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Bioresorbable Vascular Scaffold Degradation Kinetics and Endothelialisation: A Preclinical Study

Farkas L[1*], Gruber A[2] and Stanciu D[3]

[1]*Department of Biomedical Engineering, University of Debrecen, Debrecen, Hungary*
[2]*Department of Cardiology, Medical University of Vienna, Vienna, Austria*
[3]*Department of Materials Science, Iuliu Hatieganu University, Cluj-Napoca, Romania*

ABSTRACT

Background: A fully bioresorbable vascular scaffold is intended to provide temporary radial support during arterial healing and then disappear, restoring vasomotion and avoiding the long-term liabilities of a permanent metallic implant, but realising this concept depends on degradation kinetics and endothelialisation timelines that can only be characterised serially in preclinical animal models. Objective: This narrative review synthesises published porcine and rabbit arterial implantation studies of bioresorbable vascular scaffolds to characterise their degradation kinetics and endothelialisation/re-endothelialisation profiles. Methods: We reviewed preclinical coronary and peripheral artery studies of polymeric (PLLA, PLLA/PLGA blend, tyrosine-derived polycarbonate) and magnesium-alloy bioresorbable scaffold platforms, focusing on serially reported structural degradation timelines and histological or scanning electron microscopy-based endothelial coverage data. Findings: PLLA-based polymer scaffolds degrade over a relatively homogeneous multi-year hydrolytic window of roughly two to four years, whereas magnesium-alloy platforms span a much broader corrosion-driven range from under three months in first-generation designs to twelve to twenty-six months in optimised second-generation and experimental scaffolds; head-to-head rabbit iliac artery data indicate magnesium-based scaffolds achieve earlier and more complete endothelial coverage than PLLA scaffolds at matched early time points, while newer tuned polymer blends are narrowing this gap. Conclusions: Preclinical degradation and endothelialisation data remain essential for guiding rational bioresorbable scaffold material and strut-architecture design and for anticipating the thrombotic risk windows that have historically emerged during large randomised clinical trials.

Keywords: *bioresorbable vascular scaffold; scaffold degradation kinetics; endothelialisation; magnesium alloy scaffold; preclinical coronary artery model*

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Corresponding Author: *Laszlo Farkas*

E-mail Address: *laszlo.farkas@universityofdebrecen.edu*

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Introduction

The rationale for a fully bioresorbable vascular scaffold rests on a simple premise: a temporary structural cage that provides adequate radial support during the acute and subacute healing phase after percutaneous intervention, and then disappears once the vessel wall has healed, should in principle avoid the long-term liabilities of a permanent metallic implant while restoring native vasomotion and permitting late positive remodeling [1]. Realising this premise in practice, however, depends on two coupled biological processes that unfold on very different but overlapping timescales: the physicochemical degradation of the scaffold material itself, and the biological re-endothelialisation and vascular healing response of the treated artery. Because both processes are difficult or impossible to characterise serially in patients without invasive imaging or explant histology, the preclinical animal model — most often the porcine or rabbit peripheral or coronary artery — has been the principal experimental platform used to define degradation kinetics and endothelial coverage timelines for essentially every bioresorbable scaffold platform that has reached clinical evaluation [2,3].

The earliest fully resorbable coronary device, the Igaki-Tamai poly-L-lactic acid (PLLA) self-expanding stent, was first implanted in humans in 1998, and its subsequent decade-plus histological follow-up demonstrated near-complete disappearance of the polymeric strut silhouette alongside recovery of vessel vasomotion, establishing the basic biological feasibility of polymer resorption in the coronary tree [4,5,2]. This early clinical experience was complemented, and in many respects preceded, by an extensive body of porcine and rabbit arterial implantation studies designed specifically to characterise

degradation and healing kinetics under controlled, serially sampled conditions unavailable in human trials. In parallel with polymer platforms, bioresorbable magnesium alloy scaffolds emerged as a materially distinct approach: rather than degrading by hydrolysis of ester bonds, magnesium alloys are resorbed through electrochemical corrosion, a mechanism first characterised in the absorbable magnesium stent (AMS-1) porcine and human implantation studies and subsequently refined through successive device generations culminating in the drug-eluting DREAMS/Magmaris platform [6,7,8].

