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Developing Radio Opaque Coating Study of Bioresorbable Scaffold

Dr. Pramod Kumar Minocha, Kothwala Deveshkumar Mahendralal, Dave Arpit Pradipkumar

Meril Life Sciences Pvt. Ltd., Vapi, India

Email address:
devesh.kothwala@merillife.com (K. D. Mahendralal)

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Abstract: Previous technologies may not be able provide radio-opaque biodegradable polymers that are degraded and completely eliminated by the body and also have good visibility when implanted in a human or an animal body. The study of radio opaque bioresorbable polymer such as poly lactide [poly-L-lactide (PLLA), poly-D-lactide (PDLA)], polyglycolide, polydioxanone, polycaprolactone, or related copolymers materials, each of which have a characteristic degradation rate in the body. Bioresorbable scaffold acts as radio opaque coating material to evaluate the flaking out/dissipation of coated material changes occur in morphological properties at specific temperatures with qualities in specific time period at specific intervals. This study covers radio opaque coating over bioresorbable polymeric implant intended for use in cardiovascular treatments. The coating was observed at interval of days at a specified temperature of 37°C. In X-ray film, the radio opaque coating of 50% TIBA on bioresorbable scaffold revealed excellent radiopacity and clear morphology. The development of new class of radio-opaque polymer i.e. biocompatible polymers with the capability of absorbing x-rays. In many clinical applications, it is highly desirable that an implant can be visualized via routine x-ray fluoroscopy. This allows the physician to monitor location and for implants in a non-invasive manner.

Keywords: Radiopaque, Radiopacity, Bioresorbable/Biodegradable Scaffold, TIBA

1. Introduction

Bioresorbable scaffolds made up of polymeric materials, these materials are hard to detect in the fluoroscopy or other visualization techniques in pre- and post-deployment of the device at the target site [3, 10]. The application of a radio opaque coating on a bioresorbable scaffold improves precision and makes it easier for physicians or surgeons to track the device during deployment [4, 5]. The term "bioresorbable/biodegradable" refers to a substance that degrades in a biological environment by either a physiologically aided process, such as an enzyme-catalyzed reaction, or a chemical mechanism that can occur in a biological medium [2, 16]. The most efficient method would be to apply a coating of a fully dense radio opaque solution to all surfaces. The coating would have to be thick enough to produce acceptable x-ray contrast, as well as bio-medically safe and corrosion resistant [22, 15, 7]. One of such digital technology is the x-ray, where an implanted device is required to be observed in cardiovascular, lymphatic, neurological, integumental, skeletal, optical, nasal and oral parts of the body [1, 19]. Therefore, to improve radiographic visibility, a sufficient amount of radio opacity is required to detect the precise location of the implant at the site of a lesion or deployment. Additionally, it can also help to monitor the healing process and degradation rate of bioresorbable implants [27]. Bioresorbable scaffolds which comprise solely biodegradable and biocompatible materials are considered one of the most promising technologies in interventional cardiology [14]. Exogenously injecting a radio opaque substance, which is distributed in the tissue to be studied, can increase attenuation of soft tissue by x-ray radiation in medical imaging procedures such as X-ray imaging [13, 25]. The injected chemical absorbs x-ray photons in the tissue more efficiently, improving image quality [6]. As a result of the improved image, the medical condition may be diagnosed more accurately. Fluoroscopic angiography is used in numerous surgical procedures to view the deployment of bioabsorbable implanted devices in the human or animal body [12, 20]. Most biodegradable polymers used in modern clinical practice, on the other hand, have low visibility when viewed with standard medical imaging equipment [26, 8]. To create the absorbable polymer radio opaque, it must be composed of a material with a radiographic density greater than the surrounding host tissue, as well as a thickness sufficient to alter radiation transmission and provide contrast in the image [11, 18]. The biodegradable polymer must be chemically and physically changed to increase visibility. The radio opacity aids in the monitoring of implant migration away from the insertion site or implant deterioration [9]. There is a high demand for radio opaque polymers that decay quickly in the body and have no adverse effects. Polymers with high visibility under medical imaging scanners are also required [13, 24]. A radio opaque coating on medical equipment can resist the high stresses associated with its use without delamination. The most efficient way would be to cover all surfaces with a totally dense radio opaque substance [23, 17]. The coating would need to be thick enough to provide adequate X-ray contrast, as well as bio medically suitable and corrosion resistant [21, 28]. The main aim of the study is to provide the radio opaque coating to the bioresorbable scaffold for high visibility. The coating should be applied through spray coating method along with mixture of Polymer and TIBA. There were a different percentage of coating solution applied for the measure the radiopacity and visibility.

