Polylactic Acid (PLA) Scaffolds for Tissue Engineering Applications do not Biodegrade in Physiological Saline at Room Temperature

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Introduction

Three-dimensional (3D) printable scaffolds are advantageous for their ability to be custom made to fill hard tissue defects. In this approach, scaffolds are required to be osteoconductive such that cells (osteoblasts) can attach and proliferate on the scaffolds and subsequently go on to become bone. It is desirable for the scaffold to biodegrade while bone formation occurs. Biodegradation occurs through the process of polymer chains being broken down into smaller chains, resulting in eventual extinction of the polymer altogether. Knowledge of biodegradation rates is important for prediction of scaffold stiffness and strength used in engineering analysis. Polylactic acid, or PLA, is a popular filament used in 3D printing (3DP). Biodegradation of PLA occurs through the process of hydrolysis which utilizes water molecules to break down the polymer chain. In a previous investigation, candidate scaffold designs were created using host friendly poly (lactic acid) (PLA) that provided near "trabecular bone like" stiffness required to stimulate cell growth and bone healing (Cole et al., 2018)). The referenced study found that all architectures allowed fibroblast cells (a highly prolific connective tissue cell) to attach and proliferate. In the current study, PLA scaffolds were tested to determine their baseline degradation rates over an extended (32 week) period.

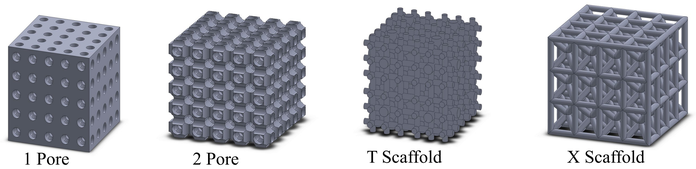

Fig. 1: Candidate Scaffolds for the current study (Cole et al., 2018)

Objectives

The X scaffold (Fig. 2) were selected for this project due to its customizable stiffness and demonstrated culturability. Utilizing this 3DP PLA scaffold specimen, the objectives of this project was to assess PLA's sustainability in a physiological-like environment, i.e., does PLA degrade with an extended period of soak time (i.e. at 32 weeks of soaking). Previous studies (Henninger et al. 2020) had compared the weight and stiffness change over a ten-week period and found no significant differences between initial and final weights and scaffold stiffnesses.

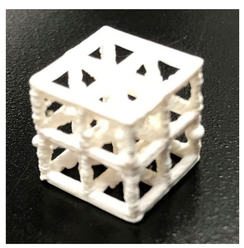

Fig. 2. X scaffold of this study

Experimental Methods

Eight X-type scaffold specimens were selected for the assessment of PLA sustainability due to soaking in cell culture media held at room temperature (20° C). Specimens were weighted, measured, and mechanically tested weeks 1-7, 10 week 32.

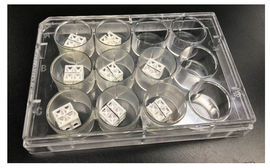

Fig. 3. Scaffold in well plate.

Mechanical testing was conducted in compression at a displacement rate of 1.27 mm/min using a Mark-10 electromechanical testing machine (Copiague, NY) (Fig. 4). Compression test were made between steel plates and specimens were only loaded within the elastic region of the material. Following testing the structural stiffness (Load/displacement) was calculated form the slope of the load-displacement curve (Fig. 5) within the linear elastic region. Statistical analysis using JMP (SAS institute, Cary, NC) was performed to detect degradation in weight and stiffness with soak time. A significant difference is indicated by P <0.05.

Fig. 4. Scaffold in Test Machine

Fig. 5 Load-Displacement of scaffolds

Experimental Results

Results and comparisons are presented here for specimen weight and stiffness for week 1 through week 32 Eight scaffolds weighted at time = 1 weeks were pooled and compared using ANOVA to their weights at time = 32 weeks (Fig. 6). There was a small (<1 %) but nonsignificant (p<0.35) drop in weight over the 32-week soak time.

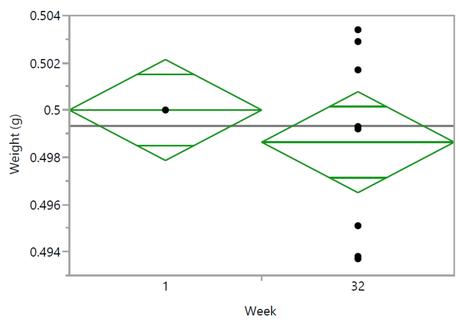

Fig. 6. ANOVA of scaffold stiffness showed NSD

The stiffness's of the scaffolds at each interval of time were compared. The 1-week scaffold average stiffness was 755 N/mm (±102 N/mm) while the scaffold with at 10-week soak time had an average stiffness of 752 N/mm (±29 N/mm) and at 32-week stiffness was of 762 N/mm (±67 N/mm) . When all time intervals were compared using ANOVA, the differences were not significant (p<0.72) (Fig. 7).

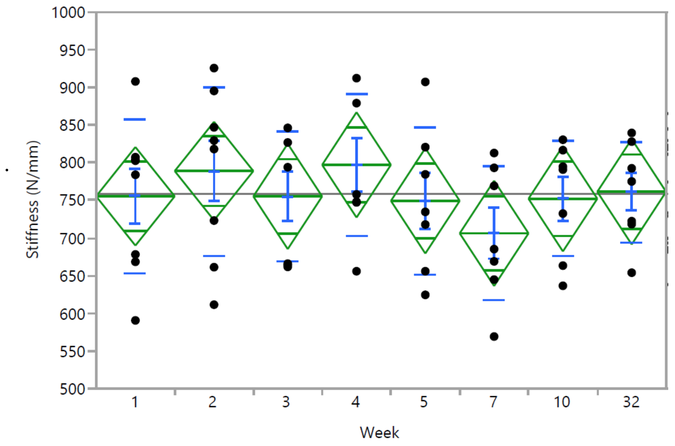

Fig. 7. ANOVA of scaffold stiffness showed NSD

Discussion

Results showed that there were no significant differences in scaffold weight or stiffness over the 32-week period of time. It was concluded that scaffolds printed from PLA do not biodegrade at room temperature over an extended period of time. Practically speaking, low or no PLA degradation may inhibit concurrent bone regeneration. This study establishes baseline information for continued studies investigating temperature and soaking effects on PLA scaffolds used for tissue engineering.

References

Cole, J, Martinelli, T., Ryan, M, Seman, S, Sidle, D, Smith,S, Rotello, R and Norman, TL, CU *Research and Scholarship Symposium,* 2018.
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