This narrative review synthesises the published preclinical literature on degradation kinetics and endothelialisation of bioresorbable vascular scaffolds, drawing on porcine coronary and peripheral, and rabbit iliac, arterial implantation studies of polymeric (PLLA, PLLA/PLGA blends, tyrosine-derived polycarbonate) and magnesium-alloy platforms. The review is organised around three themes: first, the reported degradation timelines — structural, mechanical, and gravimetric — of representative bioresorbable scaffold materials in animal models; second, the endothelialisation and vascular healing response documented histologically and by scanning electron microscopy across these same models; and third, comparative insights that emerge when polymer and magnesium platforms, and different device generations, are set side by side, together with their implications for continued clinical translation. No new animal experiments were performed for this review; all quantitative statements are drawn from previously published preclinical reports.

Degradation Kinetics of Polymeric and Metallic Bioresorbable Scaffolds in Preclinical Models

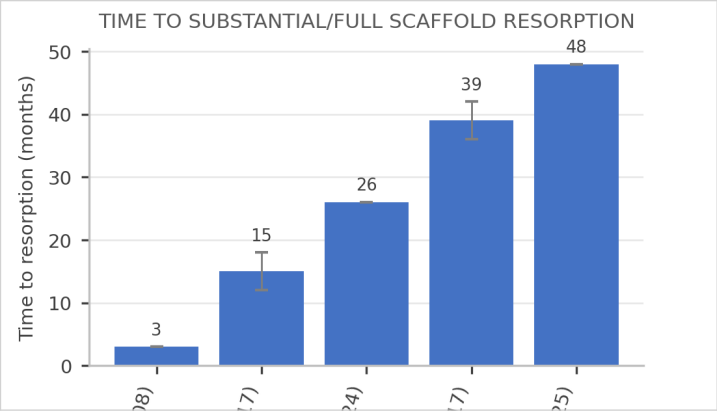
Preclinical degradation studies of PLLA-based scaffolds consistently describe a staged, multi-year resorption process that can be tracked histologically and by micro-computed tomography or optical coherence tomography in explanted arterial segments. In a long-term porcine coronary artery comparison of the everolimus-eluting Absorb bioresorbable vascular scaffold (BVS) against the metallic cobalt-chromium XIENCE V stent, Otsuka and colleagues followed implants out to 3.5 years and documented the histological signature of the staged PLLA backbone resorption process, alongside vascular injury and inflammation scores that were comparable to, or more favourable than, the durable metallic platform at matched time points [3]. Complementary rabbit iliac artery work by Vorpahl and colleagues, using the same Absorb scaffold platform, characterised the progressive replacement of polymer struts by proteoglycan-rich provisional matrix and subsequently by collagen-rich fibrous tissue as resorption advanced, providing histological benchmarks for the intermediate stages of polymer disappearance [9]. Clinically oriented comparative data assembled by Waksman and colleagues situate the Absorb PLLA backbone's full resorption at approximately 36 to 42 months post-implantation, a timeline consistent with the multi-year bulk hydrolytic degradation process described for aliphatic polyester coronary scaffolds generally [10,11].

Newer polymer chemistries have been evaluated preclinically with the specific aim of tuning this degradation timeline. A tyrosine-derived polycarbonate (Tyrocore) scaffold evaluated by Kachel and colleagues in a porcine peripheral artery model was reported to "uncage" the vessel — that is, to lose sufficient radial stiffness to no longer meaningfully constrain the arterial wall — by approximately one year after implantation, with the polymer backbone fully resorbed by around four years, a slower and more protracted resorption profile than the Absorb PLLA backbone [12]. In contrast, a novel PLLA/PLGA polymeric blend developed by Buszman and colleagues and evaluated in a porcine coronary model was engineered toward a shorter degradation timeline, with in vitro hydrolysis data supporting substantial resorption and positive vessel remodeling within approximately one year, and an estimated clinically relevant resorption window of 1.5 to 2 years — appreciably faster than the first-generation Absorb backbone while still providing adequate early scaffolding, illustrated by late lumen enlargement from 1.86 mm^2 to 3.40 mm^2 between implantation and 90-day follow-up [13]. These comparative preclinical timelines indicate that polymer chemistry and blend composition are effective and deliberately exploited levers for tuning bioresorbable scaffold degradation kinetics independent of the underlying PLLA scaffolding concept.

