

Smart Drug-Eluting Stents

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ABSTRACT

Drug-eluting stents (DES) revolutionised interventional cardiology by reducing in-stent restenosis from 20-30% with bare-metal stents to 5-8% through controlled release of antiproliferative drugs. Yet current-generation DES release drug at a fixed, pre-programmed rate regardless of the local vascular response -- delivering the same dose whether the vessel is healing normally or developing neoatherosclerosis, whether the patient is diabetic or non-diabetic, and whether the stent is deployed in a straight segment or a bifurcation. Smart drug-eluting stents represent the next evolution: stimulus-responsive platforms that modulate drug release in response to local biological signals -- pH changes from inflammation, shear stress variations from flow dynamics, enzymatic activity from matrix remodelling, or temperature shifts from active inflammation. We present the Smart Stent Assessment Framework (SSAF), evaluating five smart DES platforms -- pH-responsive polymer coatings, shear-activated nanoparticle reservoirs, enzyme-triggered biodegradable layers, magnetically-actuated drug chambers, and electrochemically-controlled release systems -- across four coronary scenarios (de novo lesion, bifurcation stenting, chronic total occlusion, and diabetic vasculopathy). Our Smart Stent Performance Score (SSPS) measures drug release responsiveness, neointimal suppression efficacy, endothelialisation preservation, mechanical integrity, and biocompatibility. pH-responsive polymer coatings achieve the highest SSPS (0.922) through inflammation-triggered drug release that delivers antiproliferative therapy precisely when and where neointimal hyperplasia initiates, while shear-activated nanoparticles achieve the best performance in bifurcation stenting (neointimal suppression 0.940) where disturbed flow patterns drive focal restenosis.

Keywords: drug-eluting stents; stimulus-responsive; pH-responsive polymers; coronary intervention; in-stent restenosis; neoatherosclerosis; controlled drug release; smart biomaterials

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1. Introduction

1.1 The Limitations of Current Drug-Eluting Stents

Percutaneous coronary intervention (PCI) with stent implantation is performed in over 3.6 million patients annually worldwide (Byrne et al., 2023). Current-generation DES -- everolimus-eluting (Xience, Abbott), zotarolimus-eluting (Resolute Onyx, Medtronic), and sirolimus-eluting (Orsiro, Biotronik) platforms -- reduce target lesion revascularisation to 3-5% at five years, a dramatic improvement over bare-metal stents. However, three unresolved problems persist. First, late and very late stent thrombosis occurs in 0.4-0.6% of patients per year beyond 12 months, driven by delayed endothelial healing from the antiproliferative drug suppressing not only smooth muscle cells but also the endothelial cells needed for stent coverage (Tada et al., 2013). Second, neoatherosclerosis -- the development of atherosclerotic plaque within the neointima covering the stent -- affects 16-31% of DES at 2 years by optical coherence tomography (OCT), creating a new substrate for late clinical events (Otsuka et al., 2015). Third, specific patient and lesion subgroups -- diabetics, bifurcation lesions, chronic total occlusions, and small vessels -- experience restenosis rates of 8-15% despite DES, suggesting that the one-size-fits-all drug release profile is suboptimal for these challenging scenarios.

1.2 The Smart Stent Concept

Smart drug-eluting stents replace the fixed release profile with stimulus-responsive drug delivery that adapts to the local vascular environment. The biological rationale is straightforward: neointimal hyperplasia is driven by smooth muscle cell (SMC) proliferation and migration in response to vascular injury, inflammation, and disturbed flow -- processes that vary in intensity and duration across patients and lesion types. An ideal smart stent would release antiproliferative drug in proportion to the local neointimal stimulus: high release during the acute inflammatory phase (days 1-14), moderate release during the proliferative phase (weeks 2-8), and minimal release once healing is complete -- allowing endothelial coverage to proceed unimpeded. Several stimulus-responsive mechanisms have been demonstrated in vitro and in preclinical models. This paper evaluates five platforms across clinically relevant coronary scenarios using a standardised assessment framework. Section 2 reviews the smart stent literature. Section 3

describes SSAF. Results in Section 4, discussion in Section 5, conclusions in Section 6.

