Effects of interlayer adhesion and crosslinking density on compliance of poly(vinyl alcohol) vascular graft

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Introduction

Background:

- Cardiovascular diseases are a leading cause of death worldwide, accounting for **17.9 million deaths per year** [1].
- Currently available synthetic small diameter vascular grafts (SDVGs), defined as smaller than 6mm in diameter [2], have a **failure rate as high as 82%** [3].
- High maintenance cost of approximately **$2.5 billion USD/year** in the United States [4].

Significance of Compliance:

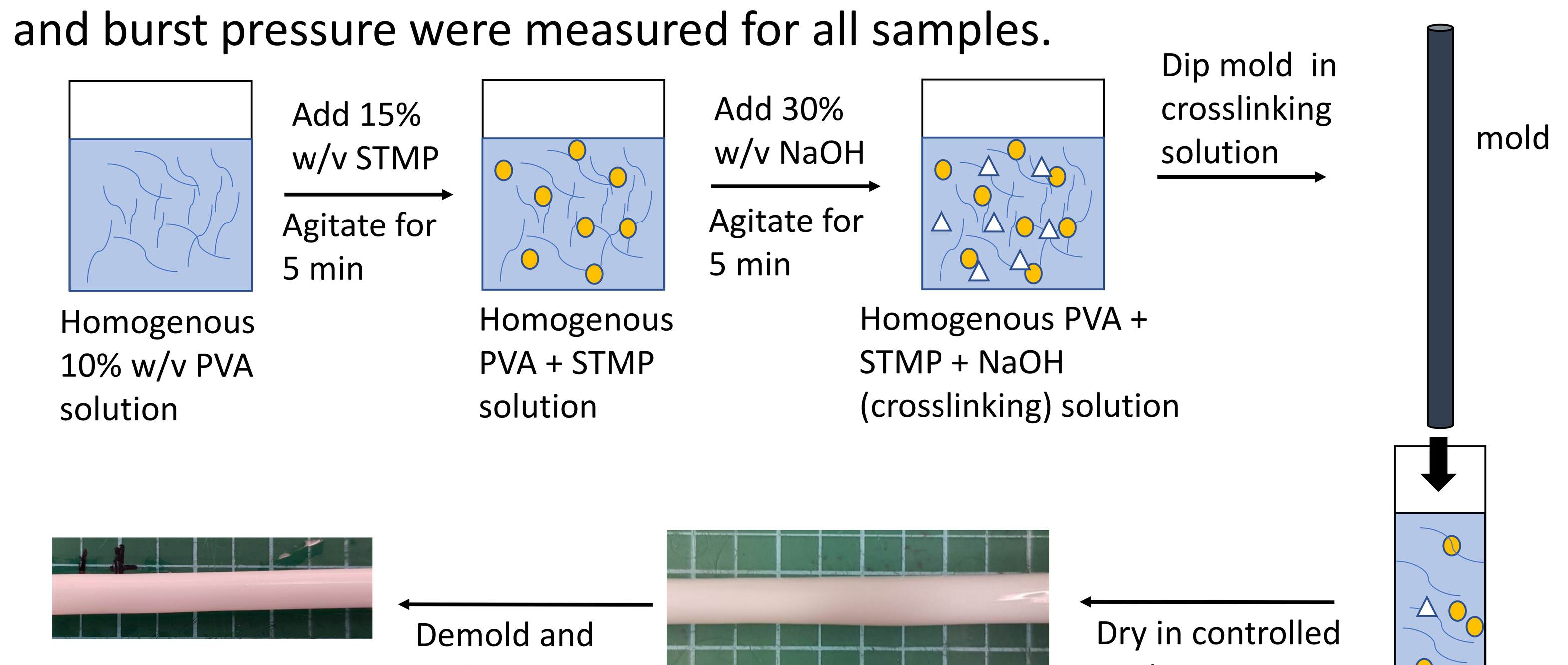
- One of the potential explanations for the unsuccessful long-term SDVGs is the **compliance mismatch** [5].
- Vascular compliance is defined as how much the blood vessel stretches when exposed to pressure.
- Clinically available synthetic grafts, composed of expanded polytetrafluoroethylene (ePTFE), have poor compliance compared to native small arteries [2].
- Compliance of poly(vinyl alcohol) (PVA) vascular grafts have been modified by optimizing the wall thickness [6].

