of cancer therapy. The merits, features, variety, necessity, potentiality, commercial strategy and future prospect of such network system are also discussed.

1.1 Definition of IPN
An IPN is a composite of at least two polymers, exhibiting varied characteristics, which is obtained

when at least one polymer network is synthesized or cross-linked independently in the immediate presence of the other [12] or in other words an IPN is a combination of at least two polymers chains each in network form, of which at least one is synthesized and/or cross-linked in the immediate presence of the other without any covalent bonds between them [13] or The two or more networks can be envisioned to be entangled in such a way that they are concatenated and cannot be pulled apart, but not bonded to each other by any chemical bond [14].

1.2 Merits of IPN

In modern era polymer IPN systems gaining huge popularity due to its following inherent advantages [14]:

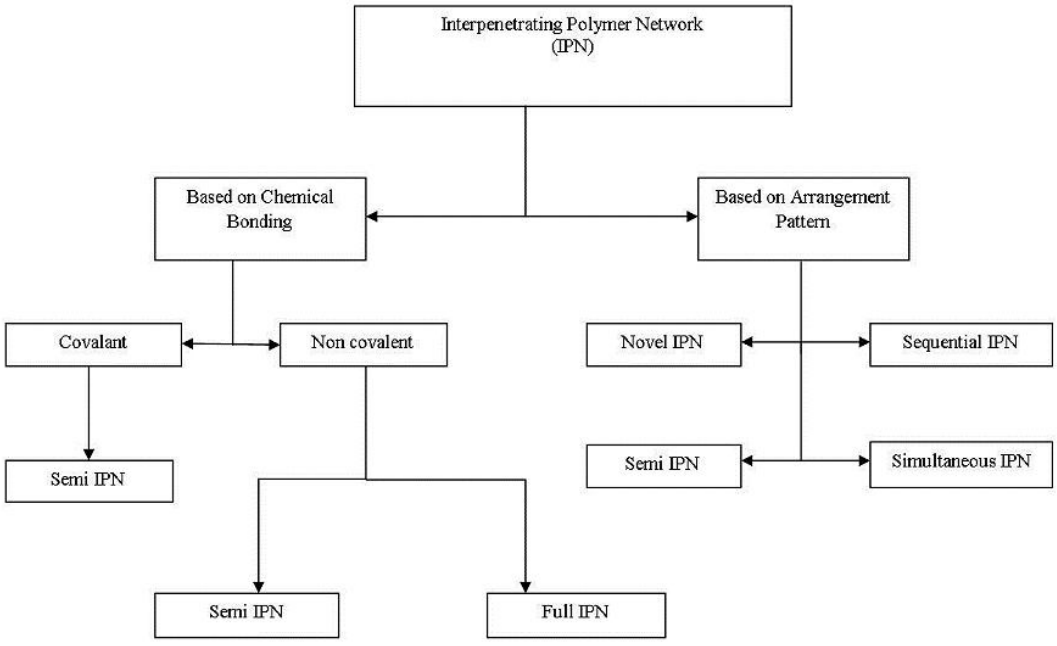
- Whenever an IPN hydrogel is formed from two polymers at a given temperature, the physical phase separation between the component polymers would be almost impossible because of the infinite zero-viscosity of the gel.
- IPN is also attractive in producing synergistic properties from the component polymers. For example, when a hydrophilic gelling polymer is interpenetrated with a relatively hydrophobic gelling polymer, the resultant IPN hydrogel is expected to have an improved capability of immobilizing a drug.
- IPN systems are known to increase the phase stability of the final product.
- IPN enhances the mechanical properties of the final product.
- As long as the reacting ingredients are blended thoroughly during the synthesis, thermodynamic incompatibility can be made to overcome due to the permanent interlocking of the network segments.

1.3 Features of IPN

The ideal characteristics of an IPN are as follows [15]:

- An ideal IPN can suppress creep and flow.
- IPN can swells in solvents without dissolving.
- IPN are distinguishable from blends, block copolymers, and graft copolymers.
- To keep the Separate phases together when the blends are subjected to stress. These systems differ mainly because of the number and types of cross-links that exist in the system.
- Materials formed from IPN share the properties that are characteristic of each network however, homopolymer alone cannot meet the divergent demand in terms of both properties and performance. Therefore, a composite or an ideal IPN of two or three different polymers would be a better choice.
- Polymer comprising two or more polymer networks which are at least partially interlaced on a molecular scale but not covalently bonded to each other and cannot be separated unless chemical bonds are broken.
- Most ideal IPN are heterogeneous systems comprised of one rubbery phase and one glassy phase which produce a synergistic effect yielding either high impact strength or reinforcement, both of which are dependent on phase continuity.
- Hence, IPN based systems have gained good potential to develop the controlled release delivery of drugs [16].

