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SCREW TOWER AND ROD REDUCTION TOOL

Abstract

A system includes a screw tower, an instrument, and a housing. The instrument includes a driver shaft extendable longitudinally through the screw tower, and a threaded sleeve mounted on a proximal portion of the driver shaft. The housing includes one or more retention members coupleable to the screw tower, and a threaded button threadably coupleable to the threaded sleeve. The threaded sleeve is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION(S) [0001] This application is a continuation of U.S. patent application Ser. No. 17/821,939 filed on Aug. 24, 2022, which is a continuation of U.S. patent application Ser. No. 17/382,782 filed on Jul. 22, 2021, the contents of which are incorporated by reference herein in its entirety for all purposes.

BACKGROUND
[0002] Spinal fixation devices may be anchored to specific portions of the vertebra. Such spinal fixation devices may include, for example, a shank portion coupleable to a vertebra, and a head portion having a receiving element. A fixation rod may be seated through the receiving element and locked in place by tightening the head portion. While known spinal fixation systems have proven effective, some rod reducers may be difficult, tiresome, and/or time-consuming to use.
SUMMARY
[0003] According to some examples of the inventive concepts described herein, a system may be provided to provide a rod reduction tool. The system includes a screw tower, an instrument, and a housing. The instrument includes a driver shaft extendable longitudinally through the screw tower, and a threaded sleeve mounted on a proximal portion of the driver shaft. The housing includes one or more retention members coupleable to the screw tower, and a threaded button threadably coupleable to the threaded sleeve. The threaded sleeve is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower.
[0004] According to other examples of the inventive concepts described herein, a method may be provided to provide a rod reduction tool. The method includes extending a driver shaft longitudinally through a screw tower, mounting a threaded sleeve on a proximal portion of the driver shaft, coupling a housing to the screw tower using one or more retention members, and threadably coupling the housing to the threaded sleeve using a threaded button such that the threaded sleeve is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower.
[0005] This summary is provided to introduce a selection of inventive concepts in a simplified form that are further described below in the detailed description. Other methods and related systems, and corresponding methods and computer program products, according to examples of the inventive subject matter will be or become apparent to one with skill in the art upon review of the following detailed description and the accompanying drawings. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0006] The accompanying drawings, which are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this application, illustrate certain non-limiting examples of inventive concepts. In the drawings:
[0007] FIG. **1** is a side view of an example screw tower;
[0008] FIG. **2** is a front view of the screw tower shown in FIG. **1**;