Objective:

- **Interlayer adhesion and crosslinking density can be used to fabricate PVA vascular grafts with desired compliance [6].**

Materials and Methods

Control PVA grafts (**C**) fabrication was performed following the previously used procedure [7] to make grafts with 4mm luminal diameter tubes with nine dips [6]. Each dip formed a layer of polymer on the mold. Compliance and burst pressure were measured for all samples.



Abbreviations:
PVA - Poly(vinyl alcohol), STMP - Trisodium Trimetaphosphate, NaOH - Sodium Hydroxide

The wait times between each layer were altered to either increase (15 min wait between dips; **15W**) or decrease (30 min wait between dips; **30W**) interlayer adhesion. Interlayer adhesion was assessed using shear strength and break profile. Chemical crosslinking density was altered using different concentration of the crosslinker (low STMP; **LS**). Physical crosslinking density was increased by additional drying after the fabrication step, and prior to storage. The additional drying time was at 60℃ for two weeks (**60-2D**), at 60℃ for four weeks (**60-4D**), at 18℃ for two weeks (**18-2D**), and at 18℃ for four weeks (**18-4D**). Lastly, PVA grafts fabricated using standard protocol were subjected to additional drying post-fabrication to increase physical crosslinking density. Crosslinking density was assessed using FTIR and phosphate content quantification.

