Computer Assisted Medical Interventions (CAMI) involving soft tissues require devices that model such tissues in order to estimate the way they are going to be deformed and/or resected by the surgical gesture. The corresponding biomechanical patient-specific models require an estimation of the constitutive behavior of the soft tissues. Since the mechanical behavior of living tissues varies between in-vivo and ex-vivo conditions, it is important for the CAMI devices to offer an in-vivo estimation with non-traumatic measurements that should undergo sterile conditions. For this purpose, among all the methods proposed in the literatur , aspiration/suction is the most widely used technique due to its simplicity and robustness. For such a technique, a device with a hole is put in contact with the soft tissue while a negative pressure aspires part of this tissue. Knowing the relationship between the negative pressure and the aspired tissue height, an inverse problem is then solved to identify the material mechanical properties. In the literature, the apex height is usually measured with a camera and a mirror or a prism, which induces design difficulties, in particular in regards on the required sterilization process for in-vivo measurements. This paper introduces a new method that replaces the optical apex height measurement with a measurement of the aspired tissue volume. The method is referred to as “rate-based method”. The camera, mirror and all electronic parts are not required which makes our device the simplest, lightest and cheapest one could achieve. In particular, this simplification enables the system to meet the severe sterilizations constraints that can be present for some surgeries. Indeed, the proposed device is only composed of a cylindrical plastic chamber (with a hole at its basis), some connection tubes, a syringe pump, a manometer and an aspiration chamber. The idea is to aspirate the tissue inside the chamber using the syringe pump, while measuring the negative pressure and the corresponding removed volume. Such a volume is due to both the aspired tissue volume inside the chamber and the volume changes in the device (air expansion and elasticity of the connections, tubes, syringe, etc.). An off-line calibration process is defined to differentiate the volume changes due to tissue aspiration from the volume changes due to the compressibility of the device (tubes, connections, syringe).

Our device was evaluated with the estimation of the constitutive behavior of two bulk cylindrical silicone samples, one being slightly softer than the other one. For each silicone, thin flat samples were extracted to characterize their constitutive behavior using a classical traction experiment (MTS Criterion machine, Model 41) and an equibiaxial extension (bulge test). Such experiments respectively provide Young modulus of 16.82kPa and 24.87kPa for silicones #1 and #2.

The aspiration tests on each silicone sample were repeated nine times to check the reproducibility of the results. The inverse method to estimate the constitutive behavior assumed a hyper-elastic Gent model with material constants computed using an updated FE simulation. The results validate the ability of our method to discriminate the two silicones with equivalent Young moduli estimated to 18.35kPa and 26.52kPa for silicones #1 and #2.