Mechanical Properties and Degradation Behavior of Additively Manufactured Porous Polydioxanone

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Summary

This study investigates the mechanical properties of biodegradable polydioxanone (PDO) specimens fabricated using 3D printing, focusing on their degradation over a 6-week period. Specimens with porosities of 5%, 25%, and 50% were tested to assess the influence of porosity on degradation behavior. Compression tests were conducted at several time intervals to evaluate changes in mechanical properties.

Introduction

Biodegradable materials offer significant potential for various medical applications, particularly in orthopedics, where controlled degradation can enhance treatment outcomes. Further research into their properties and behavior during degradation is therefore essential.

This study contributes to developing a biodegradable component that enables gradual dynamization of orthopedic implants. To ensure its functionality and reliability, changes in mechanical properties over the degradation period were investigated.

Methods

Commercially available PDO-based RESOMER X D1.75 filament (EVONIK Corp., USA) was used as the feedstock material. The specimens were additively manufactured using an FDM machine Prusa i3 Mk3S+ (Prusa Research, Czech Republic). Cylindrical samples, 5 mm in diameter and 8 mm in height, were printed with a thin perimeter shell. The internal structure featured a simple infill pattern of parallel lines, alternating by 90° in each successive layer. The porosity of the inner filling was designed at three levels: 5%, 25%, and 50%.

The specimens were immersed in phosphate-buffered saline (PBS; pH 7.4, 37 °C) (Sigma Aldrich, St. Louis, MI, USA) for 1, 2, 4, and 6 weeks to simulate the degradation process. As a reference, specimens without degradation were also tested. In total, 15 groups of specimens were evaluated, covering all combinations of porosity levels and degradation times, with each group consisting of five specimens.

A compression test was conducted to evaluate the mechanical properties of the specimens, following the ISO 13314 standard. In addition to mechanical properties, weight loss during the degradation process was also measured.

Results and Discussion

After two weeks of degradation, the specimens became brittle, and their ability to absorb energy declined rapidly across all three porosity levels. Over the six-week period, specimen strength also decreased significantly (Figure 1, left). Notably, the most pronounced reduction was observed in the 5% porosity group, which retained only 10% of its initial strength after six weeks, compared to over 30% in the other two groups. The elastic gradient initially decreased, then increased after two weeks of degradation, before decreasing again (Figure 1, right). After the six-week period the decrease of elastic gradient was again most significant in the 5% porosity group.

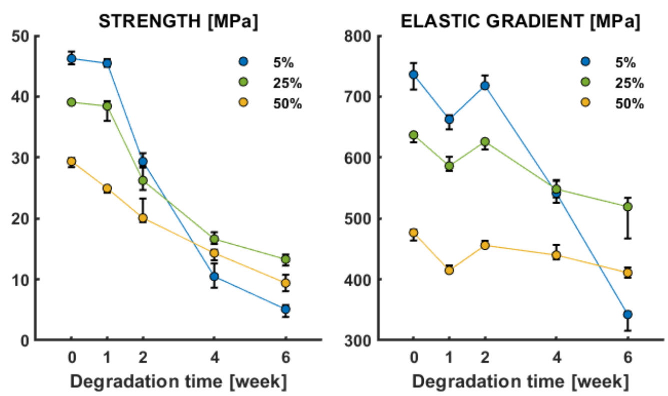

Figure 1: Strength (left) and elastic gradient (right) during six weeks of degradation for specimens with 5%, 25%, and 50% porosity. Medians and IQR are displayed.

The weight loss became progressively more significant over the six-week period, as expected in hydrolytic degradation. After 6 weeks, the 5% porosity group exhibited the highest weight loss, at 8.53 wt.%, while the other two groups each lost approximately 4 wt.%.

Conclusions

The material demonstrated a significant loss of mechanical properties over the six-week testing period, which may be advantageous for applications requiring relatively short-term degradation. However, its tendency to become brittle could be problematic. Further testing will be conducted to explore the material's behavior.

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