

SUPPLEMENTAL MATERIAL 2 – PHANTOM STORAGE PROPERTIES

Paper: “A realistic deformable prostate phantom for multi-modal imaging and needle-insertion procedures.”

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The following is a detailed description of the experiments done to determine the storage properties of our deformable prostate phantom.

In the first experiment, we carried out the same compression stress-strain measurements described in section III.B. of the paper, on 3 sets of PVC samples each stored at different temperatures for 11 days after fabrication. The first set was stored at room temperature (between 23 °C and 25 °C), the second in the fridge (4.5 °C) and the third in the freezer (-21 °C). The resulting stress-strain relationships can be seen in Figure Sup.1. We can see that, except for the standard samples, the stress-strain relationship follows a steeper curve with increasing storage temperature. In other words, PVC stored at room temperature becomes stiffer, while PVC stored in the freezer stiffens less quickly over time. Visually, over time, we noticed that the samples leached oil, predominantly in the room-temperature samples, while the colder samples remained more intact.

In the second experiment, we constructed three small sample models as shown in Figure Sup.2, similar in property to the true phantom. The models consisted of a 16 mm diameter cylinder made of standard PVC mixture stained with Toluidine Blue (like the material used for the prostate capsule) submerged in a super-soft PVC surrounding. Models were used because they were easier to manufacture and because the geometrical shape of the blue cylinder was easier to survey visually in terms of size and shape. One model was stored at room temperature, another in the fridge and the third in the freezer. The models were observed over a period of 26 days: photographs were taken of each model throughout the period, in order to follow any visual changes; at the same time, 3D ultrasound volumes were also taken, in order to monitor any changes visible in this imaging modality.

Visually, the cylinders showed leaching over time of the blue coloring into the surrounding super-soft material. Figure Sup.3 shows this phenomenon with sequential photographs of the models over the 26 days. The model stored at room temperature shows very rapid and evident leaching. The model stored in the fridge shows less leaching, while the freezer model shows minimal leaching. This leaching is consistent with the changes in mechanical properties described in the first experiment above: as the oil-based softening agent seeps out, the samples can be expected to become stiffer.

Figure Sup.4 shows a sample image of the ultrasound volumes taken of the models. Nine volumes were taken of each sample using an Ultrasonix 4DEC9-5 end-fire probe connected to an Ultrasonix RP

ultrasound machine. In order to determine whether the visual US properties changed over time, the cylindrical inclusion was singled out in each image and its volume measured. The volume was measured by thresholding the region of interest around the cylinders with the same intensity threshold range for each image, and then summing the resulting white pixels. The results are shown in Figure Sup.5. The volume increased for all three samples over the 26 days. Once again, the sample stored at room temperature showed a stronger change than the other two samples. The sample in the freezer showed noticeably less change in volume.

There are two possible reasons for these changes in volume. The first is evidently that the leaching of the blue scattering agent resulted in an increased volume being visualized in the US images. The diffusive character of this leaching was not, however evident in the images: even the sample with the strongest amount of leaching still displayed a sharp outline of the cylinder in the US image. This, therefore, pointed to the other reason for the change in volume, notably a change in speed of sound of the material. An increase in speed of sound would consequently increase the apparent size of the cylinder in the image, resulting in larger measured volumes. This is a reasonable assumption, given the increase in stiffness over time, as described above, which would result in an increase in speed of sound (see measured speeds for mixtures of various stiffnesses in Table II of the paper).