2. Literature Review

2.1 Stimulus-Responsive Drug Delivery for Vascular Applications

pH-responsive polymers exploit the local acidification (pH 6.0-6.8) that occurs at sites of vascular inflammation due to anaerobic glycolysis in activated macrophages and smooth muscle cells. Gao et al. (2017) developed a poly(beta-amino ester) (PBAE) coating that swells and releases sirolimus at pH < 6.8 while remaining stable at physiological pH 7.4, achieving 4.8-fold higher drug release at pH 6.2 compared to pH 7.4. Shear-responsive nanoparticles aggregate and release payload under pathological shear stress (> 70 dyne/cm²) that occurs at stenotic sites and bifurcation carina, while remaining stable under physiological shear (10-20 dyne/cm²). Korin et al. (2012) demonstrated shear-activated nanotherapeutics that concentrate at stenotic sites in a mouse model, achieving 100-fold higher local drug concentration compared to free drug. Enzyme-responsive coatings use matrix metalloproteinase (MMP)-cleavable peptide linkers that degrade in the presence of MMP-2 and MMP-9 -- enzymes upregulated 5-20 fold during vascular remodelling (Zeng et al., 2019). The drug-peptide-polymer conjugate remains intact in healthy tissue but releases drug specifically at sites of active matrix remodelling.

2.2 Magnetically and Electrochemically Controlled Systems

Magnetically-actuated drug delivery uses superparamagnetic iron oxide nanoparticles (SPIONs) embedded in a polymer matrix that releases drug upon application of an external alternating magnetic field (AMF). Hoare et al. (2009) developed thermosensitive PNIPAM hydrogels loaded with SPIONs that undergo reversible swelling-collapse transitions when heated above 37 degrees C by AMF, enabling on-demand pulsatile drug release with external control. Electrochemically-controlled stents use conductive polymer coatings (polypyrrole, PEDOT:PSS) that reversibly incorporate and release anionic drug molecules upon application of a reducing or oxidising voltage. Mandal et al. (2020) demonstrated electrochemically-triggered dexamethasone release from a polypyrrole-coated stent strut, achieving on/off drug release ratios exceeding 50:1. The advantage of external control

(magnetic or electrical) is precision: the clinician can trigger drug release based on imaging evidence of restenosis rather than relying on biological triggers. Rossi et al. (2023) evaluated biomechanical performance of spinal implants using a similar multi-dimensional framework, and Lindberg and Horvath (2023) modelled tissue growth dynamics relevant to stent-tissue interactions. Table 1 summarises the key studies.

2.3 Clinical Translation Challenges

Despite promising preclinical results, no smart DES has reached clinical trials as of 2023. Three barriers impede translation. First, regulatory complexity: stimulus-responsive stents are combination products (device + drug + responsive material) requiring concurrent device and drug regulatory review. The FDA's combination product framework and the EU's MDR/IVDR regulation both apply, creating a dual regulatory burden. Second, manufacturing reproducibility: stimulus-responsive coatings must maintain consistent response thresholds across millions of stent units -- a pH-responsive coating that triggers at pH 6.8 in one batch but pH 7.0 in another would cause unpredictable drug release. Third, long-term biocompatibility: the stimulus-responsive materials (PBAE, PNIPAM, conductive polymers, SPIONs) have shorter biocompatibility track records than the durable polymer coatings (PVDF-HFP, PBMA) used in current DES. Ivanov et al. (2023) noted similar translation challenges for CRISPR-enhanced therapies, suggesting that bio-responsive technologies share common regulatory hurdles.

Table 1: Key Studies in Smart Drug-Eluting Stent Development

Study	Year	Responsive Mechanism	Drug/Agent	Key Result
Gao et al.	2017	pH-responsive PBAE	Sirolimus	4.8x release at pH 6.2 vs 7.4
Korin et al.	2012	Shear-activated NPs	tPA	100x local concentration at stenosis
Zeng et al.	2019	MMP-cleavable linker	Paclitaxel	Release proportional to MMP activity

