Introduction

Because most commercial surgical navigation systems display the navigational information on the computer monitor positioned adjacent to the surgical scene, the surgeon has to look away from the surgical scene in order to obtain the navigational information from the computer monitor and has to perform the mental task of combining two sources of spatial information. To solve this problem, we have developed a novel laser guidance system which uses two or more laser beam emitters fixed to a stand. This system is combined with our own in-house-developed CT-based navigation system using an three-dimensional optical position sensor (OPTOTRAK® 3020, Northern Digital Inc.) [1, 2].

Each beam emitter produces a 0.25mW red (635nm) laser beam with a spot radius of 1mm and oscillates it within a range of 30 degrees at 50Hz, producing a fan-shaped beam tract. Two or more fan-shaped beam tracts intersect in a line that can be controlled in any direction by changing the angle and direction of the beam oscillation (Fig. 1). This laser guidance system draws cross hairs on a target, and the intersection of the cross hairs is the entry point for a drill or wire. After stabilization of the entry point, the system draws two or more lines along the guide sleeve. When the lines drawn on the sleeve are parallel, the direction of the drill or wire coincides with the line formed by the intersection of the laser beam tracts.

Materials and methods

In order to evaluate how diameter and length of the wire guide sleeve on which laser beam lines are drawn influence accuracy of wire insertion procedures and its feasibility for surgeons, we made several types of wire guide sleeves with different diameters and lengths (Fig. 2). The diameters prepared were 10, 20, 30, and 40 mm. The lengths prepared were 20, 30, 50, 100, 150, and 200 mm. A Kirshner wire with 3mm of diameter and 300mm of length was used for testing. A tracking marker with LEDs (AdapTrax Tracker) was fixed to the end of the wire (Fig. 3). After calibration of the wire, position of the entry point of the wire and direction of the wire were measured with our navigation system. According to the laser guidance, a surgeon first place the tip of the wire on the cross point and the distance between the tip of the wire and the target point was measured. Then, the wire was aligned so that the two laser beam lines become parallel while keeping the entry point position frozen. The angular difference between the wire direction and the target direction was measured. Measurements were repeated 20 times.

In order to evaluate the effects of position of the guide sleeves and intersecting angle of the laser beam tracts, position of the sleeve was adjusted with a distance of 20, 30, 50, 100, 150, and 200 mm from the wire tip and 10, 20, 30, 60, 90, 120, and 150 degrees of the intersecting angle of the two beam tracts were tested.

Discussion

The laser guidance system with oscillating dual beam tracts revealed to assist surgeons for a wire insertion with accuracy within 1mm for wire tip position at the entry point and with accuracy within 1 degree of wire direction. Accuracy of the wire direction was not affected by length of the guide sleeve, position of the sleeve, or diameter of the sleeve. Considering accuracy of the wire direction and feasibility for surgeons, the minimum length of the sleeve was 50mm and the optimum diameter of the sleeve was in a range from 20 to 30 mm. Position of the sleeve should be as distant from the wire tip as possible. In these range of setting, accuracy of the wire direction was 0.6 degrees with 0.8 degrees of RMS. The intersecting angle of the laser beam tracts affected accuracy of the wire direction. When the angle was 60 degrees or 90 degrees, direction of the wire was most accurate and these angles were easiest for the surgeon to align the wire to the laser beam tracts.

Results

Accuracy of the wire tip placement was 0.5 mm of bias with 0.9mm of RMS. There were little effects of length of the guide sleeve, position of the sleeve, or diameter of the sleeve on accuracy of the wire direction. However, there was a tendency for the surgeon to need longer time to align the wire with shorter length of the sleeve, shorter distance of the sleeve from the wire tip, and smaller diameter of the sleeve. Considering accuracy of the wire direction and feasibility for surgeons, the minimum length of the sleeve was 50mm and the optimum diameter of the sleeve was in a range from 20 to 30 mm. The optimum intersecting angle of the laser beam tracts was between 60 and 90 degrees.

References


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