



## A Review on Coronary Stents: With Polymers and without Polymers

Karra Geetha\*, S Anila, MS Bindhu

Department of Pharmaceutics, CMR College of Pharmacy, Hyderabad, Telangana, India.

\*Corresponding author: [geetabiokarra@gmail.com](mailto:geetabiokarra@gmail.com)

Received: 18-02-2024; Accepted: 12-03-2024; Published: 30-03-2024

© Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

<https://doi.org/10.55218/JASR.2024150301>

### ABSTRACT

Polymers have many uses in cardiology, such as coating matrices for drug-eluting stents and stent platforms (scaffolds) during coronary vascular intervention. Current research focuses on biodegradable polymers rather than permanent polymers. Their use may help to lessen undesirable events such as in-stent restenosis, late stent-thrombosis, and hypersensitivity reactions since they disintegrate once their purpose is served. This paper discusses factors affecting tissue and blood cell functions that should be taken into account when assessing the biocompatibility of stent polymers to improve physiologically suitable 3 Polymers are frequently used in cardiology, particularly in coronary vascular intervention, as coating matrices for drug-eluting stents and stent platforms (scaffolds). In addition to permanent polymers, biodegradable polymers are the subject of current study. Since they break down once their function is completed, using them may help prevent unfavorable outcomes such as in-stent restenosis, late stent thrombosis, and hypersensitivity reactions. This review discusses aspects of blood cell and tissue operations that should be taken into account to evaluate the biological compatibility of stent polymer compounds to improve physiologically relevant features after examining recent literature on polymers used in applications related to cardiology. The shape, difference, motion, and future of vascular cells can all be significantly influenced by the characteristics of the supporting material that they are grown. Lastly, a summary of techniques for measuring these parameters in a physiological setting will be provided.

**Keywords:** Stents, biodegradable polymer, Drug-eluting stents, Coronary artery, Biodegradable polymer, Polymer-free, poly-lactic acid, Polylactic-co-glycolic acid.

### INTRODUCTION

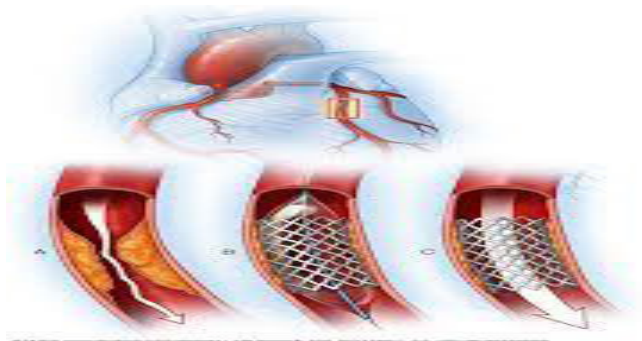
The development of vascular implants is very interested in polymers that can break down, release medications, or mimic biological functions. Because of their unique features and biocompatibility, advanced biomaterials are needed to meet specific demands. This current review is concentrated on the characteristics of polymers utilized as coating matrices and stent platforms for stents with drug-eluting properties (DES), as well as criteria of blood cells and vessel activity that are critical for the evaluation of polymers' biocompatibility.<sup>[1,2]</sup> In DES stent poly-l-lactic acid [PLLA], polymer poly-l-lactic-co-glycolic acid (PLGA) polymers are Poly-l-lactic acid [PLLA] is polyester which can be hydrolyzed to produce items that change the acidity of pH in the area and prevent cells sown into the scaffolds from differentiating. PLLA is widely paired with other biomaterials, like inorganic materials, natural and synthetic polymers, and others biomaterials in order to use it beyond the constraints of using a single polymer alone. For a range of uses in tissue engineering, there are multiple reports of creating PLLA scaffolds using electro-spinning, manufacturing by additives, particulate-leaching, and phase separation.<sup>[3-5]</sup> The tissue engineering and drug delivery applications of the biodegradable polymer poly-lactic-co-glycolic acid (PLGA) have shown great promise.<sup>[6,7]</sup>

### Coronary Artery Stent

DES was offered to the European market. DES are vascular stents that allow for the introduction of antiproliferative medicines to impede the proliferation of vascular smooth muscle cells (SMCs). In events of stent restenosis and stent thrombosis, it is anticipated to be decreased or prevented as a result of this controlled local medication delivery.<sup>[8]</sup> First-generation DES based on biostable polymeric drug carriers, such as poly (ethylene-co-vinyl acetate) (PEVA), poly (n-butyl methacrylate) (PBMA), and poly(styrene-b-isobutylene-b-styrene) block polymers (SIBS), were associated with a higher risk of death or myocardial infarction following implantation, despite their high efficacy in preventing in-stent restenosis.<sup>[9]</sup>