Representative preclinical bioresorbable vascular scaffold platforms and their reported degradation timelines.

Platform	Material	Model	Reported degradation timeline
AMS-1	Magnesium alloy	Porcine/human coronary	Swift degradation within ~90 days
DREAMS/Magmaris	Sirolimus-eluting magnesium alloy	Porcine coronary / clinical	Full resorption ~12-18 months
Experimental Mg scaffold	Magnesium alloy	Swine coronary	64.8% discontinuity by 12 months; near-complete disappearance by 26 months
JDBM stent	Magnesium alloy	Porcine coronary	Structurally intact to 90 days; ~6-month functional support window
Absorb BVS	PLLA (everolimus-eluting)	Porcine/rabbit coronary and iliac	Full resorption ~36-42 months
PLLA/PLGA blend	PLLA/PLGA polymer blend	Porcine coronary	Substantial resorption ~1 year; estimated clinical resorption 1.5-2 years
Tyrocore scaffold	Tyrosine-derived polycarbonate	Porcine peripheral artery	Vessel uncaged ~1 year; full resorption ~4 years

Reported time to substantial or full resorption of representative bioresorbable scaffold platforms in preclinical and preclinical-correlate studies: first-generation absorbable magnesium stent AMS-1 (Pinto Slottow et al., 2008, porcine/human coronary, ~3 months), second-generation drug-eluting magnesium scaffold DREAMS/Magmaris (Waksman et al., 2017, ~15 months, midpoint of reported 12-18 month range), an experimental magnesium-alloy coronary scaffold (Torii et al., 2024, swine coronary, ~26 months to near-complete disappearance), the everolimus-eluting Absorb PLLA scaffold (Waksman et al., 2017, ~39 months, midpoint of reported 36-42 month range), and a tyrosine-derived polycarbonate scaffold (Kachel et al., 2025, porcine peripheral artery, ~48 months to full resorption).



Magnesium-alloy scaffolds display a materially distinct, generally faster degradation trajectory governed by corrosion rate rather than ester hydrolysis. The first-generation absorbable magnesium stent (AMS-1), evaluated by Waksman and colleagues in porcine coronary arteries, showed favourable procedural safety but a resorption rate that proved too rapid to sustain adequate radial support, with serial intravascular ultrasound and optical coherence tomography imaging by Pinto Slottow and colleagues documenting swift degradation of the magnesium alloy within approximately 90 days of implantation in both porcine and human coronary arteries — a timeline associated with early recoil and elevated restenosis rates that prompted subsequent alloy and coating redesign [7,8,6]. The redesigned, sirolimus-eluting second-generation DREAMS/Magmaris scaffold substantially slowed this corrosion rate: comparative preclinical and clinical data reported by Waksman and colleagues place full Magmaris resorption at approximately 12 to 18 months, markedly faster than the Absorb PLLA backbone (36 to 42 months) but far more gradual than the AMS-1 predecessor [10,14]. A separately engineered magnesium alloy coronary scaffold evaluated by Torii and colleagues in a swine coronary artery model using serial angiography, optical coherence tomography, and histology out to 26 months demonstrated a well-characterised staged degradation sequence: struts remained largely intact with few discontinuities at one month, showed uneven radiolucent precipitate deposition by six months, reached 64.8% scaffold discontinuity by twelve months, were almost entirely dismantled into radiolucent degradation products by eighteen months, and had almost completely disappeared by twenty-six months [15]. A further magnesium-based drug-eluting stent (JDBM alloy) evaluated by Zhu and colleagues in porcine coronary arteries maintained good structural integrity at 30 and 90 days, with more pronounced but still mechanically competent degradation by 180 days, supporting an intended functional radial-support window of approximately six months for this platform [16]. Taken together, these preclinical degradation studies demonstrate that, unlike the relatively narrow multi-year window characteristic of PLLA-based polymers, magnesium-alloy platforms span a wide engineerable degradation range — from under three months for early first-generation alloys to well over two years for optimised second-generation and experimental designs — governed principally by alloy composition, surface treatment, and coating chemistry rather than by a single shared corrosion mechanism [17].

