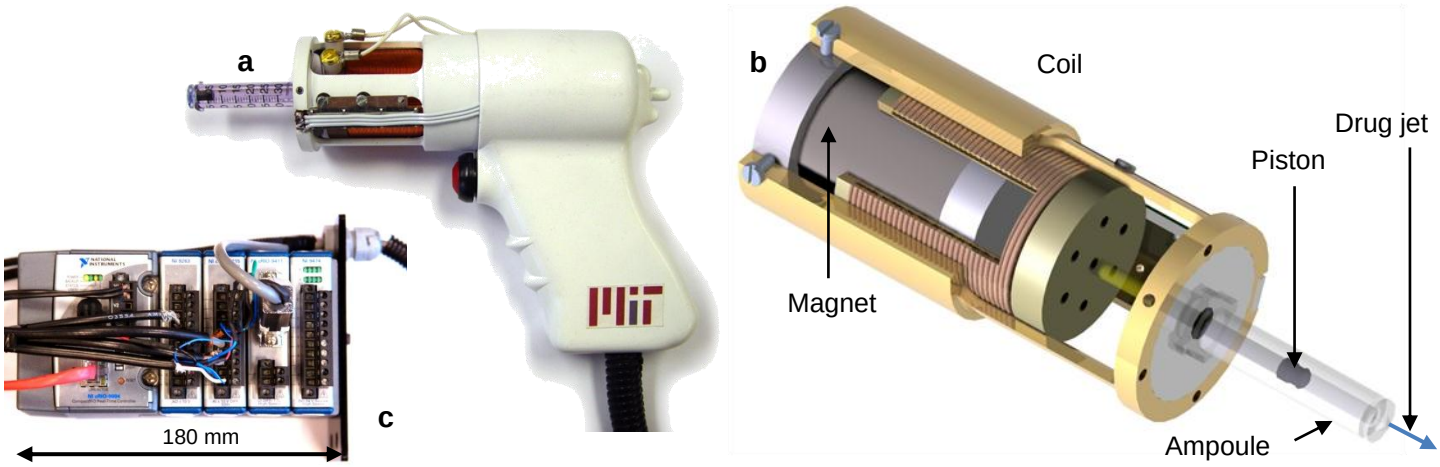

Fig. 1. (a) Handheld-injector. (b) Cutaway view of linear Lorentz-force motor. (c) cRIO controller

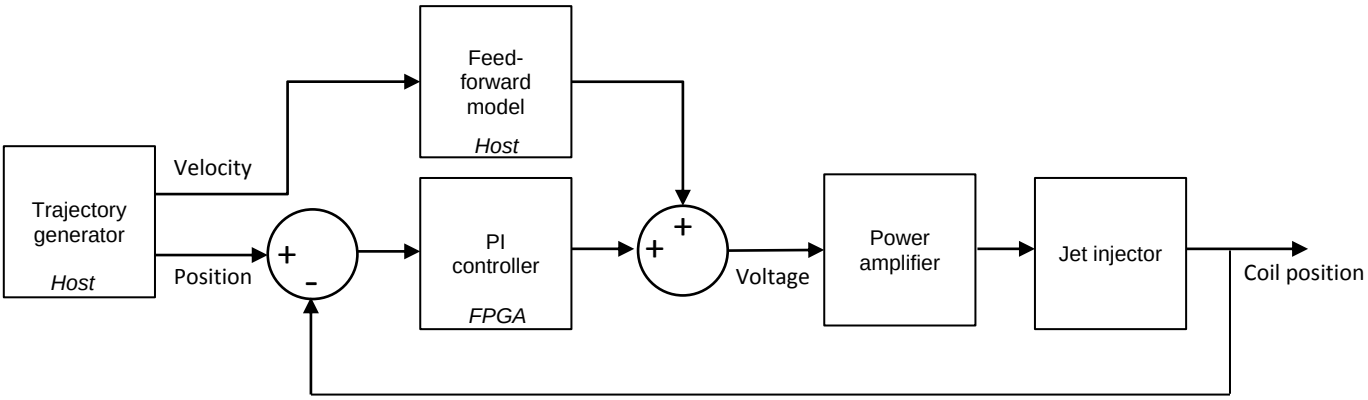

Fig. 2. Block diagram of control system architecture.