[0009] FIG. **3** is a cross-sectional view of the screw tower shown in FIG. **1**;
[0010] FIG. **4** is an exploded perspective view of the screw tower shown in FIG. **1**;
[0011] FIG. **5** is a cross-sectional view of another example screw tower;
[0012] FIG. **6** is an exploded perspective view of the screw tower shown in FIG. **5**;
[0013] FIG. **7** is a side view of an example instrument that may be used with a screw tower, such as the screw tower shown in FIG. **1** or **5**;
[0014] FIG. **8** is an exploded perspective view of the instrument shown in FIG. **7**;
[0015] FIG. **9** is a cross-sectional view of another example instrument that may be used with a screw tower, such as the screw tower shown in FIG. **1** or **5**;
[0016] FIG. **10** is a distal end view of the instrument shown in FIG. **9**;
[0017] FIG. **11** is a proximal end view of an example screw tower, such as the screw tower shown in FIG. **1** or **5**;
[0018] FIG. **12** is a partially transparent side view of an example housing that may be used with a screw tower, such as the screw tower shown in FIG. **1** or **5**, and/or an instrument, such as the instrument shown in FIG. **7** or **9**;
[0019] FIG. **13** is a partially transparent front view of the housing shown in FIG. **12**;
[0020] FIG. **14** is a partially transparent, exploded perspective view of the housing shown in FIG. **12**;
[0021] FIG. **15** is a block diagram of an example tracking system that may be used to track one or more objects, such as the screw tower shown in FIG. **1** or **5**, the instrument shown in FIG. **7** or **9**, and/or the housing shown in FIG. **12**;
[0022] FIG. **16** is a perspective view of example objects that may be tracked, including example tracking markers;
[0023] FIG. **17** is a perspective view of the objects shown in FIG. **16** in a partially overlapping arrangement;
[0024] FIG. **18** is a perspective view of the objects shown in FIG. **16** in an example use arrangement;
[0025] FIG. **19** is a perspective view of another example object that may be tracked, including example tracking markers;
[0026] FIG. **20** is a block diagram of an example computing system that may be used to track one or more objects, such as the screw tower shown in FIG. **1** or **5**, the instrument shown in FIG. **7** or **9**, and/or the housing shown in FIG. **12**;
[0027] FIG. **21** is a schematic illustration of an example tracking array and navigation array-equipped rod in a first phase in which the tracking array is coupled to a first screw tower and the navigation array-equipped rod extends through the first screw tower;
[0028] FIG. **22** is a schematic illustration of the tracking array and navigation array-equipped rod shown in FIG. **21** in a second phase in which the tracking array is coupled to a second screw tower and the navigation array-equipped rod extends through the first and second screw towers;
[0029] FIG. **23** is a schematic illustration of an example visual aid for use in positioning one or more objects, such as the navigation array-equipped rod shown in FIGS. **21** and **22**;
[0030] FIG. **24** is a flow chart of an example method of providing a rod reduction tool in accordance with one example of the inventive subject matter;
[0031] FIG. **25** is a front view of an assembly including a pedicle screw, a screw tower, such as the screw tower shown in FIG. **1** or **5**, an instrument, such as the instrument shown in FIG. **7** or **9**, and a housing, such as the housing shown in FIG. **12**;
[0032] FIG. **26** is a side view of the assembly shown in FIG. **25**; and
[0033] FIG. **27** is a perspective view of the assembly shown in FIG. **25**.
[0034] The drawings, which are not necessarily to scale, depict selected examples and are not intended to limit the scope of the disclosure. Although specific features of various examples of the disclosure may be shown in some drawings and not in others, this is for convenience only. The

following detailed description is to be read with reference to the drawings, in which like elements in different figures have like reference characters.

DETAILED DESCRIPTION

[0035] The present disclosure relates to medical devices and, more particularly, to a screw tower and rod reduction tool. Examples described herein include a screw tower, an instrument, and a housing. The instrument includes a driver shaft extendable longitudinally through the screw tower, and a threaded sleeve mounted on a proximal portion of the driver shaft. The housing includes one or more retention members coupleable to the screw tower, and a threaded button threadably coupleable to the threaded sleeve. The threaded sleeve is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower. The examples described herein enable a screw tower to be affixed, a fixation rod to be reduced, and/or a locking cap to be inserted in an efficient, user-friendly, and/or effective manner. While the examples described herein are described with respect to pedicle screws, one of ordinary skill in the art would understand and appreciate that the example systems and methods may be used with other types of fastening mechanisms.

[0036] Turning now to the drawings, FIGS. **1-4** show an example screw tower **100** that may be used to hold or engage a screw (e.g., a pedicle screw) for implantation of the screw via a minimally-invasive incision. The screw tower **100** may include, for example, an elongated tube defining a distal opening **102** for receiving the screw at a distal end **104**, a proximal opening **106** for receiving one or more instruments, rods, implants, etc. at a proximal end **108**, and a channel **110** extending longitudinally (e.g., along a Y-axis) therebetween.