Endothelialisation and Vascular Healing in Animal Models

Because incomplete or delayed re-endothelialisation of implanted struts is mechanistically linked to late stent and scaffold thrombosis, preclinical endothelialisation assessment — typically by scanning electron microscopy of the luminal surface and by histological staining for endothelial markers at serial time points — has been a central preclinical endpoint for every bioresorbable scaffold platform reviewed here. A directly comparative rabbit iliac artery study by Waksman and colleagues quantified endothelial coverage of the Magmaris magnesium scaffold against the Absorb PLLA scaffold at matched early time points and found the magnesium platform achieved more rapid coverage: at three days post-implantation, mean endothelialisation was 47.0±4.1% for Magmaris versus 31.4±9.2% for Absorb, and by 28 days, coverage had increased to 73.8±10.5% for Magmaris versus 59.2±8.0% for Absorb, indicating a consistent early-endothelialisation advantage for the corrosion-based magnesium platform over the hydrolysis-based polymer scaffold in this model [10]. This head-to-head preclinical comparison is particularly informative because it isolates the influence of scaffold material and strut architecture on early healing under otherwise matched implantation conditions.

Complete or near-complete endothelialisation has also been reported for several bioresorbable platforms once sufficient follow-up time has elapsed, though the time required to reach this endpoint varies by material and device generation. In the swine coronary magnesium alloy scaffold study by Torii and colleagues, all implanted scaffolds were well apposed to the vessel wall with complete endothelialisation documented at every serial time point examined from one month through twenty-six months, indicating that in this magnesium-alloy design endothelial coverage was achieved early and sustained throughout the entire degradation process [15]. Similarly, in the porcine peripheral artery evaluation of the tyrosine-derived polycarbonate scaffold, Kachel and colleagues reported complete endothelialisation by scanning electron microscopy and histopathology at both 30 and 90 days post-implantation, with minimal platelet or leukocyte adhesion and only minor surface artefact noted on the more slowly resorbing polymer backbone [12]. The porcine coronary evaluation of the faster-degrading PLLA/PLGA blend scaffold by Buszman and colleagues likewise reported endothelialisation that was nearly complete and comparable across study groups by 30 days, alongside lower inflammation scores relative to comparator designs, findings the authors interpreted as evidence that tuning polymer blend composition can improve the healing response without sacrificing scaffolding adequacy [13]. For the magnesium-based JDBM stent, Zhu and colleagues reported that stent surfaces showed nearly complete endothelial coverage as early as 30 days after implantation in porcine coronary arteries, with no obstructive thrombi observed in either treatment or control groups, consistent with the broader pattern of comparatively rapid early endothelial coverage reported for magnesium-alloy platforms [16].

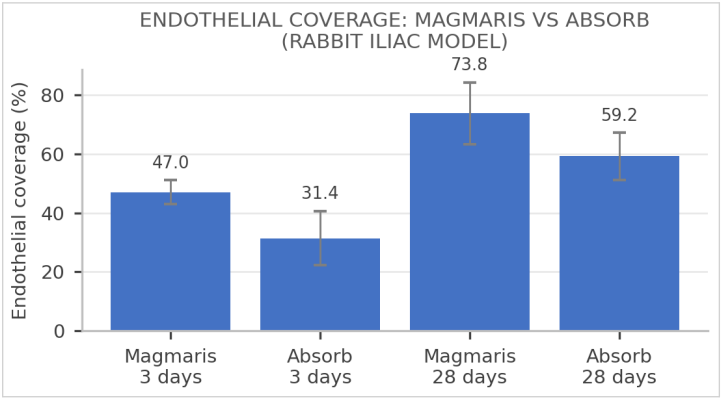
Selected preclinical endothelialisation and vascular healing findings for bioresorbable scaffold platforms.