Results and Discussion

1. 15W and LS had significantly thinner wall

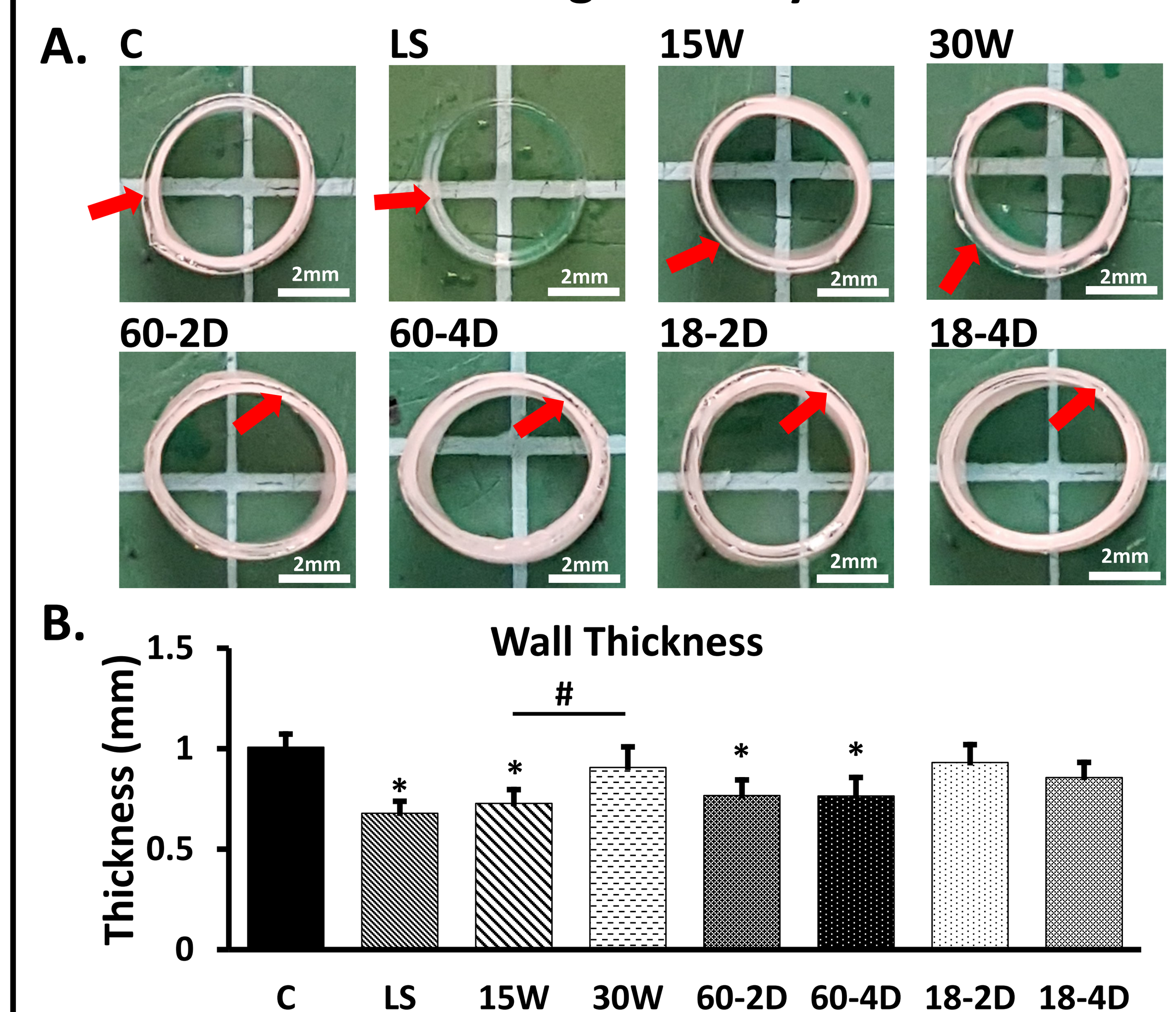