1.4 Classification of IPN: [16]



1.4.1 Based on Chemical Bonding

Covalent Semi IPN: It contains two separate polymer systems that are cross-linked to form a single polymer network.

Non Covalent Semi IPN: In this only one of the polymer systems is cross-linked.

Non Covalent Full IPN: In which the two separate polymers are independently cross-linked [16].

1.4.2 Based on Arrangement Pattern

Novel IPN: Polymer comprising two or more polymer networks which are at least partially interlocked on a molecular

scale but not covalently bonded to each other and cannot be separated unless chemical bonds are broken.

Sequential IPN: In sequential IPN the second polymeric component network is polymerized following the completion of polymerization of the first component network.

Simultaneous IPN: Simultaneous IPN is prepared by a process in which both component networks are polymerized concurrently, the IPN may be referred to as a simultaneous IPN.

Semi IPN: If only one component of the assembly is cross linked leaving the other in a linear form, the system is termed as semi-IPN [17].

1.5 Synthesis of Some IPN

1.5.1 Synthesis of IPN based on the US Patent 2007/0179605 A1

The starting material to make the hydro gel was a solution of telechelic macro monomers with functional end groups. They were polymerized to form a polymer network followed by the addition second polymer of hydrophilic monomers which were polymerized and cross linked in the presence of the first polymer. This resulted in the formation of IPN hydrogel. Polyethylene glycol (PEG) can also be used a first polymer as it is biocompatible, soluble in aqueous solution and gives wide range of molecular weights and chemical structures. IPN hydrogel was also prepared by UV initiated free radical polymerization. I t used the first network as PEG diacrylate (PEG-DA) or PEG dimethacrylate (PEG-DMA) dissolved in phosphate buffered saline (PBS) [18].

There are two methods of preparation: sequential and simultaneous but here simultaneous method is used. PEGM was synthesized (Kim *et al*., 1995) and dissolved in 2 wt% acetic acid to give 10 wt% PEGM solutions. Chitosan was also dissolved in 2 wt% acetic acid and the solid content in solution was 1.5 wt%. A given amount of PEGM/chitosan mixed solution was obtained by mechanical stirring for 2 h. To this was added 2, 2-dimethoxy-2-phenyl acetophenone (0.45 wt% based on the weight of PEGM) and 5×10-5 mol of glutaraldehyde under agitation. The mixed solution was poured into a circular glass mould and was maintained at room temperature. Then, UV irradiation was performed to polymerize and crosslink PEGM within the cross linked chitosan network using a 450 W UV lamp (Ace Glass Co.) placed above the mould at a height of 20 cm for 1 h until gelation occurred. Finally, IPN samples obtained were washed with deionized water and dried under high vacuum for 2 days [19, 20].

1.5.2 IPN hydro gels composed of PVA and chitosan

PVA was added to deionized water and heated at 80 ºC for 1 h to make a solution containing 10 wt% PVA by weight. Acryloyl chloride (3 wt %) and 1 wt. % DMPAP in tetrahydrofuran (THF) were added to the PVA aqueous solution. Chitosan was dissolved in 4wt% acetic acid aqueous solution to prepare 3 wt. % chitosan solutions. The chitosan solution was then added to the PVA mixture. This mixture was mixed for 30 min. The mixed solution was poured into a Petri dish and stored in a box and exposed to a 450-W UV lamp (Ace Glass, USA) placed 20 cm above the mould for1 h under an N2 atmosphere. The weights of the PVA-to-chitosan mixture were adjusted to 1:3, 1:1 and 3:1, respectively. The designation of each sample is listed in Table 1. The irradiated samples were dried in an oven at 50 ºC for 12 h. The dry films were removed from the oven and washed with deionized water to remove any nonreactive materials that were not incorporated into the network [20].