2. Material and Methods

Radio opaque layer includes radio opaque solution mixed with a bioabsorbable polymer. The radio opaque solution can be in particulate or granular form. Radio opaque layer includes particles mixed with a polymer. The study of radio opaque bioresorbable polymer like poly lactide [poly-L-lactide (PLLA), poly-D-lactide (PDLA)], polyglycolide, polydioxanone, polycaprolactone, polygluconate, polylactic acid-polyethylene oxide copolymers, modified cellulose, collagen, or related copolymers materials. The radio opaque layer can have a sufficient amount of radio opaque solution to make the stent fluoroscopically visible. The amount of radio opaque solution can be adjusted to obtain a desired degree of radiopacity. The required radial thickness of the radio opaque layer can be achieved to provide a desired degree of fluoroscopic visibility. The solution can further include radio opaque particles suspended or dissolved in the solvent. The coating may be applied by immersing the scaffold in the coating solution, by spray-coating, drop coating, or by other methods known. For study, we used the bioresorbable polymer due to its slow degradation rate and its preferable characteristics. To coat stents, spray coating method is used to achieve efficient radio-opaque coatings. The formulation of bioresorbable polymer: TIBA (Triiodobenzoic acid) allows for regulated the effect of radio opacity. Moreover, to make the spray coating procedure easier, the formulation can be dissolved in a suitable solvent like DCM (Dichloromethane). Dichloromethane, methylene chloride, chloroform, acetone, methanol, and combinations of these are example of some solvents. The stent is coated with a ratio of 50:50 mixture of Polymer and TIBA (Triiodobenzoic acid) using the spray coating process. To make the spray coating procedure easier, the Polymer and TIBA solution in a 50:50 w/w proportion can be dissolved in a suitable solvent (DCM) and utilized for coating in one example. By spraying the solution on the stent using a spray coating equipment results in a homogeneous and smooth coating. The parameters of the spray coating process must be precisely managed. These variables include the distance between the stent and the spray cannon tip, collate rotation, solution flow rate, and spraying inert gas pressure thickness of stent. The criteria for coating include a spacing of 4 to 10 cm between the spray gun tip and the stent. The collate may rotate at a speed of 9 to 20 rpm. The oscillation rate of spray cannon can range from 35 to 60 times per minute. The inert gas is nitrogen at a pressure of 1.0 to 2.5 kg/cm^2. The flow rate of solution is regulated between 0.15 and 0.30 ml/min. The thickness was discovered to be between 5 to 6 micron. The stent is kept under vacuum after the coating procedure to evaporate the solvent. The stent is subsequently crimped onto the catheter of the balloon. Crimping is a crucial and important procedure. It should not affect the stent surface and cause no mechanical damage to the coating or to the stent. Crimping can change the characteristics of the polymer, and hence the stent qualities. Crimping parameters alter with stent length and balloon size for successful crimping. The crimping temperature is kept between 20°C to 40°C. The radio opacity of a polymer stent is insufficient for it to be detectable in X-ray imaging. The stent is made visible in X-ray imaging.

3. Result and Discussion

A medical device has a radio opaque coating that can withstand the high strains inherent in the use of such devices without delamination. Bioresorbable polymer is radiolucent, which requires the scaffolds to have radio opaque embedded in each end so that the physician can identify the location of the scaffold under fluoroscopy. Biodegradable polymer has their valuable and adjustable characteristics such as biocompatibility, biodegradability, good mechanical properties, etc. radio opaque coating should withstand the high strains over the devices during pre-deployment and post-deployment procedures without delamination. To observe the morphological changes in coating properties, the study was conducted with different formulation percentage of 35%, 45% and 50% of TIBA along with ratio of bioresorbable polymer. With the coating solution of 35% TIBA, there is an average x-ray visibility (same as without radio opaque coating). Further, the coating carried out with 50% TIBA in the coating formulation, resulting an excellent x-ray visibility. The radio opaque coated bioresorbable scaffold should be tested for the morphological characteristics. The coating studies should be carried out at an interval period of 0, 2, 4, 6, 8, 10 and 12 days by the visual inspection. The coating has a significant impact on the stability and durability of polymer material inside the scaffold which can have significant implications for product safety and dependability.