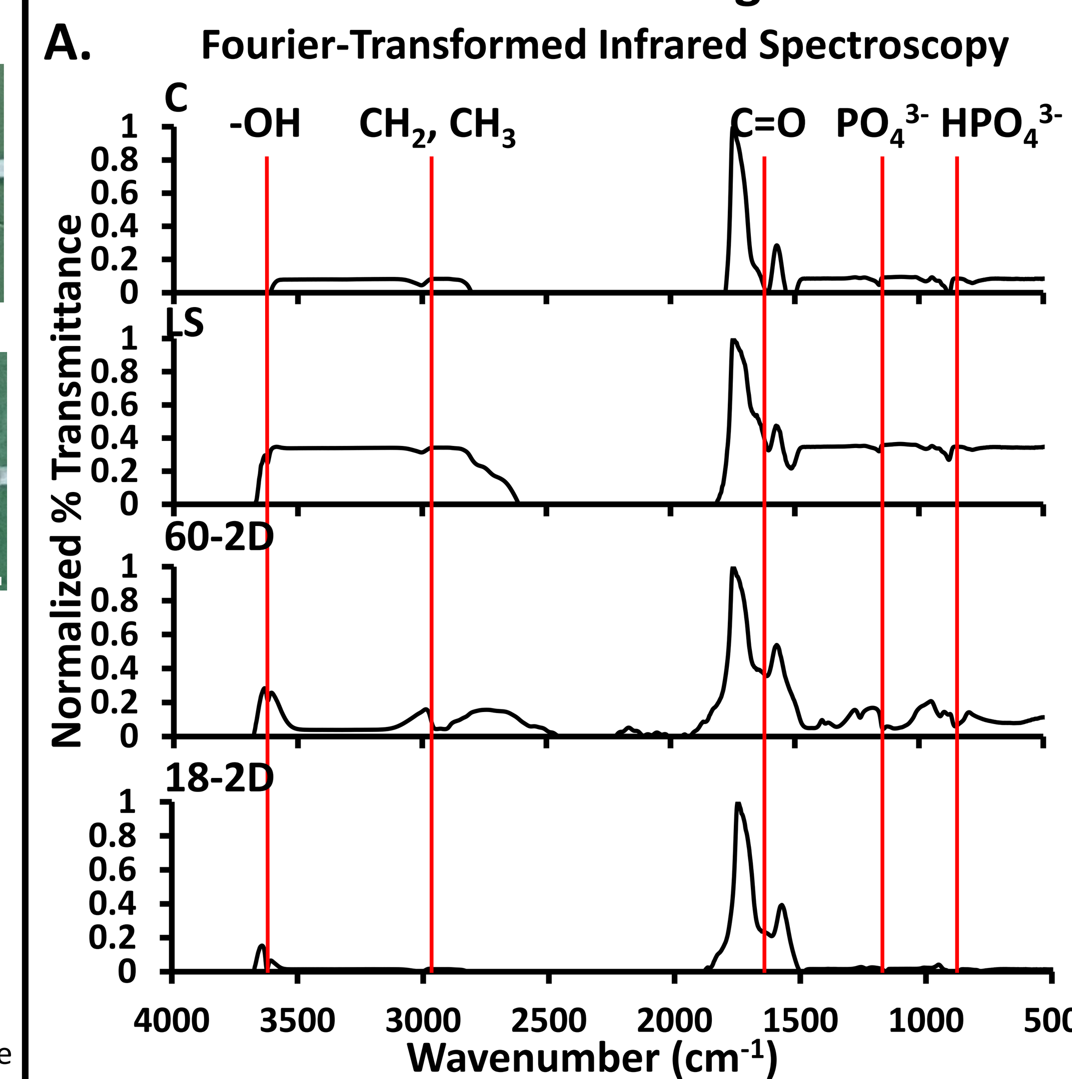
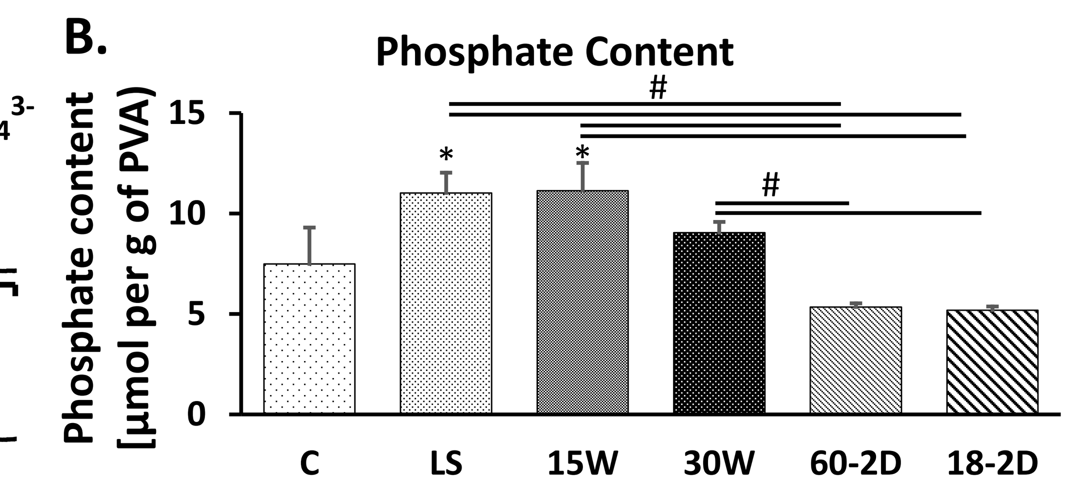