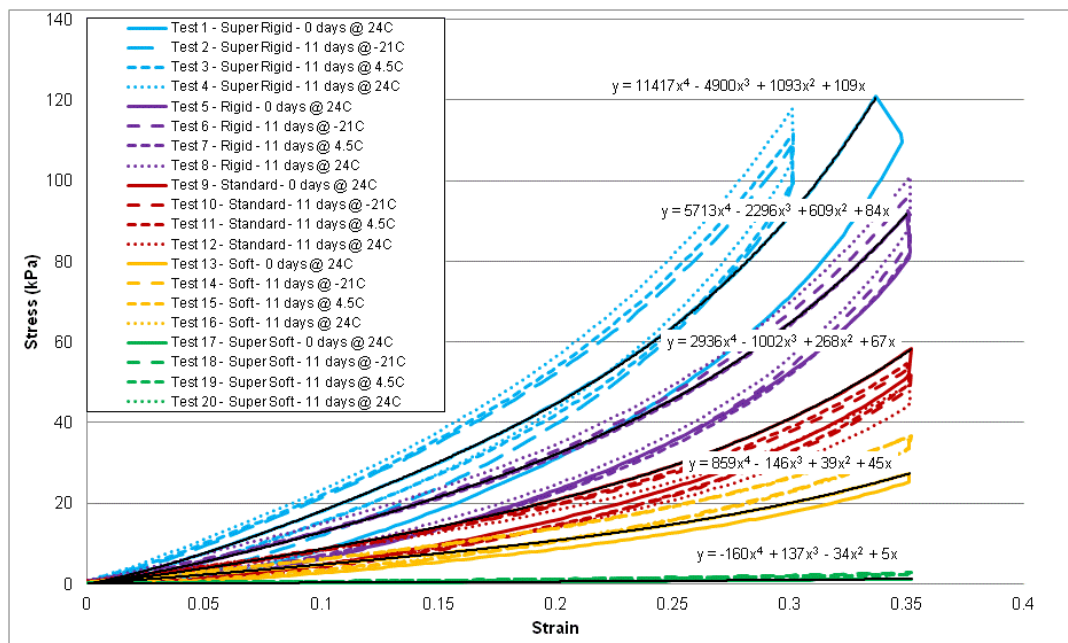


FIG. Sup.1. Stress-strain curves for the four sets of PVC samples stored at different temperatures: overnight at room temperature (0 days @ 24C), eleven days in the freezer (11 days @ -21C), eleven days in the fridge (11 days @ 4.5°C), and eleven days at room temperature (11 days @ 24C). Polynomial fits for the compression phases of the overnight samples are traced in black.

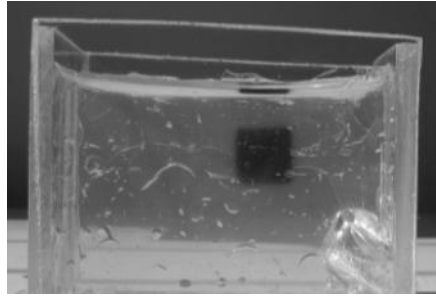


FIG. Sup.2. Small sample model of our phantom, used to observe its storage properties.

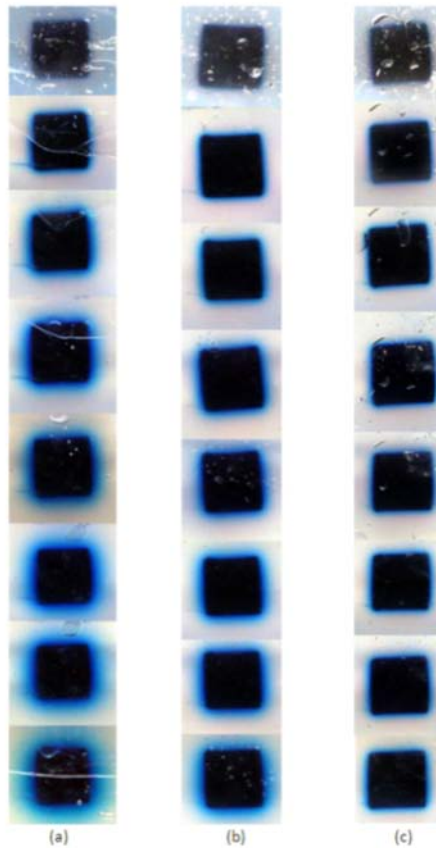


FIG. Sup.3. Close-up photographs showing the leaching of the sample models over a period of 26 days (samples grow older vertically downward). (a) Model stored at room temperature. (b) Model stored in the fridge. (c) Model stored in the freezer. Note the photographs are not homogeneously scaled: the important aspect is the relative amount of leaching observable around the cylindrical inclusion in each photograph.

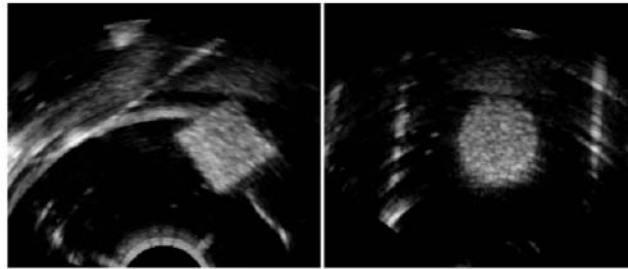


FIG. Sup.4. Sample ultrasound image of the leaching models. Left: sagittal cut. Right: transverse cut.

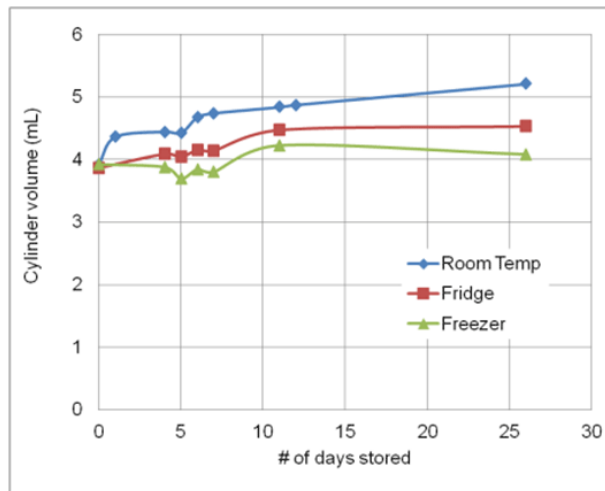


FIG. Sup.5. Volume over time of the thresholded inclusions for the three samples stored at different temperatures. The uneven jumps in the curves are likely the result of slight image inconsistencies caused by variable probe pressure or the presence of air bubbles in ultrasound gel applied at the probe-phantom interface.