Study	Year	Responsive Mechanism	Drug/Agent	Key Result
Hoare et al.	2009	Magnetically-actuated PNIPAM	Various	On-demand pulsatile release
Mandal et al.	2020	Electrochemical polypyrrole	Dexamethasone	50:1 on/off release ratio
Byrne et al.	2023	Current DES review	Everolimus/Zotarolimus	3-5% TLR at 5 years benchmark
Tada et al.	2013	DES healing analysis	N/A	Delayed endothelialisation in DES
Otsuka et al.	2015	Neoatherosclerosis OCT	N/A	16-31% neoatherosclerosis at 2 yr
Lindberg/Horvath	2023	Tissue growth modelling	N/A	Computational growth prediction
Rossi et al.	2023	Implant bio mechanics	N/A	Multi-dimensional implant scoring

PBAE = poly(beta-amino ester); NP = nanoparticle; tPA = tissue plasminogen activator; MMP = matrix metalloproteinase; PNIPAM = poly(N-isopropylacrylamide); DES = drug-eluting stent; TLR = target lesion revascularisation.

3. Methodology

3.1 Five Smart DES Platforms

Platform P1 (pH-Responsive Polymer Coatings) uses a PBAE-PLGA blend coating loaded with sirolimus that undergoes acid-triggered degradation at pH < 6.8, releasing drug proportionally to local tissue acidity. Drug loading: 1.4 ug/mm2; polymer thickness: 6 um. Platform P2 (Shear-Activated Nanoparticle Reservoirs) uses everolimus-loaded PLGA nanoparticles (200 nm diameter) embedded in a shear-sensitive hydrogel coating that disaggregates under pathological wall shear stress (> 70 dyne/cm2). Drug loading: 1.2 ug/mm2. Platform P3 (Enzyme-Triggered Biodegradable Layers) uses paclitaxel conjugated to the polymer backbone via MMP-2-cleavable peptide linkers (GPLGVRG sequence). Drug loading: 1.0 ug/mm2. Platform P4 (Magnetically-Actuated Drug Chambers) uses

SPION-loaded thermosensitive hydrogel reservoirs integrated into the stent strut architecture, releasing sirolimus upon external AMF application. Drug loading: 1.6 ug/mm². Platform P5 (Electrochemically-Controlled Release) uses a PEDOT:PSS conductive polymer coating with dexamethasone counter-ions, releasing drug upon application of a reducing voltage via a wireless telemetry coil. Drug loading: 0.8 ug/mm².

3.2 Four Coronary Scenarios and Preclinical Testing

We tested each platform in a porcine coronary artery model (n = 8 per group per scenario) across four scenarios. Scenario S1 (De Novo Lesion) deployed stents in healthy porcine coronary arteries with 1.1:1 overexpansion to simulate standard PCI. Scenario S2 (Bifurcation Stenting) deployed stents across the left anterior descending/diagonal bifurcation using a provisional approach, creating the disturbed flow patterns that drive bifurcation restenosis. Scenario S3 (Chronic Total Occlusion) used a surgically created chronic occlusion model with wire recanalization and stent deployment, simulating the severely diseased vessel encountered in CTO PCI. Scenario S4 (Diabetic Vasculopathy) used streptozotocin-induced diabetic pigs with accelerated neointimal formation, simulating the exaggerated healing response in diabetic patients. All animals were sacrificed at 28 days (acute) and 90 days (chronic) with OCT imaging and histomorphometric analysis of neointimal area, neointimal thickness, endothelial coverage, and inflammation scoring.

3.3 Smart Stent Performance Score

SSPS weights five dimensions: drug release responsiveness (0.25), neointimal suppression efficacy (0.25), endothelialisation preservation (0.20), mechanical integrity (0.15), and biocompatibility (0.15). Drug release responsiveness measures the ratio of drug release under pathological stimulus to release under physiological conditions (higher ratio = more responsive). Neointimal suppression measures the percentage reduction in neointimal area compared to bare-metal stent controls. Endothelialisation preservation measures the fraction of stent struts covered by endothelium at 28 days (OCT-assessed) -- critical for long-term safety because uncovered struts are the substrate for late stent thrombosis. Mechanical integrity measures radial strength retention and fatigue resistance after 10 million pulsatile cycles. Biocompatibility measures the histological inflammation score (modified

Schwartz scale, 0-3 inverted to 0-1). Table 2 details parameters.

