TEST BENCH FOR CHARACTERIZING THE PERMEABILITY OF TISSUE ENGINEERING SCAFFOLDS

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Introduction

To create *in vitro* functional tissue substitutes, tissue engineering (TE) approaches rely on the active interaction between cells and porous three-dimensional (3D) scaffolds [1], whose effectiveness is significantly impacted by microstructure. Porosity, pore size, tortuosity, and interconnectivity influence the ability of the scaffold to be permeated by fluids (permeability) and consequently its suitability for cell colonization. Therefore, permeability characterization is essential for a thorough assessment of the scaffold performance [2]. Several approaches were proposed to characterize the permeability of TE scaffolds; however, standardized protocols are missing. Here, we developed a versatile permeability test bench (PTB) for characterizing TE scaffolds and we validated it by testing different bone TE scaffolds and comparing the results with those obtained using a reference test bench (RTB) [3].

Methods

The proposed PTB is based on the pump method [2]. The permeability chamber (PC), equipped with custom gaskets and grids, allows housing cylindrical samples (height = 1-14 mm, diameter = 8-27 mm). The PC is connected to a closed-loop hydraulic circuit consisting of a reservoir, a peristaltic pump (Masterflex), silicone tubing, two pressure sensors (HJK) upstream and downstream of the PC, and 3-way stopcocks. The sensor signals are collected by a DAQ (National Instruments), which is operated by a computer running a purpose-built LabView interface (Fig. 1A). Tests were conducted using demineralized water. A defined flow rate was imposed to guarantee the laminar flow, consequently, permeability (k) was calculated by using the Darcy flow transport model:

$$\Delta P/L = \mu/k*(Q/A) \quad (1)$$

where ΔP is the pressure drop across the sample, L is the sample thickness, μ is the viscosity, Q is the flow rate, and A is the area of the sample cross-section. For validating the PTB, two 3D-printed PLA scaffolds with a random trabecular microstructure [4] and two commercial biomimetic scaffolds (SmartBone IBI S.A) were tested at 5 mL/min for at least 3 repetitions. Results were then compared with those obtained using the RTB [3].

Results

Performance tests confirmed watertightness and functionality of the PTB. The permeability values of PLA (P1 and P2) and SmartBone (SB1 and SB2) scaffolds tested within the PTB and the RTB are shown in Table 1. Comparing the results within the same sample for the two test benches demonstrate the reliability of the PTB. The normalized errors between PTB and RTB permeability values were less than 1.

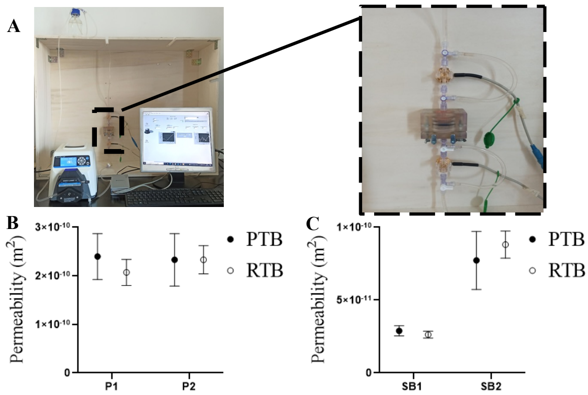

Figure 1: A) Picture of the PTB with focus on the chamber; Permeability test results on PLA (B) and SmartBone (C) scaffolds.

Sample	PTB (10^{-10}m^2)	RTB (10^{-10}m^2)
P1	2.380 ± 0.570	2.070 ± 0.269
P2	2.330 ± 0.601	2.330 ± 0.290
SB1	0.288 ± 0.034	0.263 ± 0.023
SB2	0.772 ± 0.199	0.881± 0.093

Table 1: Permeability (m^2) and confidence interval at 95% of the analyzed samples.

Discussion

A versatile test bench for characterizing the permeability of TE scaffolds was developed and validated. Despite the measurement dispersion in the PTB tests, the calculated permeability values are in accordance with the results from the reference configuration (RTB). To reduce measurement uncertainty, the PTB data-acquisition system is being optimized. Tests employing soft scaffolds are ongoing for complete validation of the PTB.

References

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