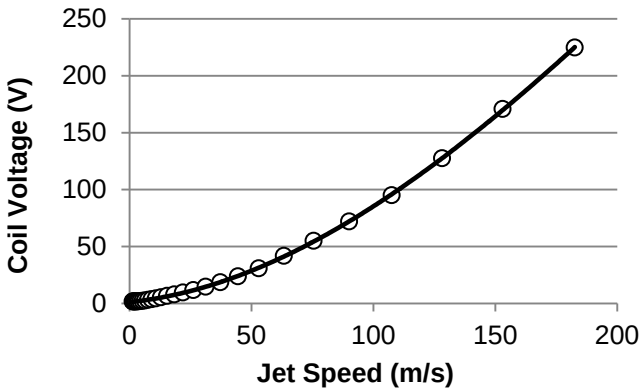

Fig. 3. Typical feed-forward model relationship. Measured points (open circles) and polynomial fit (line).

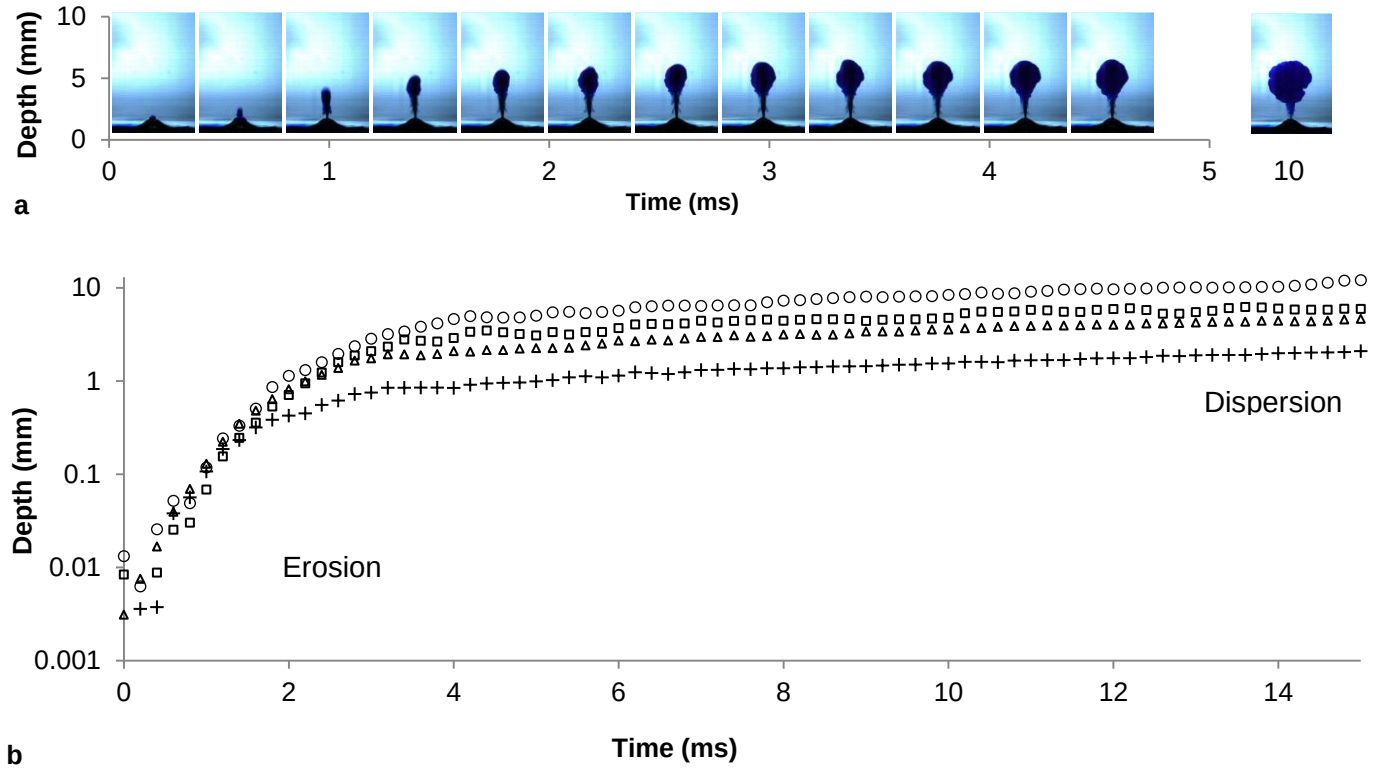

Fig. 4. Injection progress into acrylamide gel at constant jet speed. (a) Frames from a video recording of an injection (400 µs apart, jet speed = 100 m/s); last frame shows dispersion at t=10 ms. (b) Injection progress at various constant jet speeds.

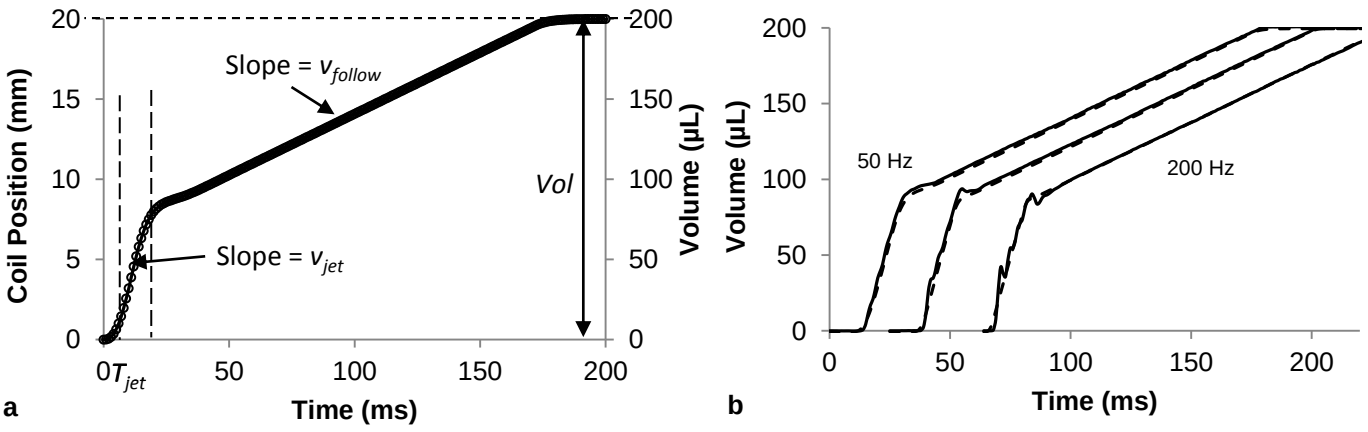