Study	Model	Device(s)	Endothelialisation/healing finding
Waksman et al. 2017	Rabbit iliac artery	Magmaris vs Absorb	3 days: 47.0±4.1% vs 31.4±9.2%; 28 days: 73.8±10.5% vs 59.2±8.0%
Torii et al. 2024	Swine coronary artery	Experimental Mg scaffold	Complete endothelialisation at all time points (1-26 months)
Kachel et al. 2025	Porcine peripheral artery	Tyrosine polycarbonate scaffold	Complete endothelialisation at 30 and 90 days
Buszman et al. 2025	Porcine coronary artery	PLLA/PLGA blend scaffold	Nearly complete endothelialisation by 30 days; lower inflammation vs comparators
Ijichi et al. 2019	Porcine coronary artery	Biodegradable- vs durable-polymer DES	Greater endothelial tight junctions, least fibrin deposition with biodegradable coating at 7-10 days

Comparative mechanistic studies of biodegradable-polymer coating chemistry, distinct from fully bioresorbable scaffold backbones, provide additional preclinical evidence relevant to endothelial recovery kinetics. Ijichi and colleagues compared a biodegradable-polymer sirolimus-eluting stent against a durable-polymer everolimus-eluting stent in porcine coronary arteries and found, by transmission electron microscopy, that the biodegradable-polymer device achieved a significantly greater number of endothelial cell tight junctions and the least fibrin deposition at both 7 and 10 days after implantation, supporting the broader hypothesis that abluminal or rapidly eluting biodegradable polymer coatings can accelerate early endothelial maturation relative to durable, uniformly coated alternatives [18]. Rabbit iliac artery data from Park and colleagues, comparing an everolimus-eluting bioresorbable scaffold against an everolimus-eluting metallic stent over twelve months, found the bioresorbable platform delivered superior acute radial force (2.75 N/mm versus 0.162 N/mm) and lower recoil (3.2% versus 6.3%) than the metallic comparator, even as percent area restenosis remained numerically higher for the bioresorbable device at all time points assessed, underscoring that mechanical performance and vascular healing metrics do not always move in the same direction across bioresorbable scaffold generations [19]. Corroborating human histological data from four explanted Absorb scaffolds examined by Kraak and colleagues showed struts covered by a thin fibrin-platelet layer within the first week after implantation, progressing to smooth muscle cell-rich coverage by 113 days, but with multinucleated foreign body giant cells persisting adjacent to struts across all examined time points up to 501 days, indicating that a low-grade absorptive inflammatory response can accompany polymer resorption even after luminal endothelial coverage is grossly achieved [20]. Collectively, these preclinical and correlative human observations indicate that while most contemporary bioresorbable scaffold platforms — both polymeric and magnesium-based — achieve substantial to complete luminal endothelial coverage within the first one to three months after implantation, the completeness, uniformity, and inflammatory quiescence of that coverage vary meaningfully by material class, strut architecture, and coating chemistry.

Comparative Insights and Translation Toward Clinical Practice

Endothelial coverage (mean percent, with reported standard deviation) of the Magmaris magnesium scaffold versus the Absorb PLLA scaffold at matched early time points in a rabbit iliac arterial model, as reported by Waksman et al. (2017).



