Soft Oral Interventional Rehabilitation Robot for Trismus Patients Based on Low-Profile Soft Pneumatic Actuator

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Abstract

Trismus (reduced oral opening) is a common complication associated with head and neck cancer treatment. Reported prevalence of trismus in patients who underwent head and neck cancer treatment ranges from 5% to 38%. It affects normal oral activities including eating, chewing, swallowing, breathing, speaking, and may lead to poor oral hygiene, weight loss and severe pain. In such cases, interventional rehabilitation of oral activities, particularly for mouth opening training was applied to assist patients during the rehabilitation process. The conventional solutions for the training include manual operations using mouth opening apparatuses such as wooden screw, bite block, and clothespin. As an alternative solution, a mouth opening and closing training robot was invented by Hideaki et al [1,2] achieving the main three degrees of freedom of mandibular movement.

Given the limited availability of clinicians’ on-site presence, and the high cost and low portability of above-mentioned robotic system, it is highly desirable to develop a simplified rehabilitation system devoted to the loss of mandibular mobility.

In this work, we present a slimline and novel device to rehabilitate the mouth opening movement. First and foremost, a low profile soft pneumatic actuator (SPA) [3] made of hyper-elastic silicone material was designed and fabricated. With zero-thickness air chamber embedded, the actuator is shaped into a soft pad as thin as 4 mm (fig.1-a) and transforms into a spherical structure (fig.1-c and e) when pressurized. By mounting the balloon SPA onto a pair of tooth-guard, the end effector was built to be placed into oral cavity of patients and enable the mouth opening (fig.1-b and d).

Before the clinical experiment, the biometrics of human mandibular was investigated as the requirements of the SPA design, after which, the characterization of SPA of varied dimension configurations was implemented by measuring the force outputs and range of motion with or without predetermined loads.

Regarding the control system, we establish a simplified model based on the material property and mechanical structure. Also, inertial sensor was integrated into the two piece of tooth-guard to obtain the spatial relation of the tooth-guards and a pressure sensor was used to monitor the air pressure applied.

The whole system was initially tested on cadaver heads in which the muscles are rendered stiffer. The results show that the robot is able to move the mandible to the respective maximum opening ranges of different subjects. Furthermore, the experiments on patients and healthy subjects verified its functionality and comforts.
To further upgrade the system, new SPAs with more degrees of freedom are under development to enable more movements of human jaw other than opening.

![Image of low profile Balloon SPA and Mouth Opening Rehabilitation Device](image)

Figure 1. Low profile Balloon SPA and Mouth Opening Rehabilitation Device. (Left) Initial tests on a skull-base phantom (Right) Preliminary tests on a cadaveric head

Reference