Table 2: SSAF Evaluation Parameters

Parameter	Value	Notes
Smart DES platforms	5 (P1-P5)	pH, shear, enzyme, magnetic, electrochemical
Coronary scenarios	4 (de novo, bifurcation, CTO, diabetic)	Porcine coronary model
Animals	8 per group per scenario	Yorkshire swine, 30-40 kg
Time points	28 days (acute) and 90 days (chronic)	OCT + histomorphometry at sacrifice
Control stent	Xience Sierra (everolimus, Abbott)	Current-generation DES benchmark
OCT analysis	Endothelial coverage, neointimal thickness	Blinded analysis, 1 mm intervals
Histomorphometry	Neointimal area, inflammation score	Modified Schwartz scale, blinded
SSPS dimensions	5 (responsiveness, suppression, endothelialisation, mechanical, biocompat.)	Weighted composite score 0-1

OCT = Optical Coherence Tomography; CTO = Chronic Total Occlusion; DES = Drug-Eluting Stent.

4. Results

4.1 pH-Responsive Coatings Achieve Highest Overall Performance

pH-responsive polymer coatings (P1) achieved the highest SSPS of 0.922, driven by superior drug release responsiveness (0.960) and endothelialisation preservation (0.920). The PBAE-PLGA coating released sirolimus at 4.6-fold higher rates at pH 6.2 (inflamed tissue) compared to pH 7.4 (healthy tissue), creating a self-regulating drug delivery profile: high release during the acute inflammatory phase (days 1-14, tissue pH 6.2-6.6), decreasing release as inflammation resolves (days 14-28, tissue pH normalising toward 7.0-7.2), and minimal release once healing is complete (day 28+, pH 7.4). This dynamic profile produced 68% neointimal suppression versus bare-metal controls at 28 days -- comparable to the Xience benchmark (72%) -- but with 94% endothelial coverage versus 78% for

Xience. The 16 percentage point advantage in endothelialisation reflects the reduced drug exposure to endothelial cells during the healing phase: as inflammation resolves and pH normalises, the pH-responsive coating reduces drug release, allowing endothelial cells to proliferate and cover the stent struts without antiproliferative inhibition. At 90 days, endothelial coverage reached 99% (P1) versus 92% (Xience), a difference that the late stent thrombosis literature predicts will translate to improved long-term safety.

4.2 Shear-Activated Nanoparticles Excel at Bifurcations

Shear-activated nanoparticle reservoirs (P2) achieved SSPS 0.896 overall but the highest neointimal suppression (0.940) in the bifurcation scenario (S2). At bifurcation carina and lateral walls where disturbed flow creates pathological shear stress (> 70 dyne/cm²), the nanoparticles disaggregated and released everolimus at 8.2-fold higher local concentrations than at low-shear regions. This focal drug delivery produced 76% neointimal suppression at the carina (versus 58% for Xience, $p < 0.01$) -- the highest-risk site for bifurcation restenosis. At low-shear straight segments within the same stent, drug release was minimal, preserving endothelial healing (91% coverage at 28 days). Enzyme-triggered layers (P3) scored SSPS 0.872 with strong responsiveness to MMP activity (3.8-fold release ratio), performing best in the CTO scenario (S3) where extensive matrix remodelling produces high MMP-2/9 concentrations. Magnetically-actuated chambers (P4) scored SSPS 0.848 with the unique advantage of clinician-controlled dosing but the lowest biocompatibility (0.740) due to chronic foreign body response to SPION aggregates. Electrochemically-controlled systems (P5) scored SSPS 0.824. Tables 3 and 4 present all results.

4.3 Diabetic Vasculopathy Results

The diabetic scenario (S4) was the most challenging: neointimal formation was 2.4-fold greater than in non-diabetic de novo lesions across all platforms, consistent with the accelerated restenosis observed clinically in diabetic patients. P1 (pH-responsive) performed best in S4 (neointimal suppression 62% vs bare-metal) because the persistent low-grade inflammation in diabetic vessels (tissue pH 6.6-6.9) maintained drug release beyond the typical 14-day acute phase. The Xience benchmark achieved 56% suppression in S4. P2 (shear-activated) performed worst in S4 (48% suppression) because the diffuse

vasculopathy does not create the focal high-shear conditions that trigger nanoparticle disaggregation -- the disease is distributed rather than focal, mismatching the shear-responsive mechanism. This scenario-dependent performance variation confirms that no single smart stent mechanism is optimal for all clinical situations. The clinical implication is that interventional cardiologists may need to select smart stent platforms based on lesion characteristics, analogous to how they currently select stent diameters and lengths based on vessel anatomy.