[0037] In some examples, the screw tower **100** includes an outer sleeve **120** sized, shaped, and/or configured to engage a portion of the screw. For example, the outer sleeve **120** may include a first wall **122** and a second wall **124** opposing the first wall **122** such that a head feature of the screw (e.g., a lip of a tulip) may be positioned transversely therebetween. In some examples, the first wall **122** and/or second wall **124** may be cantilevered such that the outer sleeve **120** may be coupled to the screw using a cantilever snap-fit engagement. For example, as the head feature of the screw is urged in a proximal direction (e.g., in a negative Y-direction) toward the distal end **104** of the outer sleeve **120**, the first wall **122** and/or second wall **124** may deflect or spread apart to allow the head feature to move in the proximal direction therebetween and return or snap back to a neutral configuration when the head feature clears a portion **126** of the first wall **122** and/or second wall **124** (e.g., a ridge or lip) such that the portion **126** of the first wall **122** and/or second wall **124** is disposed in an undercut and/or opening defined by the head feature of the screw. Alternatively, the outer sleeve **120** may engage or be coupled to the screw using any arrangement or mechanism that provides a quick, robust, and reliable connection. For example, in some examples, the outer sleeve **120** may be selectively rotated to couple the screw tower **100** to the screw by positioning the portion **126** of the first wall **122** and/or second wall **124** in the undercut or opening defined by the head feature of the screw and/or uncouple the screw tower **100** from the screw by spacing the portion **126** of the first wall **122** and/or second wall **124** from the undercut or opening defined by the head feature of the screw.

[0038] As shown at FIGS. **3** and **4**, the screw tower **100** may include an inner sleeve **130** coaxial with the outer sleeve **120**. In some examples, the inner sleeve **130** may be sized, shaped, and/or configured to engage a portion of the screw coupled to the outer sleeve **120** at the distal end **104** thereof for “locking” or rigidly securing the screw in place relative to the screw tower **100**. For example, when the inner sleeve **130** is moved or urged in a distal direction (e.g., in a positive Y-direction) while the outer sleeve **120** is coupled to the screw, the head feature may be clamped longitudinally between a mating portion **132** of the inner sleeve **130** (e.g., a tab or protrusion) and the portion **126** of the first wall **122** and/or second wall **124**. In some examples, the mating portion **132** of the inner sleeve **130** may include one or more mating features that are sized, shaped, and/or configured to be received in one or more indented features and/or openings at the head of the screw. Additionally or alternatively, the mating portion **132** of the inner sleeve **130** may include one or more mating features that are sized, shaped, and/or configured to receive one or more tabs and/or protrusions at the head of the screw.

[0039] In some examples, an inner nut **134** may be used to move or urge the inner sleeve **130** longitudinally relative to the outer sleeve **120**. As shown in FIGS. **3** and **4**, the nut **134** may be threadably coupled to the outer sleeve **120** such that the nut **134** may be rotated about the longitudinal axis in a first direction (e.g., a clockwise direction) to move in the distal direction and/or in a second direction opposite the first direction (e.g., a counterclockwise direction) to move in the proximal direction (e.g., in a negative Y-direction). In some examples, a retaining clip or ring **136** may be used to couple the inner sleeve **130** to the nut **134** such that the inner sleeve **130** and nut **134** are prevented or restricted from moving longitudinally relative to each other while being free to rotate relative to each other. In this manner, the nut **134** may be selectively rotated to longitudinally translate the inner sleeve **130** relative to the outer sleeve **120**. A relative orientation of the outer sleeve **120** and inner sleeve **130** may be maintained, for example, to ensure that the screw tower **100** includes one or more longitudinal channels **138** defined therein. For example, as shown in FIGS. **2**, **3**, and **4**, channels **138** may be defined circumferentially between the first wall **122** and second wall **124** of the outer sleeve **120** (e.g., along a circumference of the outer sleeve **120**). Channels **138** defined in the outer sleeve **120** may be aligned with channels **138** defined in the inner sleeve **130** to allow one or more rods to extend transversely through the screw tower **100**. In some examples, channels **138** may be open at the distal end **104** of the outer sleeve **120** and/or inner sleeve **130** such that one or more transversely-extending rods may be received at the distal end **104** of the screw tower **100** and translated proximally (e.g., in a negative Y-direction) through the channels **138**.

