Micro-Precise Surgery Assistant

Maximum precision for miniature parallel robot

A miniature, high precision hexapod with 6 DOF is used as guidance assistance for spinal surgery. The bone-mounted system, named SpineAssist, will accurately guide the surgeon for maximized precision when placing implants destined to stabilize spinal (vertebrae) fusions in both open and minimally invasive surgery. A part from the miniature hexapod robot, the system also consists of a preoperative planning software with automatic fluoroscopic and CT image processing and a set of rigid bone fixation clamps and platforms.

The inventor of the SpineAssist system and surgical procedure, Mazor Surgical Technologies, was established in 2001 as a spin-off of the mechanical department of the Israel Institute of Technology. The company's offices are located in Caesarea, Israel and Norcross, GA, USA (Mazor Surgical Technologies Inc.). Mazor specializes in development of medical robots whereas the precision mechanics manufacturing is outsourced to the Swiss based Faulhaber Group company, MPS Micro Precision Systems AG.

Accuracy in implant placement is very important in spinal surgery since most procedures are performed close to the nerve roots and spinal cord, where every millimetre counts. This, together with other biomechanical considerations makes accuracy and precision of the utmost importance.

Spinal fusion is a surgical intervention that is performed for example to straighten the spine and prevent further deformation due to scoliosis or other disorders; to support a weakened or injured spine, or to reduce or prevent pain from pinched or injured nerves. Although spinal fusion is associated with a high rate of success, implant displacement is disconcertingly high, up to as much as 25% for scoliosis related interventions according to some sources. Misplacement is associated with a heightened risk of neural and vascular complications, as well as injury to the spinal cord membrane.

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Intervention

The intervention using the SpineAssist consists of five steps:

1) preoperative planning based on a CT scan of the patient's spine;

2) rigid fixation of the SpineAssist platform to the patient's spine;

3) positioning calibration by matching a fluoroscopic image of the bone mounted platform to the CT-image from the preoperative plan;

4) rigid mounting of the SpineAssist robot to the platform;

5) the robot guide arm is now ready to automatically position itself at the exact location according to the preoperative plan and serve as a guiding tool when the surgeon drills or performs some other intervention on the bone.

The SpineAssist intervention has FDA and CE approval and has, as of today, been clinically used in over 250 cases in hospitals all over the world

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Benefits

Minimally invasive surgery (MIS) is one on the most important trends in the medical device industry. The benefits from a minimally invasive procedure are potentially many: a smaller incision - and smaller scar - reduces the risk of infection and bleeding. Less pain and trauma, as well as decreased length of hospital stay and recovery time are other advantages that incite the medical device industry to constantly develop new instruments supporting MIS.

With the SpineAssist a spinal fusion intervention can be performed with only a couple small incisions compared to open surgery where a large incision potentially causes more muscle damage. The miniature size of the robot with no need for "line of sight" and its high accuracy simplifies the surgical procedure and minimizes the risk for screw misplacement. Since the robot is rigidly attached to the patient there is no need for a tracking coordinate system. The procedure using the SpineAssist only requires a few fluoroscopic images, adding reduced radiation exposure for the surgeon and the patient as an important benefit to the system.

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Spine Assist robot

The hexapod robot measures 50 mm (2 in) in diameter and 80 mm (3.15in) in height for a weight of 250 g (0.5 lb) - much like the size of a soda can. The working volume is several cubic centimetres depending on the guide arm used.

The overall system accuracy and repeatability is less than 100 microns and 10 microns respectively. The motion control accuracy is of 10 microns. When you take into account human influence and the CT- and fluoroscopic-image distortion, the system accuracy in placing an implant with respect to the preoperative plan is of less than 1.5 mm.

Six of Faulhaber's DC brushless smoovy® gear motors with custom drive electronics drive the linear actuators based on a high precision, miniature lead screw design. Accurate and absolute displacement measurement is assured by seven LVDT sensors, one for each actuator and the seventh tracking the performance of the others.

The miniature size of the hexapod involved several design challenges, where one of the most important one probably was finding a miniature drive solution. The smoovy® DC servomotor, measuring only 5 mm in diameter, proved an excellent trade off between miniature size and required torque and speed for the application. The overall thigh tolerances for small dimensions and the precision of the M2.5 custom thread lead screw, as well as precision actuator ball and socket joints are all examples of engineering specifications that make the hexapod a true manufacturing challenge.

The SpineAssist software for image Processing and pre-surgical planning

Outsourcing partner

The collaboration between Micro Precision Systems AG and Mazor Surgical Technologies was initially limited to the MPS developed smoovy® DC motor but rapidly extended when market demand picked up and Israeli based Mazor needed outsourcing solutions for serial manufacturing of the robot.

MPS ensures today manufacturing, precision assembly and quality control of the complete SpineAssist robot.

MPS was founded and joined the Faulhaber Group in 2003. The history of the company however dates back to the 1930, since when the company has evolved from a miniature ball bearing manufacturer to a 200 employee strong micromechanics solution provider for customers in industries with high demands on precision and miniaturized mechanisms.

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