

Dear editor and reviewers:

Thank you for your constructive feedback. Please find below our reply to your requests which are blue coloured in the revised version of the manuscript.

Editor's comments:

1. Only first letter of heading and subheadings are capitalized. For example, 1. Introduction and clinical background

Done. All section and subsection headings now use sentence case, and trailing full stops have been removed from headings.

2. The introduction section sounds like a thesis, not a scientific article. Please present the methodology in a separate chapter, not under Section 1.3. 3.

Done. The methodology is now presented in a separate section (Section 3. Methodology), covering the design approach (3.1), the finite element modelling of crimping (3.2) and the fabrication and experimental testing (3.3). Section 1.3 now only states the novelty and objectives of the work, and the subsequent sections have been renumbered.

The reference list is not properly formatted. For instance, Ref. [2] when properly formatted will look like this. [2] Bałabuszek K, Toborek M and Pietura R 2022 Comprehensive overview of the venous disorder known as pelvic congestion syndrome. *Ann. Med.* 54, 22–36. Note: journal names are abbreviated and formatted in italic, volume number is in bold. doi is optional. Please all reference lists accordingly. See examples in the template.

Done. The reference list has been reformatted following the template: year after the authors, abbreviated journal names in italics, volume number in bold and page range at the end. Incomplete entries ([11], [13], [23], [25]) have also been corrected.

Comments of Reviewer #1 The manuscript presents an interesting and relevant study on the development of crimpable embolisation devices using computational modelling, additive manufacturing, and experimental testing. The progressive development of the proposed sinusoidal-ring concept is clearly presented, and the work provides a useful foundation for future development of bioabsorbable embolisation devices. The following minor comments are suggested to further improve the manuscript:

1. Clarify the main novelty by clearly distinguishing the truly auxetic structures from the final SROM design, which is not strictly auxetic.

Done. A new paragraph in Section 1.3 distinguishes the truly auxetic structures studied (missing-rib, re-entrant honeycomb and hexachiral lattices, and the axisymmetric chiral structure) from the SROM. The SROM is not strictly auxetic: it is designed to keep a nearly constant length under radial compression. The novelty of the work is stated explicitly in the same section, and the abstract and conclusions have been adjusted accordingly.

2. Explain the discrepancy in crimped diameter, particularly the difference between the theoretical value of 2.41 mm and the simulated minimum diameter of 5.67 mm.

Done. A paragraph has been added to Section 4.3. Equation (8) is an idealised lower bound that assumes rigid, straight segments parallel to the axis and in line contact. In the simulation,

the crests keep a finite curvature and the lobes remain inclined, so adjacent lobes come into contact at a larger diameter. In addition, once self-contact developed, the explicit analysis could not be progressed further in a stable manner. The value of 5.67 mm is therefore the practical limit reached in simulation.

3. Strengthen the simulation and experiment comparison by providing quantitative comparison of deformation or axial elongation, where possible.

A fully quantitative comparison cannot be provided with the current experimental data. The funnel imposes the same final diameter as the simulation, so radial deformation is prescribed rather than independently measured, and axial elongation was not recorded during testing. We have therefore limited the comparison to deformation modes and fracture occurrence. This limitation is now explicitly acknowledged in Section 4.3, and future work will include quantitative measurements of crimped length and deformation evolution using image-based metrology.

4. Clarify the PLA material assumption and emphasise that the reported strain values are primarily intended as a preliminary geometric screening criterion.

Done. Section 3.2 now states the PLA assumption explicitly. It explains that, under displacement control and within the linear elastic regime, the strain field is essentially governed by geometry. The reported strains are presented as a preliminary geometric screening criterion, and the related statements in Section 4.3 have been toned down accordingly. The purpose of the simulations at this stage is therefore comparative ranking of geometric concepts rather than prediction of final device performance.

5. Present the experimental results more quantitatively, including specimen numbers, failure rates, and variability where available.

Done. Section 3.3 now gives the number of printed specimens (14 rings: four per 0.5 mm configuration and three per 1 mm configuration). Section 4.3 reports the failure rates: no fractures in the 0.5 mm specimens, and 2/3 (67%) in the 1 mm specimens for both  $N = 3$  and  $N = 4$ . Given the small number of specimens, variability could not be assessed statistically, which is now acknowledged as a limitation.

6. Strengthen the justification for selecting  $N = 3$  and  $N = 4$  by briefly comparing axial elongation, maximum strain, crimping margin, and manufacturability.

Done. Only  $N = 3$  and  $N = 4$  were fabricated and tested, and the justification has been strengthened in Section 4.3. Equation (6) shows that the 1 mm wire becomes geometrically invalid for  $N \geq 5$ , while  $N = 2$  provides only two anchoring points for the membrane. The two selected variants are then compared using the values in Table 2 in terms of axial elongation, maximum strain, theoretical crimping margin and manufacturability.

Comments from Reviewer #2 Title: Crimping analysis of additive manufacturing coils for pelvic congestion

1. Page 4 (Section 2): Look closely at the sentence describing vessel/catheter sizes: "...have a mean diameter of approximately 12 mm [18] meter of 1.67 mm throughout the approach. The anatomical bottleneck..." This is a severe copy-paste or typesetting collision. A reference tag [18] has collided directly into the word "diameter".

