Real-Time Depth Measurements During Operations

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Depth measurement is indispensable during orthopedic surgeries to choose the correct screw length. Depending on the anatomic spot, this choice is crucial and – if incorrect - may lead to severe damage of nerves, joints or blood vessels, thus often screws must be replaced afterwards. State of the art measurement is done mechanically and requires experience. The actual drill position or the final screw placement is found by X-ray imaging. In order to minimize operation time and X-ray exposure a system for real-time depth measurement is developed.

Materials and Methods

The evaluation of the study of principles takes into accounts not only the engineers', but also surgeons' as well as industries' views. These are obtained by interviews with people working in the field and a survey among orthopedists. The resulting most promising principle is based on the electromagnetic induction of co-axial solenoids, which is influenced by a metal ring, fixed on the drill.

Material research is required to find beneficial steels for drill and core. By using simulations based on FEM the beneficial parameters for the prototype are found. The prototype is then realized using rapid prototyping and self-made coils.

A measurement environment has been set up, which allows calibrating of the sensor as well as control-measurements.

Results

Figure 1 depicts deviations from five different measurements in relation to the actual drill depth. All measurements are in the range of ±0.4 mm and are even much more accurate between 15 mm and 45 mm.

The calibration is expected to be long-term stable at least within the scope of days. The observed trends are explained with the change in length of the primary coil due to changes of temperature caused by the current, but they are not related to the time of calibration.

In the final prototype, an excitation coil frames two receiver coils that are wound in opposite sense to increase the sensitivity in detecting the perturbation due to the metallic core (see Figure 2).

Discussion

The overall objective, namely to design a working prototype capable of measuring the depth of a drill hole in real-time, has been reached. Furthermore the device meets the demands, hence is reliable, easy to use and accurate enough. However, a further improved prototype should use a scaffold out of a rigid, temperature stable material such as PEEK. Furthermore it should comprise a metallic covering which prevents the device from environmental influence. The accuracy of such an improved device is estimated to be ±0.15 mm.

Further work must inevitably include investigations concerning the sterilization capabilities. These are dealt with only theoretically in the present study. It is reasonable to do further investigation with an industry partner. The aim is to extend the device's function insofar that it could additionally sense the drills environment and thereby detect or prevent a breakthrough.

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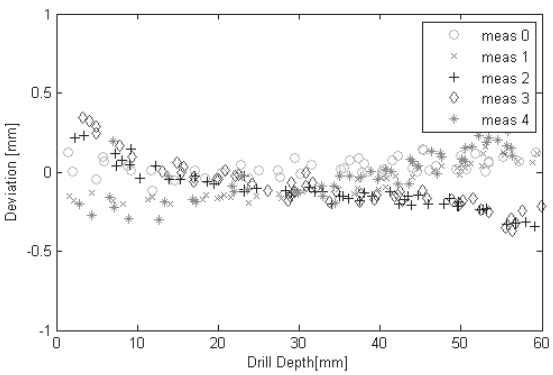

Figure 1: Deviation for five measurements within six days.

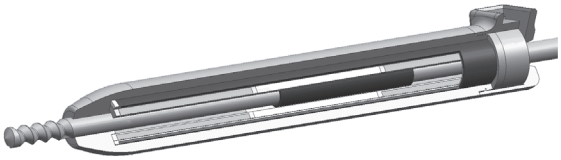

Figure 2: CAD sketch of the prototype.