### Understanding Metal-less Angioplasty

Metal-less angioplasty, with the help of DCB and BRS, also known as dissolving stents, is a minimally invasive procedure designed to treat blocked arteries and restore blood flow (Fig. 1). Unlike traditional angioplasty involving metal stent placement, DCB employs a special balloon coated with medication. When Inflated at the site of the blockage, the balloon delivers medication directly to the artery walls, whereas new generation. BRS employs a dissolving stent that dissolves in the arteries in a time span of approximately two to three years. This approach helps to uncage the heart arteries and keep them metal-free.



**Fig. 1:** A healthcare provider will find the blocked heart artery (A) when placing a coronary artery stent. A balloon on the tip of a flexible tube (catheter) is inflated. It widens the blocked artery. Then, a metal mesh stent is placed (B). The stent holds the artery open so blood moves through (C)

## Benefits of DCB

### *Avoids permanent metallic caging*

Unlike conventional metallic DES, Drug Coated Balloons do not cage the artery and keep the artery free from any temporary or permanent implants.

### *Preservation of future treatment options*

The absence of a permanent metal implant in the artery means that future treatment options remain open and flexible in case they are needed.

### *Avoid lifelong medication*

Patients who undergo traditional angioplasty with metal stents often need to take lifelong medications, such as blood thinners, to prevent complications like blood clot formation. DCB eliminates the need for these medications, reducing potential side effects.

### *Reduced risk of long-term adverse events*

One of the primary advantages of DCB is its ability to significantly reduce the risk of long-term adverse events often associated with permanent implants. Enhanced quality of life: Patients who opt for metal-less angioplasty often report an improved quality of life due to the absence of medication-related side effects and concerns about stent-related complications.

## Benefits of Dissolving Stents

### *Temporary support*

Dissolving stents offer temporary support to keep the artery open during the crucial healing period and get dissolved naturally in the form of CO<sub>2</sub> and water post-healing.

### *Reduced restrictions for future treatments*

Due to its ability to get dissolved, just like DCBS, BRS creates reduced restrictions in future treatment options if required.

### *Natural healing*

As the stent dissolves, the artery can return to its natural state.

## POLYMERS USED IN THE CORONARY STENT

### Poly-L-Lactice Acid Polymer

A biopolymer for use in pharmaceutical and medical device applications is poly (L-lactide). The outstanding biocompatibility, high mechanical strength, and low poly-L-lactic acid (PLLA) cost. It is a random and amorphous semi-crystalline polymer with considerable crystallinity. Because to its outstanding mechanical qualities, high-molecular-weight PLLA is employed for clinical purposes, particularly stents.<sup>[10]</sup> PLLA has recently also been utilized as a substrate for stents. The thicker struts of PLLA DESs cause a higher incidence of in-stent thrombosis, and PLLA stents have worse mechanical qualities than those composed of metallic materials.<sup>[11]</sup> Structure and properties of PLLA is shown in Fig. 2.

### Polylactic-Co-Glycolic Acid Polymer

PLGA has been used to make a few of the most intriguing polymeric devices for the engineering of tissue drug delivery. PLGA is an FDA-approved polymer with a broad spectrum of erosion duration adjustable mechanical properties, and—most significantly—biocompatible and biodegradable.<sup>[12]</sup> Lactic and glycolic acids are produced during PLGA polymer biodegradation (Table 1).

### Biomatrix

The Biomatrix DES from Biosensors Europe in Morges, Switzerland, has a coating made of a 50:50 mixture of poly -lactic acid (PLLA) & biolimus-A9. It has a thick strut (150 mm) of 316L stainless steel.<sup>[13]</sup>

### Nobori

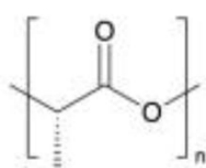
The Nobori DES (Terumo Company, Tokyo, Japan) would be the second BP-DES with substantial clinical evidence; it combines a PLLA polymer with biolimus-A9.<sup>[14]</sup>

### Biomine

Utilising a sirolimus-eluting stent and a cobalt-chromium alloy, the BioMime BP-DES (Meril Life Sciences Pvt.Ltd., Gujarat, India) is an ultra-thin strut design that has shown safe in the MeriT-1 first-in-human trial.<sup>15</sup>