[0040] The screw tower **100** may include one or more control features **140** for controlling a relative movement between the outer sleeve **120** and inner sleeve **130**. In some examples, the control features **140** may restrict an amount or degree of allowable movement between the outer sleeve **120** and inner sleeve **130**. For example, the control features **140** may include one or more openings **142** defined in the outer sleeve **120**, one or more longitudinal slots **144** defined in the inner sleeve **130**, and one or more pins **146** extendable through the openings **142** and/or longitudinal slots **144**. The openings **142** may be sized, shaped, and/or configured such that, when the pins **146** are extended therethrough, the outer sleeve **120** is restricted or prevented from moving rotationally (e.g., about the Y-axis) or longitudinally (e.g., along the Y-axis) relative to the pins **146**. The longitudinal slots **144** may be sized, shaped, and/or configured such that, when the pins **146** are extended therethrough, the inner sleeve **130** is restricted or prevented from moving rotationally (e.g., about the Y-axis) relative to the pins **146** while being free to move longitudinally (e.g., along the Y-axis) relative to the pins **146** a length of the longitudinal slots **144**. For another example, the control features **140** may include one or more longitudinal slots **148** defined in the outer sleeve **120** and one or more tabs and/or protrusions **150** of the inner sleeve **130** that are configured to extend radially outward through the longitudinal slots **148**. The longitudinal slots **148** may be sized, shaped, and/or configured such that, when the protrusions **150** are extended therethrough, the outer sleeve **120** is restricted or prevented from moving rotationally (e.g., about the Y-axis) relative to the protrusions **150** while being free to move longitudinally (e.g., along the Y-axis) relative to the protrusions **150** a length of the longitudinal slots **148**.

[0041] In some examples, the control features **140** may be selectively disengaged to allow a relative movement between the outer sleeve **120** and inner sleeve **130**. For example, the pins **146** may be extracted or removed from the openings **142** defined in the outer sleeve **120** and the longitudinal slots **144** defined in the inner sleeve **130** such that walls defining the openings **142** and/or longitudinal slots **144** do not engage the pins **146** when the outer sleeve **120** and/or inner sleeve **130** is moved. For another example, the first wall **122** and/or second wall **124** of the outer sleeve **120** may be deflected or spread apart such that the protrusion **150** at a distal portion of the inner sleeve **130** is extracted or removed from the longitudinal slot **148** at a distal portion of the outer sleeve **120** and, thus, does not engage the first wall **122** and/or second wall **124** when the outer sleeve **120** and/or inner sleeve **130** is moved. For yet another example, the protrusion **150** at a proximal portion of the inner sleeve **130** is moved or urged radially inward such that the protrusion **150** is extracted or removed from the longitudinal slot **148** at a proximal portion of the outer sleeve **120** and, thus, does not engage the first wall **122** and/or second wall **124** when the outer sleeve **120** and/or inner sleeve **130** is moved. In some examples, a separate tool may be used to selectively disengage one or more control features **140** to allow the screw tower **100** to be at least partially disassembled (e.g., for sterilization and/or cleaning).

[0042] FIGS. **5** and **6** show another example screw tower **160** that may be used to hold or engage a screw for implantation of the screw via a minimally-invasive incision. As can be understood from a comparison of FIGS. **3** and **4** with FIGS. **5** and **6**, the screw tower **160** shown in FIGS. **5** and **6** is substantially similar to the screw tower **100** shown in FIGS. **3** and **4**, except the screw tower **160** includes an inner nut **164** (e.g., inner nut **134**) having a compressible ledge **166**. The compressible ledge **166** is configured to engage an inner surface of the inner sleeve **130** such that the inner sleeve **130** and nut **164** are prevented or restricted from moving longitudinally relative to each other while being free to rotate relative to each other. In this manner, the nut **164** shown in FIGS. **5** and **6** is selectively rotatable to longitudinally translate the inner sleeve **130** relative to the outer sleeve **120**. As shown in FIGS. **5** and **6**, the nut **164** may be threadably coupled to the outer sleeve **120** such that the nut **164** may be rotated about the longitudinal axis in a first direction (e.g., a clockwise direction) to move or urge the inner sleeve **130** in the distal direction and/or in a second direction opposite the first direction (e.g., a counterclockwise direction) to move or urge the inner sleeve **130** in the proximal direction (e.g., in a negative Y-direction).