Fig. 5. (a) Typical injection trajectory; v_{jet} = 200 m/s, T_{jet} = 10 ms, v_{follow} = 20 m/s, *Vol* = 200 µL. (b) Requested (dashed lines) and achieved (solid line) injection trajectories as acceleration/deceleration frequency is set at 50, 100 and 200 Hz.

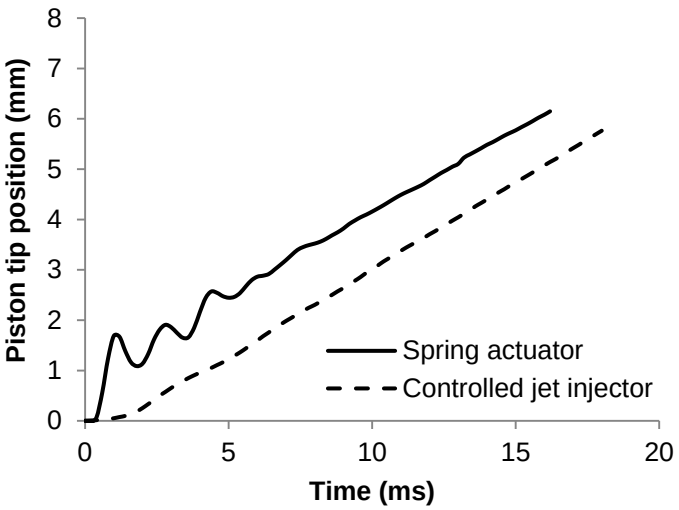

Fig. 6. The measured piston-tip displacement response of an Injex ampoule when driven by an Injex30 spring-based injector (solid line) and our servo-controlled Lorentz-force actuator (dashed line)

