Various Fabricated Micro-Scale Tips for Laparo-Endoscopic Surgery Instruments

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Abstract:

A new surgical micro-scale tip for laparo-endoscopic interventions is developed. The instruments tip allows movement and manipulation with two wrist joints and a gripper. The joints as well as the gripper are cable driven through the instruments shaft. The main topic of this publication is the processing of this micro-scale instrument tip using various production methods for prototyping, e.g. milling, fused deposition modeling, and selective laser micro melting.

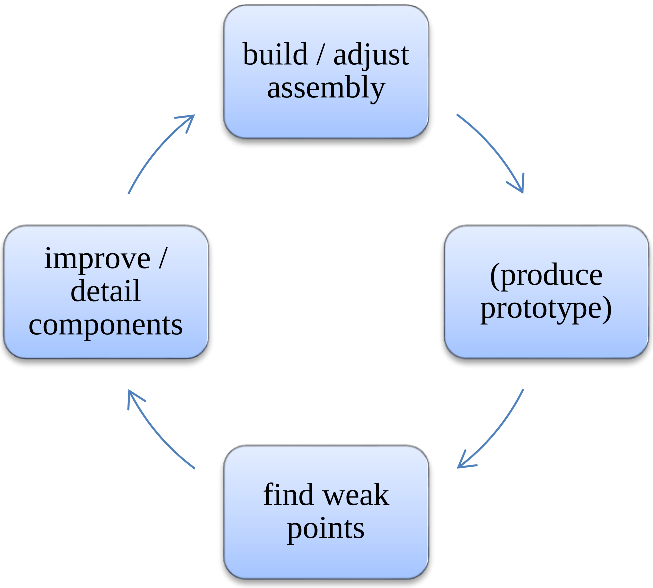
Laparo-endoscopic surgery is a wide spread surgical method. In the process, the abdominal cavity of the patient is opened through small incisions. Through an abdominal access a laparoscope is inserted to illuminate and capture the internal organs. The latter are shown to the surgeon by appropriate means of visual representation. To manipulate tissue or perform stitching usually two handheld laparoscopic instruments are applied, offering four degrees of freedom (DoF) at the instrument's tip. To expand the range of applications for this gentle surgical technique instruments with two additional DoF at the instruments tip are used thus full manipulability is provided [1]. High functionality, high forces, and small cross sections are challenging issues for the design of such instrument tips.

This work presents a new mechanical design for such improved instruments tips. The basic idea is the implementation of

- sliding guides for the cables instead of pulleys in order to reduce the number of components for lower production and assembling costs,
- Ultra-High-Molecular-Weight Polyethylene (UHMW-PE), known by its trading name Dyneema®, for the cables in order to increase the achievable gripping forces and to decrease friction,
- and new manufacturing methods for the components allowing high levels of functionality.

All these technologies allow but also require a new design of the instrument tip. This new design was evolved following the recursive routine shown in Figure 1. That means, after defining the requirements, the development of the assembly is performed using CAD. Therefore, an alternation between adjusting the assembly, finding weak points of the construction, as well as improving or detailing components is performed in many sequences. For a fast and cost effective development, it is important to find the weak points of the construction very early. Therefore, beside functional analysis software, e.g. finite element methods, new rapid prototyping technologies are very helpful. During the development of the micro-scale instrument tip fused deposition modeling (FDM) was used to produce the first prototype (see Fig. 2 a)). This technique offers the benefit of low costs and short production time but the resulting parts have low mechanical stability. Anyway, the first prototype is suitable for very low manipulation forces and gives well direction to improve the construction, e.g. the cable guidance.

Fig. 1: Recursive routine of developing a micro scale instrument tip.



A second prototype (see Fig. 2 b)) is produced using selective laser micro melting (SLμM). This technology offers the benefit of high mechanical stability but the surfaces of the produced parts are raw and need to be finished. However, the second prototype is suitable for high manipulation forces and gives well direction to further improve the construction, e.g. the cable friction. A final prototype (see Fig. 2 c)) is produced using both, CNC-machines and SLμM. The use of CNC-machines offers the benefit of high mechanical stability, accuracy, and surface quality, but the setup and programming of the machines needs time and leads to high manufacturing costs. Also the complexity of the parts is limited. However, the final prototype can be produced in small batches and is ready for further studies, e.g. permanent load experiments, investigation of stiffness.

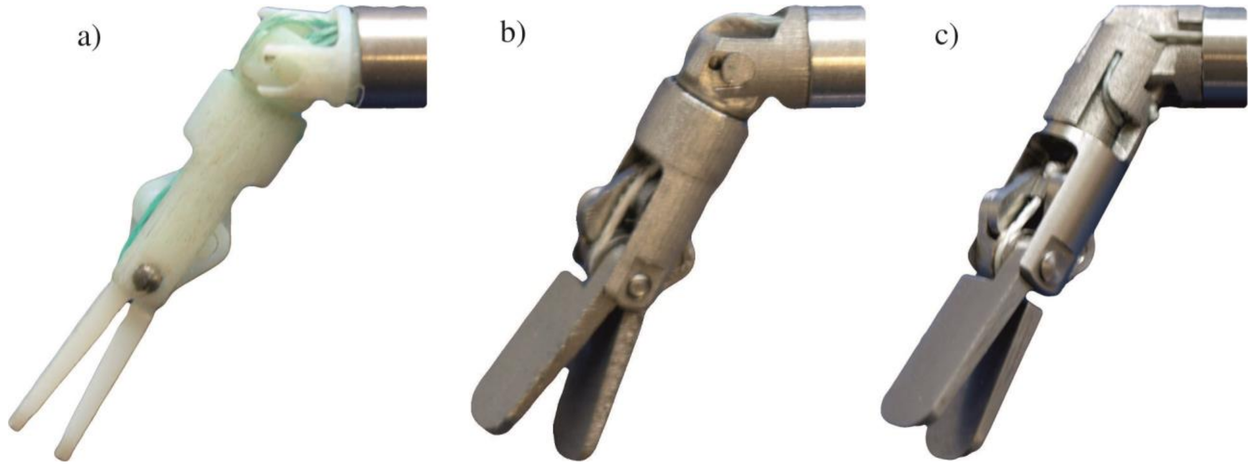


Fig. 2: Prototypes of micro scale instrument tip (shaft diameter 8 mm): a) FDM, b) SLμM, c) milling and SLμM

References:

[1] Mastery of Endoscopic and Laparoscopic Surgery, W. Stephen; M.D. Eubanks; Steve Eubanks (Editor); Lee L., M.D. Swanstrom (Editor); Nathaniel J. Soper (Editor) Lippincott Williams & Wilkins 2nd Edition 2004