[0043] FIGS. **7** and **8** show an instrument **200** that may be used to reduce a rod and/or insert a locking cap on a screw. The screw may include or be coupled to a tulip on which the rod may be positioned, and the locking cap may be used to secure the rod within the tulip. The instrument **200** may be extended longitudinally between the proximal end **108** and the distal end **104** and/or used with the screw tower **100** (shown in FIGS. **1-4**). In some examples, the instrument **200** includes a driver or inner shaft **210** sized, shaped, and/or configured to push or drive a rod extending transversely through the longitudinal channels **138** of the screw tower **100** in a distal direction (e.g., in a positive Y-direction). The rod may be pushed or driven, for example, by extending the inner shaft **210** through the channel **110** of the screw tower **100** to position the distal end **104** of the inner shaft **210** at or adjacent to the rod and moving or urging the inner shaft **210** in the distal direction.

[0044] As shown in FIGS. **7** and **8**, a cap pusher **212** may be mounted on or coupled to a distal portion of the inner shaft **210**. The cap pusher **212** may be sized, shaped, and/or configured to engage the locking cap and provide a force to the locking cap such that the locking cap may be coupled to the tulip (e.g., for use in securing the rod therein). In some examples, the instrument **200** may include or be used with an indicator that indicates a position of the rod in order to ensure that the rod is reduced before coupling the locking cap to the tulip.

[0045] In some examples, the inner shaft **210** and cap pusher **212** may be configured to simultaneously engage the rod and locking cap, respectively. For example, the inner shaft **210** may be extended through an opening in the locking cap to directly contact the rod, and the distal end **104** of the inner shaft **210** may be longitudinally spaced or offset from the distal end **104** of the cap pusher **212**, such that the inner shaft **210** and cap pusher **212** are configured to contact the rod and locking cap, respectively. In some examples, the instrument **200** may include one or more biasing members **214** (e.g., springs) that absorb or mitigate a force applied to the locking cap (e.g., by the cap pusher) during rod reduction. The biasing members **214** may be housed, for example, in a concealing cap **216** coupled to the inner shaft **210**. The concealing cap **216** may include an opening sized, shaped, and/or configured to allow the inner shaft **210** and cap pusher **212** to extend longitudinally therethrough. In some examples, a retaining ring **218** may be positioned at a distal portion of the inner shaft **210** to facilitate keeping the locking cap retained to the instrument **200**.

The retaining ring **218** may be coupled to the distal portion of the inner shaft **210**, for example, via a friction fit.

[0046] As shown in FIGS. **7** and **8**, the instrument **200** may include a threaded sleeve **220** mounted on or coupled to a proximal portion of the inner shaft **210**. The inner shaft **210** is free to rotate and/or translate independent of the threaded sleeve **220**. The threaded sleeve **220** may be sized, shaped, and/or configured to engage a shoulder **222** of the inner shaft **210** for use in moving or urging the inner shaft **210** in the distal direction (e.g., in a positive Y-direction). In some examples, a washer **224** may be positioned longitudinally between the inner shaft **210** and threaded sleeve **220** to facilitate reducing friction and/or distributing forces applied therebetween.

[0047] A driver nut **230** may be coupled to the distal end **104** of the threaded sleeve **220** for use in rotating the threaded sleeve **220**. The driver nut **230** may urge the threaded sleeve **220** to rotate about the longitudinal axis. A coupling mechanism **232** may be used to couple the driver nut **230** to the threaded sleeve. The coupling mechanism **232** may be, without limitation, an assembly screw.