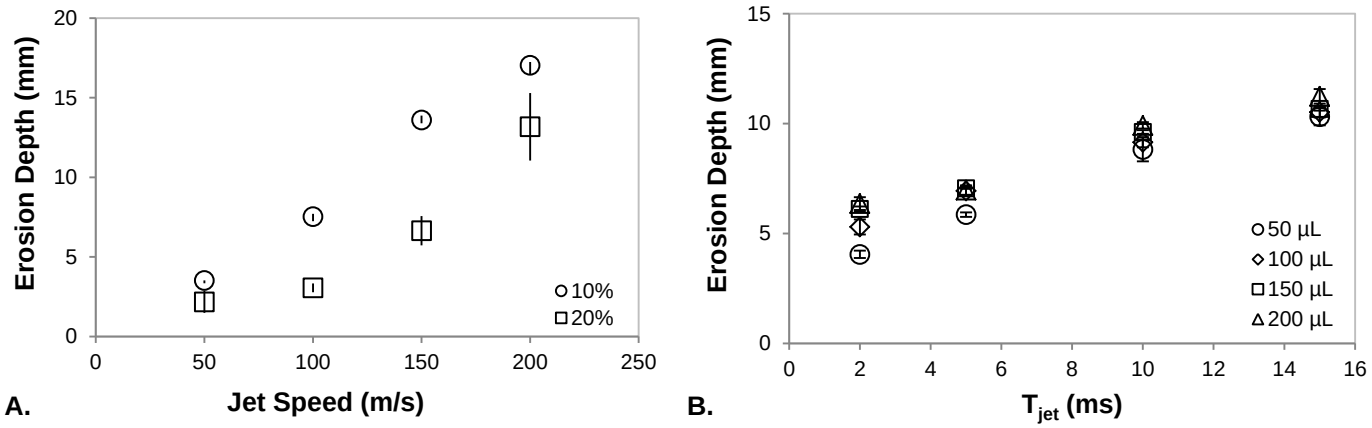

Fig. 7. Controllability of injection depth. (a) Erosion depth as function of jet speed in 10% and 20% acrylamide gels, with T_{jet} = 8 ms. Each point with error bars represents the mean and standard deviation respectively of 4-5 injections. (b) Erosion depth in 10% acrylamide gels as a function of increasing time at high jet speed. Volumes (50 µL, 100 µL, 150 µL, 200 µL) of 0.25% bromophenol blue were injected into the gels using V_{jet} =100 m/s and V_{follow} = 50 m/s. Each point with error bars represents the mean and standard deviation respectively of 6 injections.