Done. Part of the sentence had been lost during editing. It now reads: "...a mean diameter of approximately 12 mm [18]. A 5F catheter, with an outer diameter of 1.67 mm, therefore remains well below the vessel diameter throughout the approach."

2. Page 8 (Parametric Equations): In equations (1), (2), and (3), subscript formatting and Greek letters display formatting artifacts (e.g.,  $\theta = (-1)^i \theta_0$ , alignment blocks, and font corruption). Ensure standard mathematical typesetting (LaTeX/Word equations) renders cleanly without raw XML or encoding residue.

The equations are correctly defined as native Word equations in the source manuscript. During PDF generation some symbols appear to have been rendered incorrectly. We have carefully checked the revised manuscript and will verify again that the final PDF displays Equations (1)-(7) correctly.

3. Page 10 (Equation 6): The denominator reads  $m_a(s)$ . This is clearly meant to be  $\kappa(s)$  (kappa), matching Equation (7).

As with the previous comment, equation (6) reads  $d_{\max} = 2/\max \kappa(s)$  in the source manuscript. The missing characters appear to be a PDF conversion artefact, which will be checked in the revised PDF.

4. Clarification Regarding Material Selection and Strain-Based Screening: According to the authors, they have utilized a linear elastic surrogate material that possesses the characteristics of PLA or VeroWhite, mentioning that the definitive device material has not yet been determined. The authors further say that the analysis being displacement-controlled means that the strain field is determined by geometry in this case, rather than by the material properties. Although this may hold purely in the elastic realm, if any bioabsorbable polymer or shape memory alloy exhibits some degree of nonlinear plastic deformation or possesses a different Poisson ratio under large strain, the stress-strain outcomes will change. This point should be mentioned clearly as a limitation of the approach that features elastic strain maps in material screening.

Done. Section 3.2 now discusses this limitation explicitly. The strain field is governed by geometry only within the linear elastic regime. If the material departs from linear elasticity (plasticity, viscoelasticity or rate dependence in bioabsorbable polymers, superelasticity in shape-memory alloys), or has a different Poisson's ratio under large strain, both the stress and the strain fields would change. This limitation is also mentioned in the limitations paragraph of Section 4.3 and in the conclusions.

5. Discrepancy Between Theoretical Limits and Simulation Limits On page 10, the authors note a striking difference: the theoretical minimum crimp diameter calculated via Equation (8) is 2.41 mm, whereas the actual simulated limit achieved in ANSYS before self-intersections or extreme distortions occurred was 5.67 mm. The text mentions that 5.67 mm corresponds to the limit for the  $N=4, d_{\text{wire}}=1$  mm configuration, but does not deeply explain why theory and simulation diverge so dramatically (over a 130% difference). Is it due to finite-element mesh contact constraints, self-contact algorithms, or the fact that Equation (8) assumes idealized rigid line segments rather than 3D solid circular cross-sections undergoing 3D contact? This divergence should be addressed.

Done (see also our reply to Reviewer 1, comment 2). The divergence results from a combination of the factors mentioned by the reviewer, and a paragraph explaining it has been

added to Section 4.3. Equation (8) assumes idealised rigid straight segments in line contact. The simulated wire, by contrast, is a three-dimensional solid of circular cross-section that keeps curved crests and inclined lobes, so adjacent lobes come into contact at a larger diameter. In addition, the onset of self-contact prevented the explicit analysis from progressing further in a stable manner.

6. The caption says "Three starting design concepts of SROM." However, Figure 6 displays a single continuous sinusoidal curve/ring concept or variations of it. Check if the caption matches the intended graphic.

The figure shows the same SROM with three alternative occluding-membrane designs. The caption has been changed to "SROM concept with three alternative occluding-membrane designs".

7. The connection to gender bias in healthcare (Section 1.3) is an interesting sociopolitical note, but ensure the core engineering findings (crimpability, axial elongation reduction) remain the primary focus of the discussion and conclusions.

Done. The paragraph on gender bias has been moved to the clinical background at the beginning of Section 1, and the discussion and conclusions now focus only on the engineering findings.

8. It is critical to highlight the novelty of the research and concisely show how the proposed sinusoidal ring design is different from other existing axisymmetric chiral designs. In addition, the authors need to present an explanation for the significant difference between the obtained theoretical results and the simulated findings with regard to the minimum crimping diameter. Furthermore, present the FEA technique and the experimental validation in more detail. Moreover, it is crucial to specify that the conclusions made are preliminary due to the use of the surrogate PLA, a small number of samples, and the absence of membrane, deployment, and embolization tests.

The novelty of the work and its differences from existing axisymmetric chiral designs are now presented in Section 1.3 (see our reply to Reviewer 1, comment 1). The discrepancy between the theoretical and simulated crimped diameters is explained in Section 4.3 (see comment 5). The FEA technique (solver, mesh, crimping boundary conditions, contact, material model and quasi-static verification) and the experimental procedure are now described in detail in the new Section 3. Finally, the limitations paragraph and the conclusions state that the results are preliminary, because of the surrogate material, the small number of specimens and the absence of membrane, deployment and embolization tests.

Unlike previously reported axisymmetric chiral lattices, the proposed SROM consists of a single continuous sinusoidal wire specifically conceived for crimping into catheter-scale diameters while maintaining low axial elongation and facilitating attachment of an occluding membrane.