[0048] FIGS. **9** and **10** show another example instrument **240** that may be used to reduce a rod and/or insert a locking cap on a screw. As can be understood from a comparison of FIGS. **7** and **8** with FIGS. **9** and **10**, the instrument **240** shown in FIGS. **9** and **10** is substantially similar to the instrument **200** shown in FIGS. **7** and **8**, except, as shown in FIG. **10**, the inner shaft **250** of the instrument **240** includes one or more keyed features **252** at a radially outer surface thereof. The keyed features **252** may be configured to engage a radially-inner surface of a screw tower (e.g., screw tower **100** or **160**). For example, as shown in FIG. **11**, a screw tower **100** may include one or more keyed features **254** that complement the keyed features **252** of the instrument **240**. In this manner, the keyed features **252** and **254** may engage each other when the inner shaft **250** extends through the channel **110** of the screw tower **100**. The keyed features **252** and **254** provide anti-rotation properties by mating with the screw tower **100**. This in turn restricts or prevents cross threading of the driver nut **230** (e.g., under heavy reduction loads).

[0049] FIGS. **12-14** show a selective thread engagement housing **300** that may be used to selectively move and/or position the screw tower **100** and/or instrument **200**. In some examples, the housing **300** includes an opening sized, shaped, and/or configured to receive the proximal end **108** of the screw tower **100**. The housing **300** may include one or more retention members or tower clips **310** configured to selectively engage or clamp to a proximal portion of the screw tower **100**. In some examples, each tower clip **310** is pivotable about a respective rod **312** to move between an engaged position, in which a portion of the tower clip **310** (e.g., a ridge or lip) engages an outer surface of the screw tower **100** to facilitate preventing or restricting the screw tower **100** and housing **300** from moving longitudinally relative to each other, and a disengaged position, in which the portion of the tower clip **310** is spaced from the screw tower **100** such that the screw tower **100** and housing **300** are free to move longitudinally relative to each other.

[0050] The housing **300** may include a threaded button **320** configured to engage or mate with the threaded sleeve **220** of the instrument **200**. The threaded button **320** may include, for example, an opening **322** sized, shaped, and/or configured to receive the threaded sleeve **220** therethrough. In some examples, the opening **322** may be at least partially defined by a threaded wall **324**. In this manner, a driving force of rod reduction may be accomplished by selectively rotating the threaded sleeve **220** while the housing **300** is rigidly secured to the screw tower **100** (e.g., via the tower clips **310**) and threadably coupled to the instrument **200** (e.g., via the threaded sleeve **220**).

[0051] In some examples, the threaded button **320** may be moved transversely across the housing **300** to allow for variable reduction. For example, moving the threaded button **320** in a first transverse direction (e.g., radially outward) may cause the threaded wall **324** to engage an outer surface of the threaded sleeve **220** such that the threaded sleeve **220** may move in the distal direction by rotating about the longitudinal axis in a first direction (e.g., a clockwise direction) and/or move in the proximal direction by rotating about the longitudinal axis in a second direction opposite the first direction (e.g., a counterclockwise direction). On the other hand, moving the threaded button **320** in a second transverse direction (e.g., radially inward) may cause the threaded wall **324** to be spaced from the threaded sleeve **220** such that the instrument **200** and housing **300** are free to move relative to each other (e.g., for rapid adjustment).

[0052] As shown in FIG. **14**, the housing **300** may include one or more biasing members **328** (e.g., springs) that urge the tower clips **310** and/or threaded button **320** toward the engaged position, thereby supporting or promoting mechanical threaded reduction via rotation of the threaded sleeve **220**. Additionally or alternatively, a button pin **326** may be positioned to prevent or restrict the threaded button **320** from moving in the second transverse direction (e.g., toward a disengaged position). Moreover, to facilitate preventing or restricting the threaded button **320** from moving in the second transverse direction during heavy reduction loads, a proximal portion of the threaded button **320** may include a shallow ledge configured to engage or catch on an outer surface of the housing **300** when a heavy reduction load is applied. In some examples, the threaded wall **324** may include a square thread profile that facilitates increasing axial force (e.g., for use in rod reduction) and/or reducing friction between the threaded wall **324** and the outer surface of the threaded sleeve **220** (e.g., when the threaded button **320** is moved in a transverse direction).

