the medical device and a method of characterizing a healing with the medical device, and other aspects as disclosed herein. The medical device generally has a structure configured to extend at least partially into boney tissue. For example, the structure may be a screw, a pin, a rod, a nail, a part of a joint replacement implant (e.g., hip, shoulder, knee, etc.), a part of a spinal fixation device, or a part of other orthopedic devices. In one embodiment, the medical device is a screw. The implantable smart medical device includes a sensor for obtaining one or more measurements indicative, e.g., of the healing state of fractured boney tissue within which the device is implanted, and communication circuitry for communicating such measurements to an external device.

[0006] Disclosed herein is a smart medical device that includes a structure configured to be at least partially implanted in a body, and an electronics cartridge that is configured to be inserted into the structure after the structure is implanted in the body. The structure may be a cannulated screw for use in treating bone fractures. The medical device includes an impedance sensor for monitoring and reporting on the healing state of bone fractures. The sensor includes components of the electronics cartridge and electrodes that are either associated with the cannulated screw or with the insertable electronics cartridge.

[0007] Disclosed herein is a medical device that includes a structure having a lumen extending at least partially therethrough and an insertable electronics cartridge including electronics. The structure is configured to be at least partially implanted in a body, and the electronics cartridge is configured to be inserted into the lumen after implant of the structure.

[0008] According to an aspect of the present disclosure, there is provided a medical device including a structure having a lumen extending at least partially therethrough, and configured to be at least partially implanted in a body; an electronics cartridge including electronics and configured to be inserted into the lumen after implant of the structure; a sensor for measuring an electrical property of tissue, the sensor including: a plurality of electrodes; and a sensing module of the electronics cartridge, coupled to the plurality of electrodes; wherein the plurality of electrodes comprising a first electrode and a second electrode; and the sensing module configured to enable the first electrode and the second electrode to function in either of an application mode during which a signal is applied across the electrodes, or a sensing mode during which an impedance between the electrodes is sensed.

[0009] Disclosed herein is a medical device that includes a cannulated structure having least one aperture through a sidewall of the structure, and an insertable electronics cartridge. The cannulated structure has a lumen extending therethrough and is configured to be at least partially implanted in a body. The electronics cartridge includes a plurality of electrodes and electronics electrically coupled to the electrodes. The electronics cartridge is configured to be inserted into the lumen, and to provide alignment between the plurality of electrodes and the at least one aperture upon such insertion.

[0010] Disclosed herein is a medical device that includes a cannulated structure having a distal end opening and a proximal end opening, and an insertable electronics cartridge. The cannulated structure has a lumen extending therethrough and is configured to be at least partially implanted in a body. The electronics cartridge includes a plurality of electrodes and electronics electrically coupled to the electrodes. The electronics cartridge is configured to be inserted into the lumen, and to position a first electrode of the plurality of electrodes at the distal end opening of the cannulated structure and a second electrode of the plurality of electrodes at the proximal end opening upon such insertion.

configured to be at least partially implanted in a body and having a lumen extending therethrough. The method also includes associating an electrode with each of the plurality of apertures, and associating an electronics cartridge with the lumen of the cannulated structure. The electronics cartridge includes electronics and a plurality of electrical contacts, wherein the association aligns each of the plurality of electrical contacts with one of the apertures to establish an electrical coupling between the electronics and each electrode.

[0021] Disclosed herein is a method of implanting a medical device. The method includes implanting an implant structure at least partially in a body. The structure has a lumen extending at least partially therethrough. The method also includes inserting an electronics cartridge into the lumen after implanting the implant structure.

[0022] Disclosed herein is a tool for implanting an implant structure having a proximal end having a head, a shaft extending from the head to a distal end of the implant structure, and a lumen extending through the shaft. The tool includes a drill bit, and a mechanism for applying rotational torque to the drill bit. The drill bit includes a first portion configured to directly couple to the head of the implant structure, and a second portion extending from the first portion. The second portion is configured to extend at least partially into the lumen of the implant structure.

[0023] Disclosed herein is a coupling device for implanting an implant structure having a proximal end having a head, and a shaft extending from the head to a distal end of the implant structure. The coupling device includes a body having a proximal end region and a distal end region. The distal end region is configured to establish a mechanical coupling to a distal end portion of the implant structure. The coupling device may also include a cap configured to the couple to the proximal end region of the body without directly coupling to the implant structure.

[0023a] Disclosed herein is a method of characterizing a fracture in boney tissue, the method including identifying a fracture in boney tissue, inserting the above medical device into the bony tissue, where the medical device is inserted across the fracture; and characterizing the fracture with a sensor located in the medical device

[0023b] Disclosed herein is a set of medical devices, the set including at least one first medical device according to the above aspect, the set further including at least one second medical device configured for insertion into boney tissue, where the second medical device does not contain a sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Exemplary features of the present disclosure, its nature and various advantages will be apparent from the accompanying drawings and the following detailed description of various

CLAIMS

1. A medical device comprising:

a structure having a lumen extending at least partially therethrough, and configured to be at least partially implanted in a body;

an electronics cartridge including electronics and configured to be inserted into the lumen after implant of the structure;

a sensor for measuring an electrical property of tissue, the sensor comprising:

a plurality of electrodes; and

a sensing module of the electronics cartridge, coupled to the plurality of electrodes; wherein

the plurality of electrodes comprising a first electrode and a second electrode; and

the sensing module configured to enable the first electrode and the second electrode to function in either of an application mode during which a signal is applied across the electrodes, or a sensing mode during which an impedance between the electrodes is sensed.

2. The medical device of claim 1, wherein the sensing module comprises a signal generator configured to apply signals at different frequencies to measure tissue impedance in accordance with electrical impedance spectroscopy (EIS) techniques.

3. The medical device of claim 1, wherein:

the sensor further comprises an electrode switch;

the plurality of electrodes further comprises a first electrode, a second electrode, a third electrode and a fourth electrode switchably coupled to the sensing module through the electrode switch; and

the sensing module is further configured to enable an application mode during which a signal is applied across the first electrode and the second electrode, and to enable a sensing mode during which an impedance between the third electrode and the fourth electrode is sensed.

4. The medical device of claim 3, wherein the sensing module comprises a signal generator configured to apply signals at different frequencies to measure tissue impedance in accordance with electrical impedance spectroscopy (EIS) techniques.

5. The medical device of claim 1, wherein the electrical property of tissue comprises impedance measurements, and further comprising a controller configured to process impedance measurements over time to determine a characterization of a bone fracture, the characterization corresponding to a healing state of the bone fracture.

6. The medical device of claim 5, wherein the healing state corresponds to one of union, likely non-union, and non-union.

7. The medical device of claim 1, wherein:

the plurality of electrodes are associated with the structure and spaced apart to enable placement of a first electrode and a second electrode on opposite sides of a bone fracture; and

the electronics cartridge comprises a plurality of electrical contacts located to electrically couple with the plurality of electrodes when the electronics cartridge is inserted into the lumen of the structure.

8. The medical device of claim 1, wherein:

the plurality of electrodes are associated with the electronics cartridge and spaced apart to enable placement of a first electrode and a second electrode on opposite sides of a bone fracture.