Figure 1. (A) Cross-sectional images. Red arrows are used to identify difference level of transparency between layers within a sample. (B) Wall thickness. # indicates p<0.05. * indicates p< 0.05 with respect to control group.

2. LS and 15W had higher crosslinking density compared to the control





C. Differential Scanning Calorimetry

	Heat of Fusion (J/g)	Fractional Crystallity (%)
Control	50.27	36.3
60-2D	52.24	37.7
18-2D	57.13	41.2

Figure 2. (A) Fourier-transform infrared spectroscopy data. Data was normalized to PVA film. (B) Quantification of phosphate content for the samples to characterize covalent crosslinking by STMP. (C) Heat of fusion and fractional crystallinity of the samples. * indicates $p < 0.05$ with respect to the control groups. # indicates $p < 0.05$.

3. 15W displayed highest interlayer adhesion

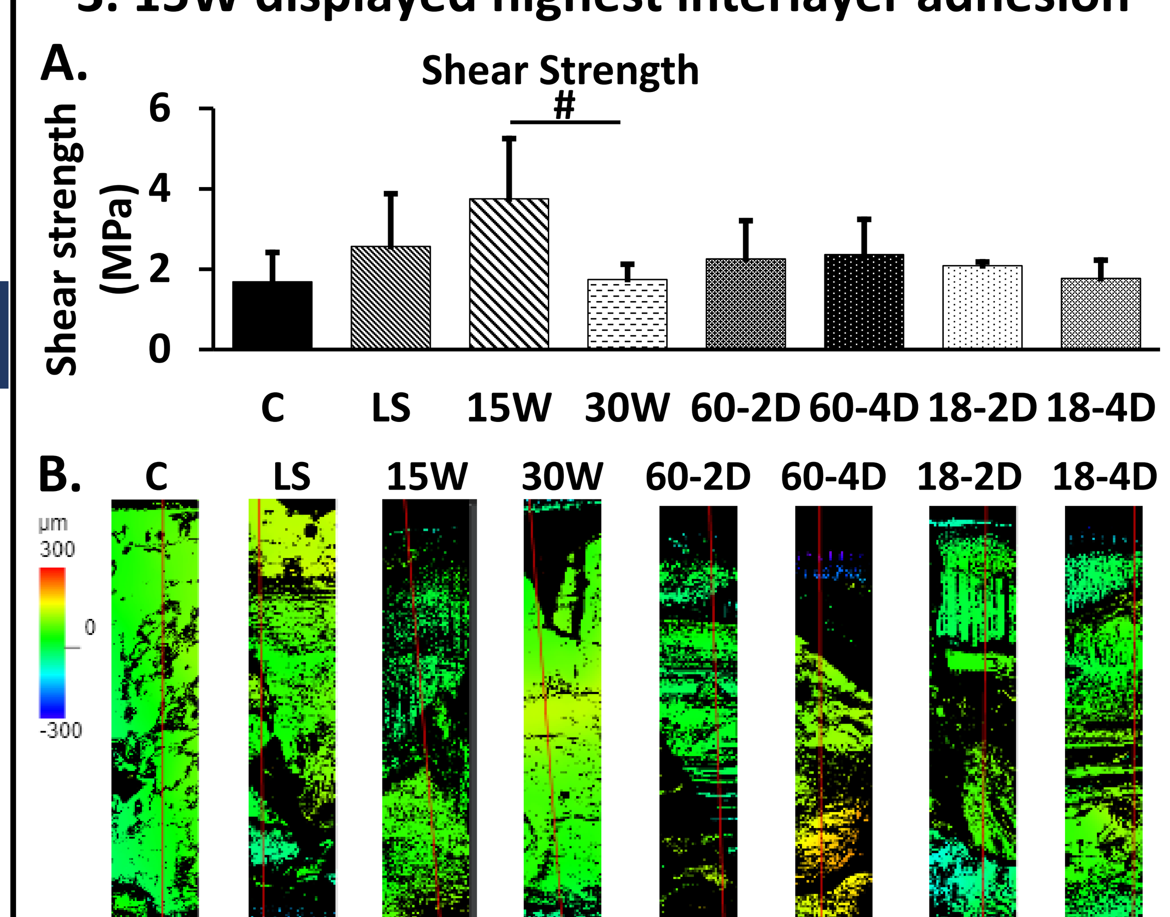


Figure 3. Interfacial energy. (A) the adhesive strength of groups. 15W had p=0.0571 with respect to the control group, and p=0.0495 with respect to the 30W. (B) height map of the samples after adhesive shear test. # indicates p<0.05.