Table 1: Composition and designation of IPN hydro gels

Sample designation	PVA (wt %)	Chitosan
IPN1	75	25
IPN2	50	50
IPN3	25	75

Preparation of semi-IPN

The semi-IPNs were prepared by a free radical polymerization method. Prior to performing experiments, the reactants (Poly vinyl alcohol) PVA and N, N9-methylene bis-acrylamide (MBA) were degassed by purging dry N2 for 30 min. Then, into a Petri dish (diam. 20, Corning) were added 0.75 g PVA, 14.0 mM AM, 17.3 mM ST, 0.12 mM MBA, 0.073 mM KPS, and 1.4 M water. The dish was covered with the lid and reaction mixture homogenized by manual mixing. The Petri dish was then kept in an oven maintained at 80 ºC for 3 h which was found to be a sufficient time for formation of the IPN. The IPN so formed was taken out and purified [21, 22].

1.5.3 Synthesis of Poly (dimethylsiloxane) (PDMS) IPNs

Samples of the extracted and dried base networks (Base networks were formed by end-linking the long-chain PDMS with the tetra functional cross linker tetra (dimethylsiloxy) silane in the presence of a platinum catalyst were swollen to various extents with short chains and proper amount of the catalyst cis dichlorobis(diethyl sulfide) platinum(II)/toluene solution. The networks were put in an oven at 30 ºC to facilitate the swelling, and to evaporate the toluene present with the catalyst. For high concentration of absorbed short chains, more time was needed to swell the base networks with the short chain PDMS. After the networks were fully and uniformly swollen, a stoichiometric amount of cross-linker was incorporated with a small amount of toluene onto the inverse side of the network. The samples were put in a refrigerator overnight to allow the cross-linker to diffuse before extensive reaction takes place. After sufficient time had elapsed for homogeneity to be attained, the PDMS short chains were tetra functionally cross-linked by heating the samples to 35 ºC for 2 days. Re-extractions and swelling gave soluble fractions from the second end-linking process and the equilibrium swelling ratios of the interpenetrated networks in toluene [23].

1.6 IPN Based Drug Delivery Systems

IPN based drug delivery systems are designed to deliver drugs at a particular rate with minimum fluctuation for a desired period of time. Currently several approaches are being pursued for improved delivery of therapeutic products like sheets, films, hydrogel, calcifiable matrix, sponges, tables, capsules, transdermal patches, microspheres, nanoparticles etc.

1.6.1 Sheet

A novel method of producing IPN based drug delivery system is sheeting. Polymeric material comprising an interpenetrating network of a polyol(allyl carbonate), e.g., Nouryset®200 and epoxy resin is prepared by polymerizing 70 to 95 parts by weight of the polyol(allyl carbonate) by radical initiation and

polymerizing partially or entirely simultaneously an epoxy resin-forming mixture by acid catalysis. The epoxy resin-forming mixture comprises 10-90 wt. % of aliphatic or cyclo-aliphatic polyepoxide and 90-10 wt. % of a polyol/anhydride adduct [24]. Sheets can be used in various types of wound dressings and scar management products [25].

1.6.2 Films

IPN films can be used as a piezodialysis membrane. These membranes are not mosaic membranes. It was found that some of these membranes did show piezodialysis effects. One of the successful applications of IPN based delivery systems shows good mechanical as well as tensile strength [26]. Biodegradable collagen films or matrices have served as scaffolds for a survival of transfected fibroblasts [27]. While these methods seem to allow an adequate cell survival, the concerns about long-term biocompatibility of non-degradable materials should be taken into account. In several animal models, a long-term expression of a foreign gene after implantation of transfected cells has not been achieved [28]. A combination of collagen and other polymers, such as atelocollagen matrix added on the surface of polyurethane films, enhanced attachment and proliferation of fibroblasts and supported growth of cells [29]. Transplantation of cells embedded in a lattice of polytetrafluoroethylene fibers coated with rat collagen followed by a mixing with matrigel as well as basic fibroblast growth factor showed that a long-term expression of human β-glucuronidase by retroviral-transduced murine or canine fibroblasts was achievable using a collagen-based matrix system. Therefore, IPN based film systems seem to need to contain extra matrices that improve conditions for a long-term cell survival [30, 31].