### DESyne BD

The novolimus cobalt chromium platform known as the DESyne BD stent (Elixir Medical Corp., Sunnyvale, CA, USA) features thin struts made of PLLA polymer with a BP coating.<sup>[16]</sup>



| Tensile strength (MPa) | Elastic modulus (GPa) | Glass transition temperature (°C) | Melting temperature (°C) | Degradation time |
|------------------------|-----------------------|-----------------------------------|--------------------------|------------------|
| 15.5–150               | 2.7–4.1               | 55–65                             | 170–200                  | 2–3 years        |

**Fig. 2:** Structure and properties of PLLA

**Table 1:** Biodegradable polymer stent characteristics

| Stent name | Manufacture              | Material | Drug        | Polymer       | Stent thickness |
|------------|--------------------------|----------|-------------|---------------|-----------------|
| Biomatrix  | Biosensors               | 316L     | Biolimus A9 | PLLA          | 120             |
| Biomine    | Meril                    | CoCr     | Sirolimus   | PLLA and PLGA | 65              |
| Cordimax   | Rientech                 | 316L     | Sirolimus   | PLGA          | NA              |
| DESyne BD  | Elixir                   | CoCr     | Navolimus   | PLLA          | 81              |
| Infinium   | Sahajanand Medical Tecsh | 316L     | Paclitaxel  | Polymer blend | 80              |
| Mistent    | Micell Tech.             | CoCr     | Sirolimus   | PLLA          | 64              |
| Nobori     | Terumo                   | 316L     | Biolimus A9 | PLLA          | 120             |
| Orsiro     | Biotronik                | CoCr     | Sirolimus   | PLLA          | 60              |
| Supraflex  | Sahajanand Medical Tech  | CoCr     | Sirolimus   | PLLA/PLGA     | 60              |
| Supralimus | Sahajanand Medical Tech  | 316L     | Sirolimus   | Ploymer blend | 80              |
| Synergy    | Boston Scientific        | PrCr     | Everolimus  | PLGA          | 74              |
| Ultimaster | Terumo                   | CoCr     | Sirolimus   | PLGA          | 80              |

### MiStent

The MiStent (MiCell, Durham, NC, USA) sirolimus-eluting stent with a thin strut design that uses a cobalt chromium combines with a PLGA polymer.<sup>[17]</sup>

### Polymer-free drug-eluting stents

The possibility of “polymer-free” stents has gained attention, with a focus on cutting-edge techniques for preparing stents with anti-ostenosis compounds. The production of polymer-free drug-eluting stents (PF-DES) presents numerous challenges in manufacturing and engineering, particularly with regard to sustaining drug concentration/elution over an extended period of time in the absence of a polymer for conveyance. Modern engineering solutions have been used by manufacturers, including drug reservoirs, crystallization, and textured or non-porous metallic surfaces.<sup>[18]</sup> Examples of platforms that are undergoing clinical testing are shown in Table 2. These technologies are currently the subject of first-in-human studies, and new, creative concepts are constantly being created.

### Yuko

The PF-DES is composed of a pre-mounted micro-structured stainless steel microporous stent and coating device. Translumina, Hechingen, Germany is the Yukon. The hospital performs the drug coating of a stent, using a procedure that allows for flexible drug dosage in accordance with the preferences and requirements of the doctors.<sup>[19,20]</sup>

### Bio Freedom

By retaining biolimus-A9 within the abluminal surface of its stainless-steel construction through a selectively micro-structured surface, the Biofreedom PF-DES (Biosensors Europe) builds on the original success of the Biomatrix stent and its biodegradable polymer. The surface is texturized using a micro-abrasion procedure, which offers a reliable way to bind the medication to the stent interface without requiring polymer.<sup>[21]</sup>

### VESTAsync

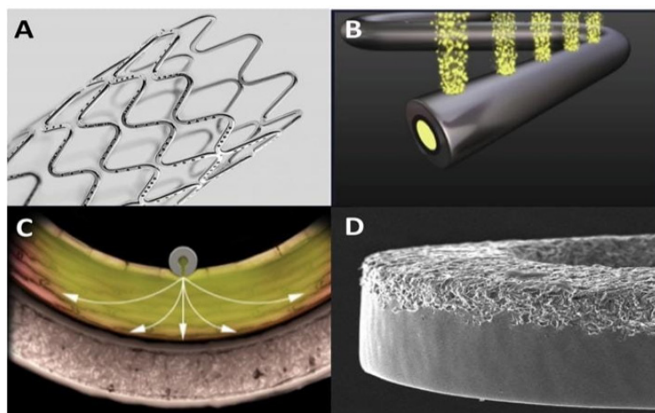
A sirolimus-eluting hydroxyapatite PF-DES is called the VESTAsync (MIV Therapeutics, Atlanta, GA, USA). The device is made up of a microporous hydroxyapatite-covered stainless-steel substrate that carries the biocompatible sirolimus formulation as a medication as shown in Fig. 3.

