Development of an Advanced Injection Device for Highly Viscous Materials

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INTRODUCTION: In several interventions on the spine, such as Vertebroplasty and disc nucleus replacement, highly viscous fluids are injected into bony or cartilaginous structures through a cannula. Currently, the material is delivered with traditional syringes, which suffer from low pressure, or screw plunger systems[1], which eliminate tactile information.
We are presenting an advanced injection device that overcomes the limitations of current injectors and provides real time parameter assessment.

METHODS: An injection device generating 5 MPa peak pressure in a 6 ml polycarbonate syringe has been built. It is driven by a DC motor, which creates 640 N compressive force on the syringe plunger. An integrated encoder provides precise position and speed information used to calculate the injected volume and flow rate. Furthermore, strain gauges measure the force applied to the plunger, which is proportional to the pressure created in the syringe barrel. The system is controlled from a syringe-like actuator with force feedback for precise operation.

Fig. 1: The motorized injection device loaded with a 6 ml polycarbonate syringe

In most procedures dealing with the injection of substitution materials, the viscosity of the substitute is a central parameter relating to complications. When viscosity is to be assessed in a standard viscometer during the injection procedure, material curing is affected by the measuring process itself. Therefore, measurements do not correspond to the viscosity of the material contained in the syringe barrel. Our system however provides all necessary parameters for viscosity estimation during injection based on the capillary rheometer principle[2]:

$$\eta = \tau/\gamma = (PD/4L)/(32Q/\pi D^3) \quad (1)$$

(η: viscosity, τ: shear stress, γ: shear rate, P: applied pressure, D,L: diameter, length of the cannula, Q: volumetric flow rate)

RESULTS: The device has been used in animal and cadaver studies investigating various aspects of Vertebroplasty. Furthermore, verification of viscosity estimation has been performed against Newtonian standard fluids rated at 41, 72, 200 and 380 Pa·s, as shown in Fig. 2.

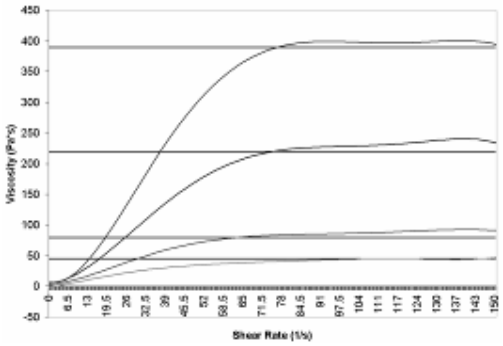

Fig. 2: Viscosity estimation against four different Newtonian fluids (horizontal lines) at increasing shear rate.

DISCUSSION & CONCLUSIONS: The presented injection device provides the means for consistent, repeatable and well-documented research and interventions. The integrated parameter assessment capabilities pave the way for identification and prevention of injection related complications, such as leakage due to low viscosity or excessive volume.

REFERENCES: [1]S.T. Lee and J.F. Chen, *A syringe compressor for vertebroplasty: technical note*, Surg.Neurol., 61-6: 580-584 (2004). [2]A. Allahham, D. Mainwaring, P. Stewart, et al, *Development and application of a micro-capillary rheometer for in-vitro evaluation of parenteral injectability*, J.Pharm.Pharmacol., 56-6: 709-716 (2004)