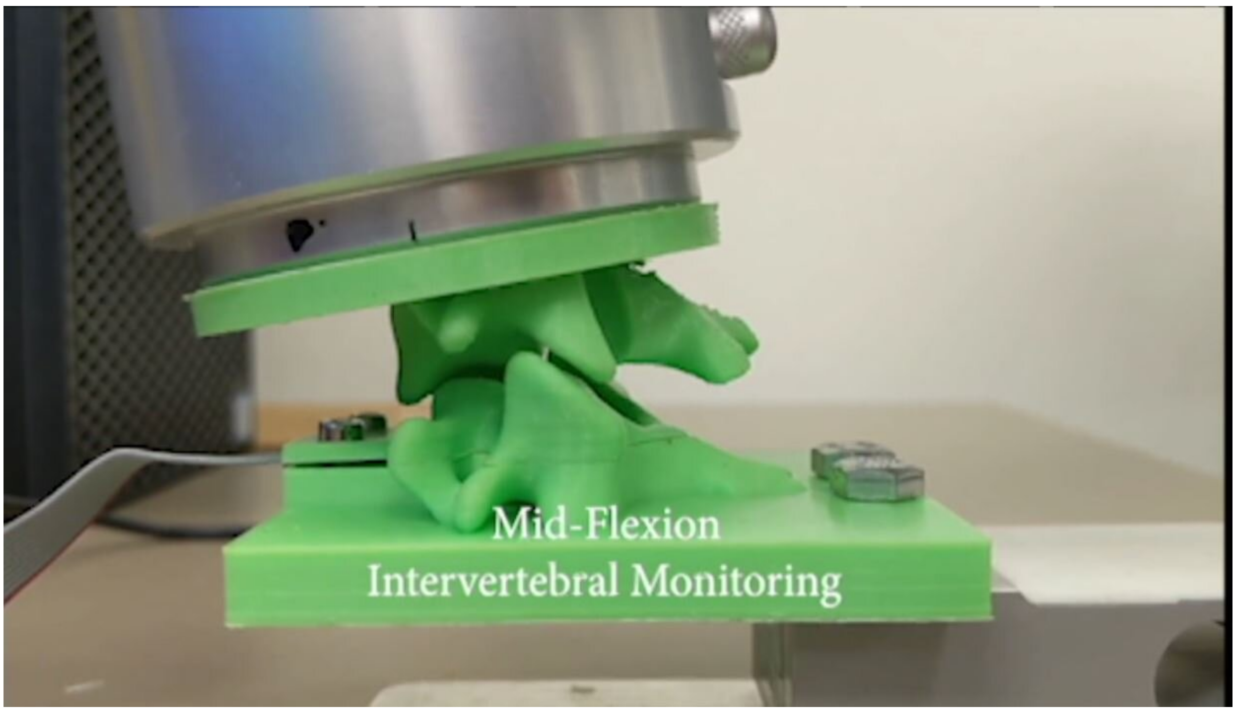
3D robotic spine 'twin' and sensor offer new way to preview surgical interventions

January 19 2022



Researchers have developed a 3D printed spine replica modified to include an artificial disc implant and outfitted with a soft magnetic sensor array. Credit: Florida Atlantic University

Degenerative disc disease affects about 40 percent of people aged 40, increasing to about 80 percent among those aged 80 or older. The disease, which is the deterioration of one or more intervertebral discs of the spine, often is surgically treated with cervical disc implants.

In order to determine if a patient is a candidate for a cervical disc implant, surgeons have to rely primarily on the findings of diagnostic imaging studies, without any input from biomechanical data to optimize the type of prosthesis. This may occasionally lead to complications and implant failure.

To address these problems, Florida Atlantic University's Erik Engeberg, Ph.D., senior author of the study, and researchers from the College of Engineering and Computer Science, in collaboration with Frank Vrionis, M.D., senior author of the study and director of the Marcus Neuroscience Institute, part of Baptist Health, have created a novel robotic replica of a human spine to enable surgeons to preview the effects of surgical interventions prior to the operation.

The researchers have developed a 3D printed spine replica modified to include an artificial disc implant and outfitted with a soft magnetic sensor array. The Marcus Neuroscience Institute has its hub on Boca Raton Regional Hospital's campus and satellite locations at Bethesda Hospital in Boynton Beach and Deerfield Beach.

The patient-specific robotic spine model was based on a CT scan of the human spine. A modified artificial disc was 'implanted' into the cervical spine replica and the soft magnet was embedded in the vertebra replica. A robotic arm flexed and extended the cervical spine replica while the intervertebral loads were monitored with the soft magnetic sensor array to classify the spine posture with four different machine-learning algorithms. The algorithms classified the amplitude and the locations that external loads were applied. Researchers then compared the capabilities of the algorithms to classify five different postures of the human spine robotic replica (center, mid-flexion, flexion, mid-extension and extension).

Results of the study, published in the journal *Sensors*, showed that the soft magnetic sensor array system had the high capability to classify the five different postures of the spine with 100 percent accuracy, which can be a predictor of different problems of the spine that people experience. These results indicate that the integration of the soft magnetic sensor array within the artificial disc 'implanted,' robotically actuated spine replica has the potential to generate physiologically relevant data before invasive surgeries, which could be used preoperatively to assess the suitability of a particular intervention for specific patients.

"A flexible magnetic sensor array is a new method to realize soft and stretchable magnets by mixing silicone with magnetic powder," said Engeberg, a professor, Department of Ocean and Mechanical Engineering within the College of Engineering and Computer Science, member of FAU's Center for Complex Systems and Brain Sciences within the Charles E. Schmidt College of Science, and a member of the FAU Stiles-Nicholson Brain Institute. "These sensors are low-cost, highly sensitive, and easily integrated into robotic systems as the soft medium can be manipulated in many shapes and sizes."

In addition to preoperatively assessing the suitability of a particular intervention for specific patients, this new approach could potentially assist the postoperative care of people with cervical disc implants. Currently, postoperative instructions for patients with spine implants are qualitative (do as much as you can until the pain starts), creating fears in both the patient and the surgeon. Questions regarding how much bending, lifting, and exercising is permissible after a cervical implant operation could be studied and correlated with biomechanical data generated by the sensorized robotic replica with individually tailored postoperative care that could be prescribed to reduce complications.

"This new approach has a powerful potential to enable surgeons to preview and compare the effects of different surgical interventions in a patient-specific manner using robotically actuated spine twins," said

Vrionis. "Moreover, the novel system could help in determining whether a constrained, semi-constrained, or unconstrained device could be the best fit or even a fusion device. Following surgery, the spine replica could also assist us in estimating whether there is sufficient motion at the operated level and possibly helping us to determine if we need to change the rehabilitation program to prevent calcification and subsequent loss of intended motion."

In the future, the researchers say that this sensor could also potentially be coupled with CT scans to address the issue of spinal malalignment.

"Our new approach could provide surgeons with first-hand data to compare the effects of different surgical interventions to treat diseases of the spine before surgery and potentially reduce the rates of complication and failure of artificial disc implantation," said study co-author Chi-Tay Tsai, Ph.D., a professor in FAU's Department of Ocean and Mechanical Engineering.

More information: Maohua Lin et al, Robotic Replica of a Human Spine Uses Soft Magnetic Sensor Array to Forecast Intervertebral Loads and Posture after Surgery, *Sensors* (2021). DOI: 10.3390/s22010212

Provided by Florida Atlantic University

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