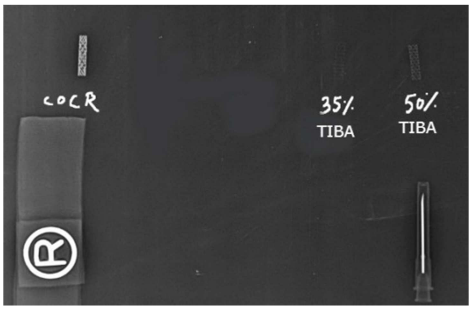

Figure 1. *Radiopacity of Bioresorbable scaffold.*

1. The study was conducted at 0 day along with 37°C temperature after completing the radio opaque coating (50%) in real time (after solvent evaporation). According to the results, the uniform surface coating of the sample was observed in figure 2.

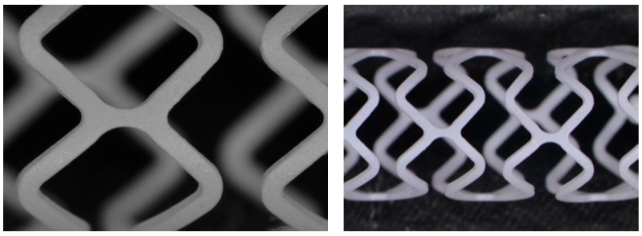

Figure 2. *Coating surface after a zero-day interval.*

2. This study was conducted at 2 day interval along with 37°C temperature after completing the radio opaque coatings 50 percent in real time (after solvent evaporation). According to the analysis, no major degradation was observed after 2 day (48 hours) observed in figure 3.

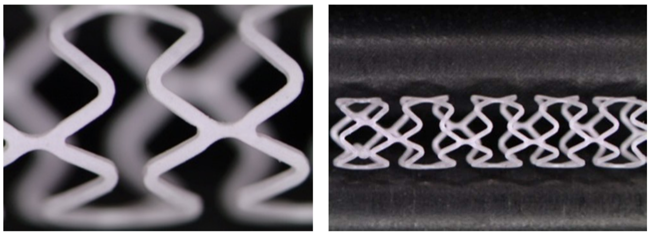

Figure 3. *Coating surface after a two-day interval.*

3. The study was conducted at 4 day along with 37°C temperature after completing the radio opaque coating (50%) in real time (after solvent evaporation). According to the results, there was no removal of coating after 4 days and the salt deposition is shown in figure 4.

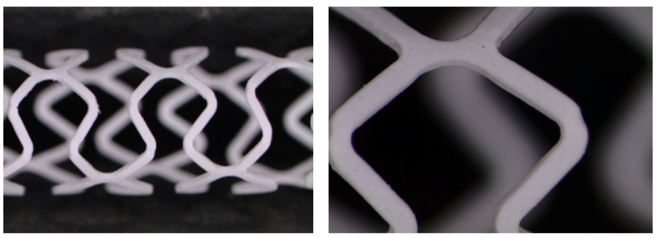

Figure 4. *Coating surface after a four-day interval.*

4. The study was conducted at 12 day along with 37°C temperature after completing the radio opaque coating (50%) in real time (after solvent evaporation). Analysis of results concluded that the coating did not degrade significantly or remove significantly observed in figure 5.

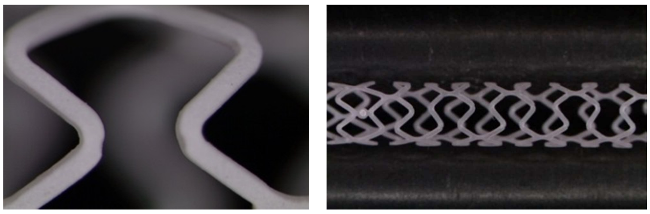

Figure 5. *Coating surface after a twelve-day interval.*

4. Conclusion

The morphological characteristics of the final device have been used to analyze the radio opacity of coated bioresorbable scaffold. The x-ray visibility of the radio opaque coating with the 50 percent TIBA radio opaque coating formulation was discovered to be consistent in coating surface and that no ablation of the coating surface observed at different time intervals. Because the polymer has degradation feature, the coating also undergoes degradation along with time due to presence of bioresorbable (degradable) polymer in the coating material. The achieved results of radio opaque coating lasts for around 12 days (as shown in results) which is advantageous to trace the device in the body before and after implantation. There will be a scope for further research into the long-term coating attributes over bioresorbable scaffolds that may include the radio opaque coating by changing composition of the coating with one or more parameters or components which may last for more than 12 days.

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