

# An implantable wireless suture sensor for in situ tendon and ligament strain monitoring

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**INTRODUCTION:** Tendon and ligament tears are common and severe sports injuries often requiring surgical repair or autograft reconstruction. The healing process and biomechanical properties of the reconstructed tissue determine the speed and quality of the patient's return to sports. However, in the current clinical settings, it is difficult for physicians to monitor the state of tissue strain through physical examination and imaging, and it is difficult to monitor and warn of serious complications such as overstretching and graft tear outside the hospital. This study aims to develop an implantable flexible sensor to monitor tissue strain wirelessly after tendon and ligament surgery.

**METHODS:** Here, we report a thread capacitive strain sensor functionalized and encapsulated with biocompatible polymer and medical-grade silicone to realize real-time and in situ readout of the tissue strain. The sensor overcomes the mismatch between the sensor shape and the anatomical structure, facilitates firm fixation during surgical suturing, and provides accurate in-vivo strain measurement. The biocompatibility of the implant is verified by cell and histopathology experiments.

**RESULTS SECTION:** We demonstrated that the strain sensor could be anatomically adapted to the graft on isolated knee joints and animals. It has obtained real-time strain monitoring and wireless signal transmission in reconstructing collateral ligaments, cruciate ligaments, and Achilles tendon ligaments. Implantation and cytotoxicity experiments verified no significant difference between the sensor experimental group and the blank control group.

**DISCUSSION:** In this research, the strain sensor made of flexible materials was closer to the characteristics of the tendon and ligaments, which is in line with the tendon and ligament surgery scenarios. The integrated sensor system can be used to evaluate preclinical implant performance and the effect of various implantation techniques. Future research on tendon and ligament biomechanics should continue to focus on enhancing the adaptability and biocompatibility of implants.

**SIGNIFICANCE/CLINICAL RELEVANCE:** The implantation of the sensor system would provide in vivo strain data of tendons and ligaments after surgery and provide early warning of severe surgical complications such as graft loosening and re-tearing.

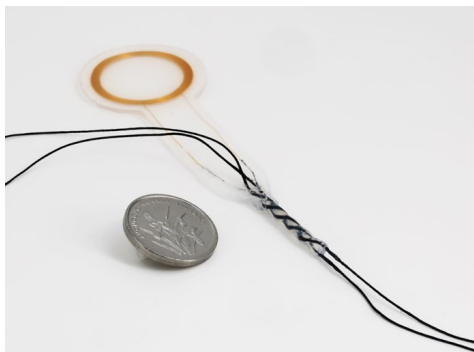


Figure 1: Photograph of a wireless strain sensor system consisting of a sensor and coil.



Figure 2: The strain sensor implanted in the Achilles tendon of a New Zealand rabbit leg.

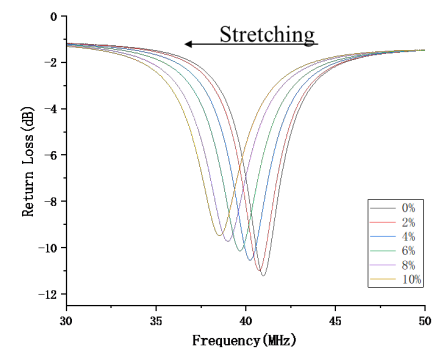


Figure 3: The calibration spectrum of reflection coefficient (S11) of wireless sensor system under 10% strain.