### Some of the Benefits and Complications of Stents Includes

- A minimally invasive substitute for some situations where a CABG (coronary artery bypass surgery) surgery would have otherwise been necessary
- Effects of maintaining adequate blood flow in a blood artery over time
- Reduce the likelihood of a stroke
- Enhancement of organ performance

**Table 2:** Polymer-free stent characterization

| Stent name             | Manufacturer     | Material | Drug                   | Strut thickness | Mechanism of drug delivery              |
|------------------------|------------------|----------|------------------------|-----------------|---|
| Yukon                  | Translumina      | 316L     | Sirolimus              | 87              | Microporous stent surface               |
| Biofreedom             | Biosensors       | 316L     | Biolimus A9            | 199             | Microstructured abluminal stent surface |
| Dual-DES               | NA               | 316L     | Sirolimus and probucol | 87              | Micropores with shellac resin           |
| VESTAsync              | MIV Therapeutics | 316L     | Sirolimus              | 65              | Microporous hydroxyapatite coating      |
| Drug filled stent(DFS) | Medtronic        | CoCr     | Sirolimus              | NA              | Diffusion from stent core               |



**Fig. 3:** VESTA sync (MIV Therapeutics, Atlanta, GA, USA) (B) exhibits a hollow design with sustained drug elution through diffusion via (C) direct interaction with the vessel wall. (D) The Bio Freedom drug-eluting stent platform (Biosensors Europe, Morges, Switzerland) as seen with electron microscopy, illustrating the highly texturized abluminal surface

- Heart attack life-saving alternative
- Frequently doesn't need general anesthesia
- No apparent scarring

Stenting could appear like the ideal treatment for a clogged blood artery given all of these advantages. There exists a chance of complications, just like with any medical operation. These may consist of:

- Toxic response to the stent material
- Development of a blood clot on the stent
- Complications from the procedure, such as blood vessel harm
- Development of scar tissue surrounding the stent
- Effects of the stent's medicinal coating
- In some circumstances, CABG may still be necessary.

## CONCLUSION

Inflammation and vascular injury induction are the main causes of issues with vascular stent implantation because they stimulate and proliferate intimal stem cells. PLA-based polymers are a promising class of materials because of their excellent biocompatibility and technological suitability for the creation of fully resorbable stents. Because of this, the polymer can function mechanically for a short while before breaking down. Biocompatibility is an essential property of a polymer used in scaffolds or stent coatings. At the moment, materials that have shown to be non-toxic and capable of sustaining cell survival and growth are considered biocompatible. However, the concept of biocompatibility for polymeric coatings and scaffolds has evolved as a result of several in vitro studies and the availability of clinical data. Stent polymer evaluation is mostly dependent on mechanical properties, hydrophilicity of the material, activation of blood cells, and endothelial cell function. The most effective defense against stent thrombosis and in-stent restenosis has been believed to be a confluent and functional endothelium on the luminal surface of cardiovascular stents. As a result, it is crucial that the materials utilized to make cardiovascular stents have antithrombotic and anti-inflammatory properties and hasten the formation and regeneration of endothelium. There is currently insufficient data to

link these biocompatibility issues to material attributes. Thus, the development of biomaterials for medical applications will require not only modifying stent designs and biomaterials to meet physiological requirements but also refining and creating in vitro techniques for sufficient assessment.