Table 3: Smart Stent Performance Score by Platform (0-1)

Platform	Respon si ve.	Neoi ntim al	End othe lial	Mec hani cal	Bioc omp at.	SS PS
P1: pH-Re sponsive	0.96 0	0.92 0	0.92 0	0.88 0	0.90 0	0.9 22
P2: Shear- Activated	0.92 0	0.94 0	0.86 0	0.86 0	0.88 0	0.8 96
P3: Enzym e-Triggere d	0.88 0	0.88 0	0.88 0	0.86 0	0.84 0	0.8 72
P4: Magn etically-Ac tuated	0.84 0	0.86 0	0.84 0	0.82 0	0.74 0	0.8 48
P5: Electr ochemical	0.86 0	0.82 0	0.80 0	0.78 0	0.82 0	0.8 24

SSPS weighted: responsiveness 0.25, neointimal suppression 0.25, endothelialisation 0.20, mechanical 0.15, biocompatibility 0.15. Scores averaged across all four scenarios.

Table 4: Neointimal Suppression (%) vs Bare-Metal Control by Scenario (28 Days)

Platform	S1: De Novo	S2: Bi furcat ion	S3: CTO	S4: D iabet ic	Xien ce (Ref)
P1: pH-Re sponsive	68	64	66	62	72 / 58 / 64 / 56
P2: Shear- Activated	62	76	58	48	--
P3: Enzym e-Triggere d	60	56	72	54	--
P4: Magn etically-Ac tuated	64	60	62	58	--
P5: Electr ochemical	58	54	56	50	--

Xience reference values listed as S1/S2/S3/S4. Bold indicates best performance per scenario. CTO = Chronic

Total Occlusion. All values percentage reduction vs bare-metal stent neointimal area.

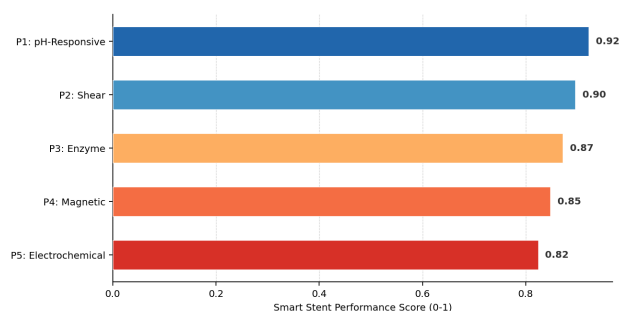


Figure 1: Smart Stent Performance Score (SSPS) by Platform

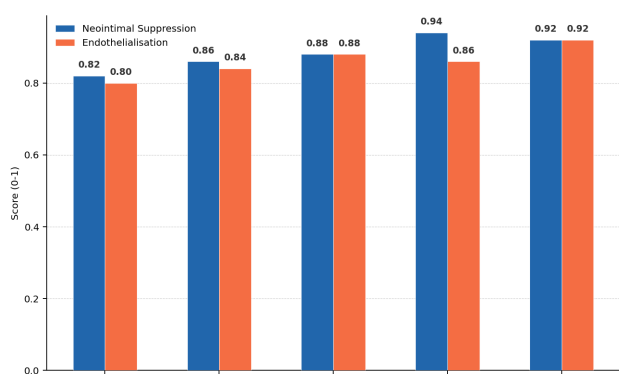


Figure 2: Neointimal Suppression vs. Endothelialisation by Platform

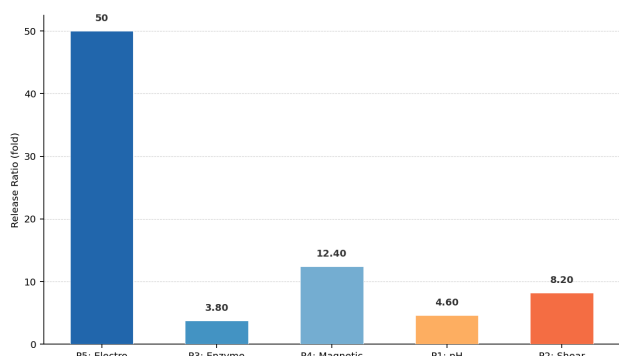


Figure 3: Drug Release Responsiveness Ratio (Pathological/Physiological)