Viewed together, the preclinical degradation and endothelialisation literature offers a coherent, if nuanced, picture of the design trade-offs facing bioresorbable vascular scaffold development. Magnesium-alloy platforms, as a class, tend to achieve earlier and more complete endothelial coverage than PLLA-based polymer scaffolds evaluated under comparable conditions, plausibly reflecting differences in strut thickness, surface chemistry, and the electrochemical rather than hydrolytic nature of magnesium corrosion, but this same corrosion-driven mechanism produces a degradation timeline that is both faster and, in first-generation alloys, difficult to control precisely — a lesson learned directly from the premature resorption and elevated restenosis of the AMS-1 platform before it was redesigned into the slower-corroding, drug-eluting DREAMS/Magmaris scaffold [7,8,14,21]. PLLA-based polymer scaffolds, by contrast, offer a longer and more mechanistically homogeneous multi-year hydrolytic degradation window, well characterised across the Igaki-Tamai and Absorb platforms and confirmed by long-term porcine and rabbit histological follow-up, but this same durability has been associated with a longer interval of incompletely resorbed, mechanically discontinuous struts during which clinical thrombotic risk appears concentrated, as documented in mechanistic optical coherence tomography registries of very late scaffold thrombosis [2,3,9,22].

The emergence of tuned PLLA/PLGA blends and alternative polymer chemistries such as tyrosine-derived polycarbonates reflects a preclinically validated strategy for narrowing the gap between these two material philosophies: preclinical data summarised here show that blend composition can shift full resorption from the roughly three-to-four-year window characteristic of first-generation PLLA backbones down toward twelve to twenty-four months while preserving, or in some reports improving, the completeness and timeliness of endothelial coverage relative to earlier single-component designs [13,12,11]. Equally, iterative magnesium-alloy engineering — moving from AMS-1 through DREAMS/Magmaris to further experimental swine-validated alloys — illustrates that corrosion kinetics can be deliberately slowed toward a twelve-to-twenty-six-month window without sacrificing the early endothelialisation advantage generally observed for this material class [15,16,10]. Clinically, the randomised trial experience with first-generation Absorb BVS — including excess device thrombosis reported in the ABSORB II, ABSORB III, and AIDA trials relative to durable-polymer everolimus-eluting metallic stents, and the device's eventual commercial withdrawal — has been interpreted

substantially through the lens of these same preclinical degradation and strut-thickness considerations, reinforcing the translational relevance of the animal-model degradation and endothelialisation data reviewed here [23,24,25,22]. Ongoing and future bioresorbable scaffold development therefore appears well served by preclinical programmes that jointly optimise strut thickness, degradation kinetics, and early endothelial coverage rather than treating these as independent design parameters [1].

Conclusion

Preclinical porcine and rabbit arterial implantation studies have been indispensable in characterising the degradation kinetics and endothelialisation timelines that ultimately determine the clinical safety profile of bioresorbable vascular scaffolds. PLLA-based polymer platforms, from the original Igaki-Tamai design through Absorb and its successors, degrade over a relatively homogeneous multi-year hydrolytic window of roughly two to four years, while magnesium-alloy scaffolds span a much broader, alloy-dependent corrosion-driven range from under three months in first-generation designs to twelve to twenty-six months in optimised second-generation and experimental platforms [7,15,10,12]. Directly comparative preclinical data indicate that magnesium-based scaffolds tend to achieve earlier and more complete endothelial coverage than polymer scaffolds under matched conditions, while emerging tuned polymer blends are narrowing this gap by combining faster, better-controlled resorption with endothelialisation profiles approaching those of magnesium platforms [10,13]. As next-generation bioresorbable scaffolds continue to be engineered and evaluated, preclinical degradation and endothelialisation data of the kind reviewed here will remain essential both for informing rational material and strut-architecture design choices and for anticipating the clinical thrombotic risk windows that have historically emerged only once large randomised trials were already underway [22,1].

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Farkas L conceived the review, conducted the literature search, and drafted the manuscript. Gruber A contributed to the literature screening and technical framing and critically revised the manuscript for important intellectual content. Stanciu D contributed additional context on scaffold materials science and approved the final version for submission.

Ethics Statement

Not applicable. This is a narrative review of previously published literature and did not involve new experimental data, human participants, or animal subjects generated by the authors.

Data Availability

No new data were generated or analyzed for this review. All sources synthesized are cited in the reference list and are available through their original publishers.

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