1.6.3 IPN Film as a Calcifiable Matrix System

One of the problems with implantable biomaterials is their calcification, which is influenced by structure of the implantable system, and determines its *in vivo* therapeutic efficiency and clinical fate [32]. Calcification of tissue or systems depends on chemical factors that operate at the cellular level around various tissues or biomaterials [33]. Both collagen and elastin are major components of connective tissues, which possess a structure that compromises collagen fibers intimately associated with a remarkably stable elastin network. The suitability of collagen and elastin in many potential medical applications in reconstructive and plastic surgery including controlled delivery of bone morphogenetic protein has been reported [34]. IPN matrix films composed of various combinations of collagen and elastin were developed and evaluated for their suitability as drug delivery systems. Biomaterials should possess mechanical properties capable of withstanding the forces and motions experienced by the normal tissues and have sufficient fatigue strength to ensure a long life of the implant *in vivo* [35].

1.6.4 Sponges

IPN sponges have the ability to easily absorb large quantities of tissue exudates, smooth adherence to the wet wound bed with preservation of low moist climate as well as its shielding against mechanical harm and secondary bacterial infection. IPN based porous sponges have been very useful in the treatment of severe burns and as a dressing for many types of wounds, such as pressure sores, donor sites, leg ulcers and decubitus ulcers by forming a semi- IPNs composed of chitosan and poloxamer [36]. Collagen sponges have been combined with other materials like elastin, fibronectin or glycosaminoglycans [37-39]. The starting material can be cross-linked with glutaraldehyde and subsequently graft-copolymerized with other polymers, such as polyhydroxyethylmethacrylate [40]. The grafted polyhydroxyethyl methacrylate chains, which are hydrophilic, keep the membranes wet and increase their tensile strength. This further affects the efficiency in the management of infected wounds and burns. The importance of matrix compliance to mechanical response was also reported [41].

1.6.5 Tablets

IPN prepared from chitosan/carbopol inter-polymer complex can be used as an extended-release matrix tablet [42]. The solid nature of IPN based tablets seems *in vivo* to have a great potential for antihypertensive action by blending with hydrophilic interpolymer complexes and a hydrophobic waxy polymer [43].

1.6.6 Capsules

Supracolloidal IPN reinforced capsules using micron-sized colloidosomes of poly(methyl methacrylate-co-divinylbenzene) microgels were used as scaffold via radical polymerisation of the interior phase to produce hollow supracolloidal structures with a raspberry core–shell morphology [44].

1.6.7 Hydrogel

Hydrogels have been widely used as a drug carrier due to its ease in manufacturing and self-application. The production of a large and constant surface area is one of the major merits for them to be widely used for clinical and fundamental applications. Various combinations of polymers were made into hydrogel formulations to investigate their potential as a drug delivery system. The combination of natural and synthetic polymers may provide mechanical stability and biological acceptability, acquiring from synergistic properties of both materials. An attempt of combining collagen and hyaluronic acid into IPN hydrogels was made to develop a delivery systems to enhance the mechanical strength of natural polymers and to overcome the drawbacks of synthetic polymers. The hydrogels were found stable and resilient [40]. Silk fibroin & polyacrylamide semi-interpenetrating network hydrogels were prepared for the controlled drug release [45]. Antibiotics loaded interpenetrating network hydrogel based on poly (acrylic acid) and gelatin for treatment of experimental osteomyelitis [46]. IPN hydrogels such as gelatin and dextran are widely used as a drug carrier due to their biodegradability and removable versatility in terms of composition and size [47]. It was found that a coupling of modified gelatin and poly (ethylene glycol) diacrylate of protein loaded interpenetrating network interacts with the cell membrane & elict deserved pharmacological responses [48]. IPN hydrogel was also used as Stimuli responsive gels based on interpenetrating network of hydroxy propylcellulose and poly (N-isopropylacrylamide) [49]. Collagen and polyhydroxyethyl methacrylate into hydrogels was made to develop a delivery system for anticancer drugs, such as 5-FU [50]. The hydrogels were found stable and resilient and did not show any adverse effects, such as calcification, after 6 month of subcutaneous implantation in rats. This system was also very efficient in therapeutic application, which, in this case, was anticancer therapy [51]. Hybrid copolymers of collagen with polyethylene glycol-6000 and polyvinyl

pyrrolidone were prepared for the controlled delivery of contraceptive steroids [52]. Two synthetic polymers, poly (vinyl alcohol) and poly (acrylic acid), were blended with two biological polymers, collagen and hyaluronic acid, to enhance the mechanical strength of natural polymers and to overcome the biological drawbacks of synthetic polymers. These blends were formulated into hydrogels, films and sponges, and subsequently loaded with growth hormone [53]. The results of this work showed that growth hormone could be released from collagen- poly (vinyl alcohol) hydrogels in a controlled release pattern and the rate and quantity of growth hormone released were mainly dependent on collagen content in the system.