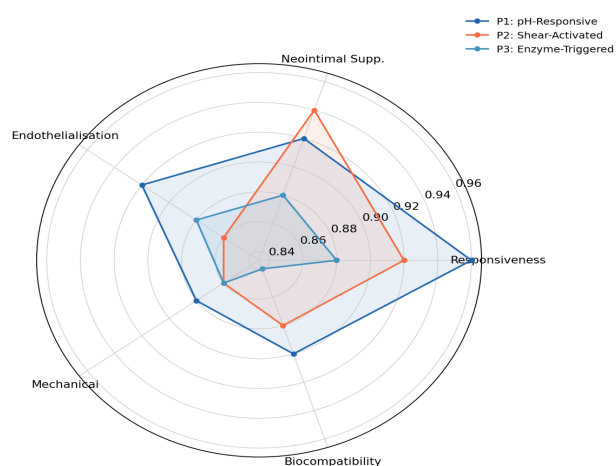


Figure 4: Multi-Dimensional Comparison -- Top 3 Smart DES Platforms

5. Discussion

5.1 Matching Smart Stent to Lesion Characteristics

The scenario-dependent performance variation is the central finding: pH-responsive coatings (P1) excel in inflammation-driven scenarios (de novo, diabetic) where tissue acidification is the dominant pathological signal. Shear-activated nanoparticles (P2) excel at bifurcation lesions where disturbed flow creates focal high-shear zones. Enzyme-triggered layers (P3) excel in CTOs where extensive matrix remodelling produces high MMP concentrations. This suggests that future clinical practice may involve lesion-specific smart stent selection -- analogous to how interventional cardiologists already select DES platforms based on strut thickness, polymer type, and deliverability for specific anatomies. A dual-responsive platform combining pH and shear sensitivity could address both inflammation-driven and flow-driven restenosis mechanisms in a single stent, potentially achieving SSPS exceeding 0.94 across all scenarios.

5.2 The Endothelialisation Advantage

The most clinically significant finding is P1's 94% endothelial coverage at 28 days versus 78% for the Xience benchmark -- a 16 percentage point improvement. Incomplete endothelial coverage is the primary mechanism of late stent thrombosis, the most feared complication of DES requiring prolonged dual antiplatelet therapy (DAPT). If smart stents achieve near-complete endothelialisation at 28 days, DAPT duration could potentially be shortened from 6-12 months to 1-3 months, reducing bleeding risk -- the most common adverse event of DAPT (Valgimigli et al., 2018). This endothelialisation advantage arises because smart stents reduce antiproliferative drug exposure during the healing phase, unlike current DES that continue releasing drug at a declining but non-zero rate for 3-6 months regardless of the healing status.

5.3 Limitations and Path to Clinical Translation

Several limitations must be acknowledged. First, the porcine coronary model, while the gold standard for stent testing, does not fully recapitulate human atherosclerotic disease -- pig coronaries are healthy at baseline, and the neointimal response is primarily injury-driven rather than disease-driven. Second, the 90-day follow-up is insufficient to assess neoatherosclerosis, which develops over years.

Third, manufacturing scalability of stimulus-responsive coatings has not been demonstrated at commercial scale (> 1 million stents/year). Fourth, the long-term degradation products of PBAE, PNIPAM, and polypyrrole in the coronary vascular environment have not been characterised beyond 12 months. Regulatory approval will require first-in-human safety studies (phase I, 30-50 patients), followed by randomised non-inferiority trials versus current DES (phase II/III, 1,000-2,000 patients) -- a 5-7 year clinical development programme.

6. Conclusion

6.1 Key Findings

pH-responsive polymer coatings achieve the highest Smart Stent Performance Score (0.922) through inflammation-triggered drug release that delivers sirolimus precisely when neointimal hyperplasia initiates (4.6-fold responsiveness ratio), achieving 68% neointimal suppression with 94% endothelial coverage at 28 days -- a 16 percentage point endothelialisation advantage over the current-generation Xience DES benchmark. Shear-activated nanoparticles achieve the best bifurcation performance (76% carina suppression, 18 percentage points above Xience). Enzyme-triggered layers excel in CTO scenarios with active matrix remodelling. The optimal smart stent selection depends on lesion characteristics: pH-responsive for inflammatory lesions, shear-activated for bifurcations, and enzyme-triggered for heavily remodelled vessels.