## REFERENCES

1. P. Wenaweser, C. Rey, F. R. Eberli et al., "Stent thrombosis following bare-metal stent implantation: success of emergency percutaneous coronary intervention and predictors of adverse outcome," *European Heart Journal*, vol. 26, no. 12, pp. 1180–1187, 2005.
2. S. Windecker and B. Meier, "Late coronary stent thrombosis," *Circulation*, vol. 116, no. 17, pp. 1952–1965, 2007.
3. O. Kantoglu et al. Radiation induced crystallinity damage in poly(L-lactic acid) *Nucl Instrum Methods B*
4. Balla E., Daniilidis V., Karlioti G., Kalamas T., Stefanidou M., Bikiaris N.D., Vlachopoulos A., Koumentakou I., Bikiaris D.N. Poly(lactic acid): A versatile biobased polymer for the future with multifunctional properties—From monomer synthesis, polymerization techniques and molecular weight increase to PLA applications. *Polymers*. 2021;13:1822. doi: 10.3390/polym13111822
5. Pauck R.G., Reddy B.D. Computational analysis of the radial mechanical performance of PLLA coronary artery stents. *Med. Eng. Phys.* 2015;37:7–12. doi: 10.1016/j.medengphy.2014.09.014
6. R.A. Jain The manufacturing techniques of various drug loaded biodegradable poly(lactide-co-glycolide) (PLGA) devices *Biomaterials*(2000)
7. Crotts G, Park TG. Protein delivery from poly (lactic-co-glycolic acid) biodegradable microspheres: Release kinetics and stability issues. *J Microencapsul.* 1998; 15:699–713.
8. S. Windecker and B. Meier, "Late coronary stent thrombosis," *Circulation*, vol. 116, no. 17, pp. 1952–1965, 2007.
9. T. C. Woods and A. R. Marks, "Drug-eluting stents," *Annual Review of Medicine*, vol. 55, pp. 169–178, 2004.
10. Pauck R.G., Reddy B.D. Computational analysis of the radial mechanical performance of PLLA coronary artery stents. *Med. Eng. Phys.* 2015;37:7–12. doi: 10.1016/j.medengphy.2014.09.014.
11. Ang H.Y., Huang Y.Y., Lim S.T., Wong P., Jone M., Foin N. Mechanical behavior of polymer-based vs. metallic-based bioresorbable stents. *J. Thorac. Dis.* 2017;9:923–934. doi: 10.21037/jtd.2017.06.30.
12. Crotts G, Park TG. Protein delivery from poly (lactic-co-glycolic acid) biodegradable microspheres: Release kinetics and stability issues. *J Microencapsul.* 1998; 15:699–713
13. Barlis P, Regar E, Serruys PW, Dimopoulos K, van der Giessen WJ, van Geuns RJM, et al. An optical coherence tomography study of a biodegradable vs. durable polymer-coated limus-eluting stent: a LEADERS trial sub-study. *Eur Heart J* 2010;31:165–76.
14. Chevalier B, Serruys PW, Silber S, Garcia E, Suryapranata H, Hauptmann K, et al. Randomised comparison of Nobori, biolimus A9-eluting coronary stent with a Taxus(R), paclitaxel-eluting coronary stent in patients with stenosis in native coronary arteries: the Nobori I trial. *EuroIntervention* 2007;2:426–34
15. Jain RK, Chakravarthi P, Shetty R, Ramchandra P, Polavarapu RS, Wander GS, et al. One-year outcomes of a BioMime sirolimus-eluting coronary stent system with a biodegradable polymer in all-comers coronary artery disease patients: the MeriT-3 study. *Indian Heart J* 2016;68:599–603.
16. Serruys PW, Garg S, Abizaid A, Ormiston J, Windecker S, Verheye S, et al. A randomised comparison of novolimus-eluting and zotarolimus-eluting coronary stents: 9-month follow-up results of the EXCELLA II study. *EuroIntervention* 2010;6:195–205

17. Wijns W, Vrolix M, Verheye S, Schoors D, Slagboom T, Gosselink M, et al. Randomised study of a bioabsorbable polymer-coated sirolimus-eluting stent: results of the DESSOLVE II trial. *EuroIntervention* 2015;10:1383–90.
18. Chen W, Habraken TC, Hennink WE, Kok RJ. Polymer-free drug-eluting stents: an overview of coating strategies and comparison with polymer-coated drug-eluting stents. *Bioconj Chem* 2015;26:1277–88.
19. Hausleiter J, Kastrati A, Wessely R, Dibra A, Mehilli J, Schratzenstaller T, et al. Prevention of restenosis by a novel drug-eluting stent system with a dose-adjustable, polymer-free, on-site stent coating. *Eur Heart J* 2005;26:1475–81.
20. Mehilli J, Kastrati A, Wessely R, Dibra A, Hausleiter J, Jaschke B, et al. Randomized trial of a nonpolymer-based rapamycin-eluting stent versus a polymer-based paclitaxel-eluting stent for the reduction of late lumen loss. *Circulation* 2006;113:273–9
21. Harada Y, Kastrati A. Interventional cardiology: polymer-free drug-eluting stents – a safe and effective option for ACS. *Nat Rev Cardiol* 2016;13:447–8.

**HOW TO CITE THIS ARTICLE:** Geetha K, Anila S, Bindhu MS. A Review on Coronary Stents: With Polymers and without Polymers. *J Adv Sci Res*. 2024;15(3): 1-5 **DOI:** 10.55218/JASR.2024150301