1.6.8 Microspheres

One of the successful applications of interpenetrating network is for the controlled release of drugs. A microspherical formulation of poly(vinyl alcohol) and guar gum hydrogel microspheres for the controlled delivery of nifedipine by emulsion cross-linking method was developed for treatment in severe hypertension [54]. Another approach was developed by the IPN formation of graft copolymer of guar gum with modified poly(acryl-amide) to form hydrogel microspheres. The microspheres were loaded with two antihypertensive drugs, verapamil hydrochloride (water-soluble) and nifedipine (water insoluble) to investigate their controlled release characteristics [55]. IPN based microspherical formulation was also used for the prolong delivery of anti-cancer drug such as capecitabine by formation of chitosan-poly(ethylene oxide-acrylamide) inter-molecular rigid network [56] and 5-fluorouracil hydrogel microspheres of chitosan and pluronic F-127 for controlled release of drugs [57]. Novel pH-sensitive IPN microgels based on chitosan, acrylamide- grafted poly(vinyl alcohol) and hydrolyzed acrylamide-grafted-poly(vinyl alcohol) used in the controlled release of an antibiotic drug cefadroxil [54]. Another successful attempt was successful encapsulation of acyclovir, an antiviral drug with limited water solubility, into IPN microspheres by varying the ratio of acrylamide grafted dextran and chitosan. *In vitro* release studies indicated the dependence of drug release rates on both the extent of crosslinking and amount of acrylamide grafted dextran used in preparing microspheres; the slow release was extended up to 12 hour [58].

1.6.9 Nanoparticles

Current state of art is witnessing a revolution of nanoparticles in new techniques for drug delivery systems. These techniques are capable of controlling the rate of drug delivery, sustaining the duration of therapeutic activity or targeting the drug to specific site of tissue. Novel quasi-interpenetrating network/gold nanoparticles composite matrices were studied on DNA sequencing performances by capillary electrophoresis technique [59]. A thermally responsive polymer-metal nanocomposite system comprised of a solid gold nanoparticle core and thermally responsive IPN shell, which was surface functionalized or PEGylated with a covalently bound linear poly(ethylene glycol) chain layer. Gold nanoparticles (50 nm diameter) were prepared using standard gold chloride and citrate reduction method. These particles were then encapsulated inside of a polyacrylamide (PAAm)/poly(acrylic acid) IPN shell via an in situ inverse emulsion polymerization. The surface of the nanocomposite system was then PEGylated via covalent grafting of a linear methoxy-PEG-N-hydroxysuccinimide to the primary amine groups of the PAAm network [60]. Extensive research efforts were given to synthesize hydroxycamptothecin-loaded IPN nanoparticles made of amphiphilic copolymer and normal polymer for the controlled delivery of such anti-cancer drug [61]. Currently several approaches are being pursued for the synthesis and characterization of IPN based nanoparticles like thiolated chitosan coated poly hydroxyethyl methacrylate nanoparticles [62], poly(ethylene glycol)modified N trimethyl-aminoethylmethacrylate-chitosan nanoparticles [63] via inverse emulsion polymerization. Such nanospheres showed a continuous release of the entrapped drug up to 10 days *In vitro* and showed comparable in-vitro cytotoxicity against HepG2 cells compared to the free drug.

1.7 Therapeutic Applications of IPN Based Drug Delivery Systems

IPN based formulations can be used as a drug delivery system to deliver different drugs used in cancer therapy, infectious diseases, cardiac diseases.

1.7.1 Infectious Diseases

Full and semi-IPNs based on polyacrylic acid and gelatin loaded gentamicin sulfate were evaluated for tissue response in rats, which showed no additional local or systemic reaction suggesting the potential usefulness of the hydrogels as carrier for drugs [64].