4. 15W had comparable burst pressure and compliance to control LS had significantly lower compliance than the control group

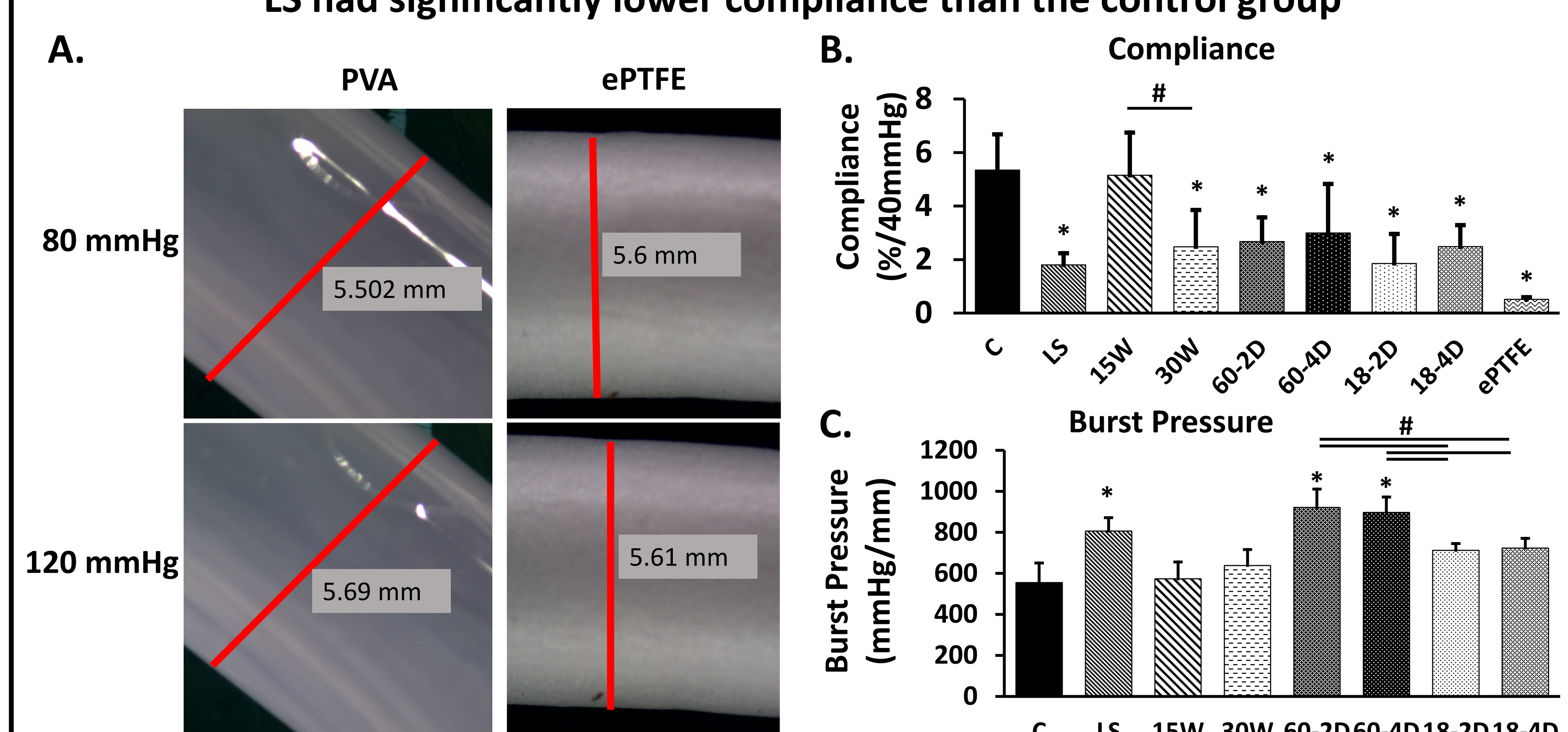


Figure 4. (A) images of the grafts during the compliance measurement. (B) Compliance of each group. (C) Burst pressure per mm of each group. # indicates p<0.05. * indicates p< 0.05 with respect to control group.

Conclusions

- Interlayer adhesion resulted in increase in burst pressure without sacrificing the compliance
- Higher crosslinking density resulted in higher burst pressure, but resulted in lower compliance.
- **Interlayer adhesion could potentially be used to increase the burst pressure without sacrificing the compliance**

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