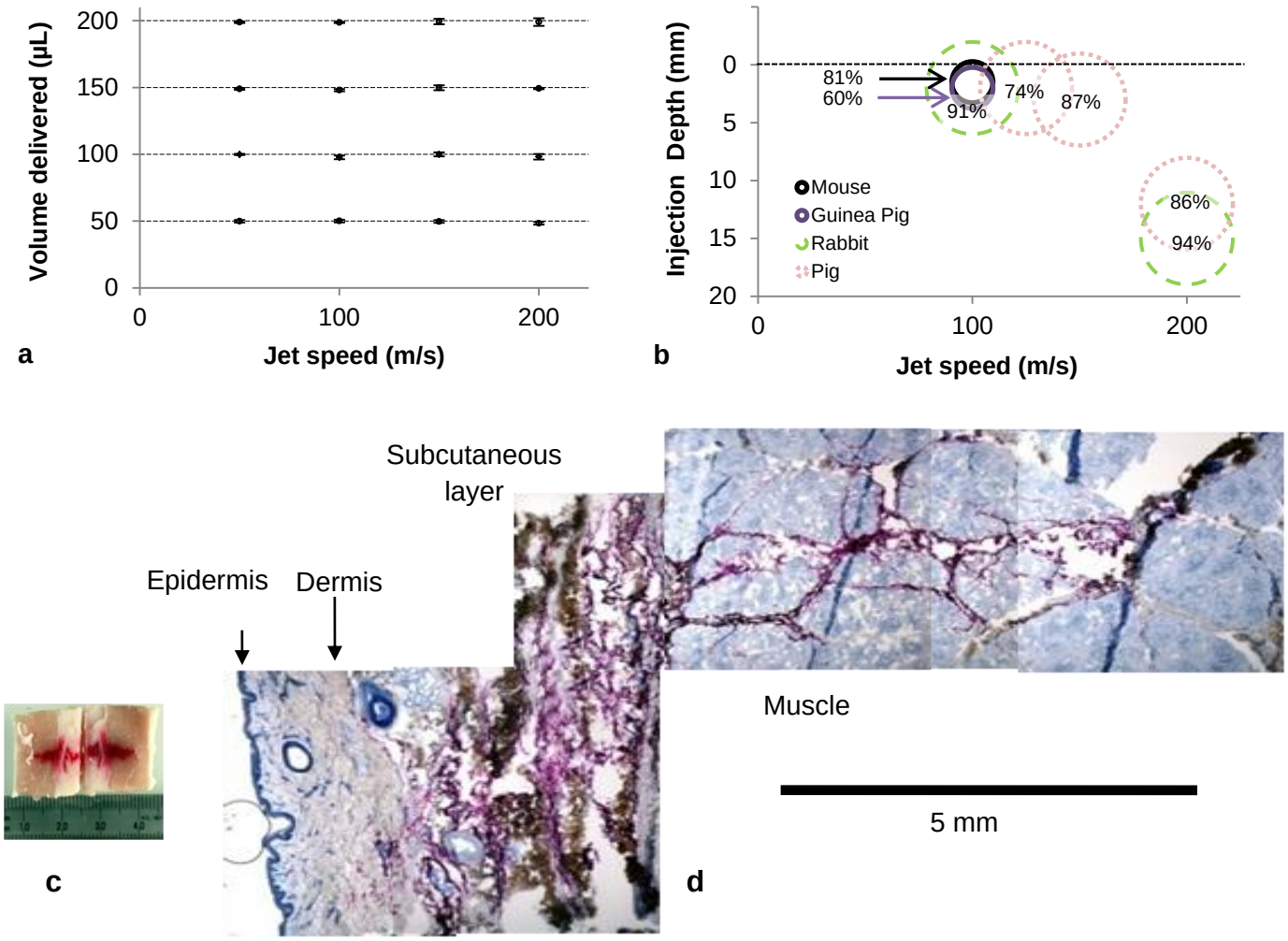

Fig. 8. Controllability and repeatability of delivery volume. (a) Volume delivered to vials as a function of jet speed for requested volumes of 50, 100, 150 and 200 µL. Each point with error bars represents the mean and standard deviation respectively of 24 ejections. (b) Injection depth for various jet injections into post-mortem tissues. The area of each circle represents the total desired injection volume (20 µL or 100 µL); the percentage quantifies the mean proportion of the drug absorbed by the tissue, by weight. Mouse: n=103, CV=0.15 @ 100 m/s; Guinea pig: n=20, CV=0.31 @ 100 m/s; Rabbit: n=30, CV=0.03 @ V_{jet} 100 m/s; n=30, CV=0.02 @ V_{jet} 200 m/s; Pig: n=20, CV=0.11 @ V_{jet} 125-150 m/s; n=26, CV=0.08 @ V_{jet} 150-175 m/s; n=20, CV=0.08 @ V_{jet} 200 m/s (c) Photograph of post mortem pig skin injected with 100 µL of a 1:20 dilution of red tissue marking dye, medially sectioned through the injection site, and splayed injection side up; V_{jet}=200 m/s, T_{jet}=25 ms, and V_{follow}=50 m/s. Ruler scale is in millimeters. (d) Reconstruction of a series of photographs of a 10 µm thick section of pig skin.