1.7.2 Cancer Therapy

A biodegradable polymer scaffold was developed using collagen and chitosan, in the form of interpenetrating polymeric network (IPN), for *In vitro* culture of human epidermoid carcinoma cells (HEp-2). The results of the above studies suggest that the scaffolds prepared from collagen and chitosan can be utilized as a substrate to culture HEp-2 cells and can also be used as an *In vitro* model to test anti-cancerous drugs [65]. A biodegradable polymer scaffold was developed using collagen and chitosan, in the form of interpenetrating polymeric network, for *In vitro* culture of human epidermoid carcinoma cells (HEp-2, Cincinnati). Glutaraldehyde was used as cross-linking agent for the development of scaffold. *In vitro* culture studies were carried out using HEp-2 cells, over the selected scaffold and its growth morphology was determined through optical photographs taken at different magnifications at various days of culture. The results of the above studies suggest that the scaffolds prepared from collagen and chitosan can be utilized as a substrate to culture HEp-2 cells and can also be used as an *In vitro* model to test anticancer drugs [66].

1.7.3 Chronic Pain Treatment

Controlled release system for local application of analgesics hydromorphone, morphine, and codeine and a local anesthetic, bupivacaine loaded interpenetrating network system was prepared by using a biocompatible, biodegradable copolyester, poly(3-hydroxybutyrate-co-3-hydroxyvalerate) and another biocompatible but synthetic, nondegradable polymer, poly (2-hydroxyethyl methacrylate), which shows prominent actions to relief from chronic pain [67].

1.7.4 Treatment of Cardiac Disease

In this study, we examined cell-surface interactions between a poly (acrylamide-co polyethylene glycol/acrylic acid) interpenetrating network (IPN) hydrogel and aortic endothelial cells (ECs). ECs migrated and proliferated at high rates

regardless of the RGD surface concentration. These results suggest that this IPN can be used to promote endothelialization of vascular implants made of polymeric and metal materials for cardiovascular applications [68]. Various combinations of collagen and elastin, showed controlled delivery device for cardio-vascular drugs. Such controlled delivery device used to simulate the calcification process of implantable biomaterials, such as bioprosthetic heart valve (BHV). In BHV, the aortic wall and leaflet have mainly served as calcifiable matrix. Recently, the calcification of the bioprosthetic aortic wall has been extensively studied due to increasing use of the stentless BHV [69].

1.7.5 Immunotherapy

The ability of monocytes to adhere, differentiate into macrophages, and fuse to form foreign body giant cells (FBGCs) on an implanted material surface is a critical step toward biomaterial degradation. Novel homogeneous surfaces were utilized to mediate adhesion. These surfaces consisted of N-(2 aminoethyl)-3- aminopropyltrimethoxysilane (EDS) and an IPN (IPN) of polyacrylamide and poly(ethylene glycol). These surfaces were designed to control cell adhesion and morphology and mediate cell differentiation, activation, metabolic ability, and apoptosis, resulting in a reduced or controlled inflammatory response. The EDS surface promotes cell adhesion and the IPN minimizes protein adsorption and subsequent cell adhesion [70].

2. Conclusion

IPN has numerous advantages as a biomaterial and is widely used as carrier systems for the delivery of drug, protein and gene. The examples described in this article represent selected potential applications of IPN in the drug delivery, and biomedical field. IPN has lead to the development of bioengineering tissues, such as bone substitutes, tissue and cartilage scaffolds. Autologous tissue engineering provides an alternative for allogeneic tissue transplantation. The study of IPN for drug delivery systems and tissue engineering may lead to a better understanding of critical diseases. The concepts of high swelling capacity, specificity and sensitivity play a crutial role in targeting delivery of drugs. By understanding the nature of drug delivery systems and their durability in the body, which can interact with the systems, can be identified. IPN has various advantages as a biomaterial and is widely used as carrier systems for delivery of the short biological half-life drugs. There has been a spiky growth in the speed of discovery and development of IPN over the past few years. Current articles support the theory that IPN can provide the resources to deliver drugs at a prolonged controlled release to specific targets. Once optimized, these targeted hydrogel microspheres will provide the better treatment options. So, it can be inferred that IPN based biomaterials for tissue engineering and drug delivery system are expected to become a useful matrix substance for various therapeutic applications in the future.

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