Effectiveness and safeness of the power tool with a real haptic interface in orthopedic surgery

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INTRODUCTION: It is frequent technique for orthopedic surgeons to drill and cut bones near blood vessels and nerves during the surgery. This is a delicate procedure and can sometimes lead to complications such as vascular and nerve injuries. When orthopedic surgeons penetrate the cortical bone with a drill, they rely on their feeling to determine whether the cortical bone has been penetrated appropriately. Therefore, neurovascular complications may occur at a certain rate. To avoid these complications, a highly secure system better than the operator's sense or experience should be developed. Real haptics is a technology to transmit tactile and force sensation between the sender and the receiver remotely. The motion of the master at the hand side and the motion of the slave at the remote side are synchronized and action force of the slave side is transmitted to the master side as the reaction force right away. By monitoring the drilling force and the drill tip position in real time, it is possible to detect penetration and stop the drill automatically. The purpose of the present study was to investigate and clarify safeness of the power tool with a real haptic interface.

METHODS: A custom made power tool with a real haptic interface was used in the present study. This power tool with a Kirschner wire is driven by a master side linear motor with optical encoders remotely. It is equipped with real haptics-based detection of penetration that can be turned on and off. We attached a Kirschner wire with a diameter 2.0mm to the tool and used femoral bone of the pig. Experiment was performed on female pigs weighing an average of 33.5 kg (13-30 months of age and 28.4-41.0 kg, n=6). Experimental Scene is shown in Figure 1. We verified effectiveness and safeness of this power tool by comparing the case with and without this detection. We measured the time required for detection and the length of Kirschner wire protruded over cortical bone after penetration. Statistical analysis was performed by two-tailed paired t-test using Statistical Package for the Social Sciences (SPSS statistics version 27.0, IBM Corp.). This experiment was approved by ethics committee of our university.

RESULTS: With the real haptic detection, the average time to detect the penetration of bone cortex on the opposite side was 0.165±0.008s, and the length of K-wire protruded over cortical bone after penetration was 2.511±1.078mm (n=43). Without the real haptic detection, the average time was 0.455±0.123s, and the length was 9.664±12.321mm (n=45). There were statistically significant differences in those parameters ($p<0.001$, respectively). The time and distance data for each experiment are shown in Figure 2, 3.

DISCUSSION: Based on previous papers, the use of conventional haptics technologies in surgical field was limited to use for simulators due to the difficulty of bi-directional transmission of tactile and force sensation. From the present study, it was suggested that this power tool with a real haptic interface could be used effectively and safely in actual surgery. However, this laboratory-based prototype is very large, and thus a practical smaller machine needs to be created in the future. In addition, we often use drill and saw as well as Kirschner wire, so we need to verify safeness of the power tool with a drill attached and safeness of the saw model with a real haptic interface.

SIGNIFICANCE: The power tool with a real haptic interface could contribute to safer and more accurate orthopedic surgery than ever before.

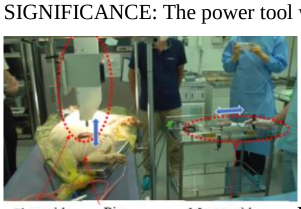

Figure 1

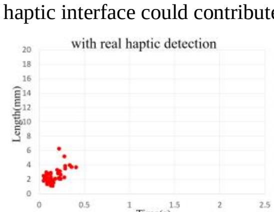

Figure 2

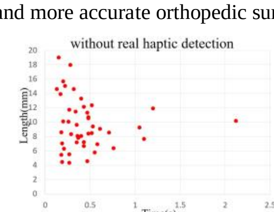

Figure3