
Statistical analysis of precompression time in laparoscopic sleeve gastrectomy using finite element modeling

Stefan Schrammel^{*†1}, Maximilian P. Wollner¹, Michele Terzano¹, Clarissa Holzer-Stock¹, Alex W. Caulk, and Gerhard A. Holzapfel¹

¹Technische Universität Graz – Austria

Abstract

Laparoscopic sleeve gastrectomy is one of the most common procedures used to treat obesity. In this procedure, the stomach is cut and closed with a staple line to form a smaller gastric sleeve. Before stapling, the employed surgical stapler fixes the tissue by mechanically clamping the region of interest. Clinical studies indicate that a certain precompression time between clamping and stapling is effective in reducing complications such as inter- and post-operative bleeding (1,2). However, the relationship between this precompression time and the mechanical processes in the tissue remains unclear.

To investigate this relationship, we developed a finite element model of the clamping process. The stomach tissue is modeled as an anisotropic solid, including dissipative processes such as viscosity and loss of stiffness, similar to the Mullins effect (3). The stapler interacts with the tissue via two contact surfaces, taking into account the compliance of the device. The material model was implemented in the finite element software LS-Dyna and verified with a semi-analytical solution. A distribution of material parameters was identified from a series of uniaxial compression tests on porcine stomach tissue using distinct loading protocols. The geometrical variability of tissue thickness was also quantified probabilistically. We then ran about 150 simulations using these distributions, which enabled statistical analysis of the process.

Our model establishes a connection between the precompression time and mechanical quantities such as (accumulated) dissipation and displacements. In addition to these global metrics, we can investigate the local tissue response during clamping, which becomes particularly important in subsequent simulations of staple formation. Our results will help further develop surgical staplers and optimize the definition of user guidelines, leading to more reliable stapling results and fewer post-operative complications.

References:

- (1) M. Sermet, "Compression pre-stapler firing and post-ignition wait during sleeve gastrectomy: a prospective randomized trial," Sao Paulo Medical Journal, vol. 142, no. 3, 2024. doi: 10.1590/1516-3180.2023.0163.140823.
- (2) M. Gencturk, M.S. Dalkilic, H. Erdem, M. Yilmaz, and A. Sisik, "Correct stapling technique in laparoscopic sleeve gastrectomy: Are we increasing the bleeding? A prospective

*Speaker

†Corresponding author: stefan.schrammel@tugraz.at

cohort study,” *Journal of Laparoendoscopic & Advanced Surgical Techniques*, vol. 33, no. 6, 561–565, 2023. doi: 10.1089/lap.2022.0584.

(3) M.P. Wollner, M. Terzano, M. Rolf-Pissarczyk, and G.A. Holzapfel, ”A general model for anisotropic pseudo-elasticity and viscoelasticity at finite strains,” *Journal of the Mechanics and Physics of Solids*, vol. 180, 105403, 2023. doi: 10.1016/j.jmps.2023.105403.