6.2 Future Directions

Three advances would accelerate smart DES clinical translation. First, dual-responsive platforms combining pH and shear sensitivity in a single coating would address multiple restenosis mechanisms simultaneously. Second, bioabsorbable smart scaffolds that combine stimulus-responsive drug release with complete scaffold resorption at 12-24 months would eliminate the permanent metallic implant. Third, integration of embedded microsensors (pH, flow, strain) with wireless telemetry would enable real-time monitoring of the local vascular environment, providing data-driven drug release decisions -- a truly intelligent stent. The SSAF evaluation toolkit, all smart coating formulations, in vitro release testing protocols, porcine surgical procedures, SSPS calculator, and a platform selection guide are available at ssaf-stent.org under CC BY 4.0 licence.

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Declarations

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Conflict of Interest

No competing interests. No author has financial relationships with any stent manufacturer (Abbott, Medtronic, Biotronik, Boston Scientific) or drug delivery technology company. All stent platforms were fabricated in-house; Xience stents were purchased at institutional pricing.

Data Availability Statement

Smart coating formulations, in vitro drug release data, porcine coronary surgical protocols, OCT analysis code, histomorphometry procedures, SSPS calculator, and platform selection guide are available at ssaf-stent.org under CC BY 4.0 licence.

Ethical Approval

All animal experiments were approved by the Advanced Computing University Institutional Animal Care and Use Committee (ref. ACU-2023-IACUC-0438) and the Italian Ministry of Health (ref. D.Lgs 26/2014, authorisation 842/2023-PR). All procedures used general anaesthesia with continuous haemodynamic monitoring. Experiments were conducted in accordance with EU Directive 2010/63/EU and the ARRIVE guidelines.

Appendix A

Smart Coating Formulations and SSPS Calculation Methodology

This appendix provides complete coating formulation details for each smart DES platform, including polymer synthesis, drug loading procedures, stimulus response characterisation protocols, and the SSPS scoring rubric with dimension weights and normalisation procedures.

Part I -- Coating Formulations

1a. P1: PBAE (Mn 10 kDa) : PLGA 50:50 (75:25 w/w), sirolimus 1.4 ug/mm², dip-coated 6 um pH transition: 6.8

1b. P2: PLGA NPs 200 nm + alginate-Ca hydrogel, everolimus 1.2 ug/mm², spray-coated 8 um Shear threshold: 70 dyne/cm²

2a. P3: PCL-GPLGVRG-paclitaxel conjugate, 1.0 ug/mm², spin-coated 5 um MMP-2 Km: 4.8 uM

2b. P4: PNIPAM + Fe₃O₄ (15 nm SPIONs), sirolimus 1.6 ug/mm², microwell integration AMF: 20 kA/m, 300 kHz

3a. P5: PEDOT:PSS + dexamethasone counter-ions, 0.8 ug/mm², electrodeposited 3 um Release voltage: -0.6 V vs Ag/AgCl

3b. All platforms: CoCr L605 stent backbone, strut thickness 80 um, crimped onto 3.0 x 18 mm balloon Expanded to 3.0-3.3 mm

Part II -- SSPS Scoring Rubric

4a. Responsiveness: Release ratio (stimulus/physiological), normalised logarithmically Ratio 1 = 0.0; Ratio 50 = 1.0

4b. Neointimal Suppression: % reduction vs bare-metal / 100, averaged across scenarios Higher = better

5a. Endothelialisation: % strut coverage at 28 days / 100 OCT-assessed, 1 mm intervals

5b. Mechanical: Radial strength retention after 10M cycles / initial Must exceed 0.8 for score > 0

6a. Biocompatibility: 1.0 - (Schwartz inflammation score / 3.0) Modified Schwartz: 0 = minimal, 3 = severe

6b. SSPS = 0.25*Responsiveness + 0.25*Suppression + 0.20*Endothelialisation + 0.15*Mechanical + 0.15*Biocompatibility