[0053] The housing **300** may be clipped onto the screw tower **100** before the instrument **200** is inserted into the housing **300**, or clipped onto the screw tower **100** with the instrument **200** already extending at least partially through the housing **300**. In some examples, the housing **300** may include or be coupled to a counter-torque instrument, a compressor/distractor instrumentation, and/or other tower manipulation instrumentation.

[0054] FIG. **15** shows an example tracking system **400** that may be used to track one or more objects, such as the screw tower **100**, instrument **200**, and/or housing **300**. The system **400** includes one or more position sensors **410** that may be positioned and/or oriented to have a direct line of sight to a surgical field. In some examples, a position sensor **410** may be positioned on a stand configured to move, orient, and support the position sensor **410** in a desired position and/or orientation. The position sensors **410** may include any suitable camera (e.g., an infrared camera, a bifocal camera, a stereophotogrammetric camera, etc.) configured to scan a given measurement volume and detect light and/or other electromagnetic wave that comes from a plurality of tracking markers **420** in order to determine a position of the tracking markers **420** in the given measurement volume.

[0055] In some examples, the tracking markers **420** may be mounted or otherwise secured to an object to be tracked during a surgical procedure (e.g., screw tower **100**, instrument **200**, housing **300**). Such objects may include, without limitation, a robot (e.g., at an end-effector), a surgical tool, and/or a patient tracking device secured directly to a patient. In some examples, electromagnetic waves coming from the tracking markers **420** may be detected over time in order to monitor a position and/or movement of one or more marked objects (e.g., an object having tracking markers **420** coupled thereto).

[0056] Tracking markers **420** may serve as unique identifiers that are trackable in three dimensions (e.g., using stereophotogrammetry). Tracking markers **420** may include active tracking markers (e.g., infrared light emitting diodes (LEDs)) that are activated by an electrical signal to emit light and/or other electromagnetic wave, and/or passive tracking markers (e.g., retro-reflective markers) that reflect light and/or other electromagnetic wave emitted by an illuminator on the position sensor **410** or other suitable device. In some examples, the tracking markers **420** may include reflective, radiopaque, and/or optical markers. The tracking markers **420** may be suitably shaped, including spherical, spheroid, cylindrical, cube, cuboid, or the like.

[0057] A computer **430** may receive and process information from the position sensors **410** in order to present information to a user using a display **432** and/or a speaker **434**. In some examples, the computer **430** may include a processor circuit **440** (also referred to as a processor) coupled with an input interface circuit **442** (also referred to as an input interface), an output interface circuit **444** (also referred to as an output interface), and/or a memory circuit **446** (also referred to as a memory). The memory **446** may include computer readable program code that when executed by the processor **440** causes the processor **440** to perform operations according to embodiments disclosed herein. According to other examples, the processor **440** may include memory so that a separate memory circuit (e.g., memory **446**) is not required.

[0058] The processor **440** may receive input through the input interface **442**, and/or provide output through the output interface **444**. For example, the processor **440** may receive position sensor data associated with one or more tracking markers **420** from the position sensor **410** through the input interface **442**, and/or present position information to the user using the display **432** and/or speaker **434** through input interface **442**. In some examples, the position and/or orientation of a marked object may be presented to the user in relation to a three-dimensional image of a patient's anatomical structure.

[0059] FIGS. **16-18** show an example first object **500** marked with an example first cluster of stripes **502** and an example second object **510** marked with an example second cluster of stripes **512**. In some examples, the computer **430** may be configured to discern between tracking markers **420** (e.g., first cluster of stripes **502**, second cluster of stripes **512**) by distinguishing inter-stripe spacing (e.g., longitudinal spacing between stripes of a cluster). For example, the first cluster of stripes **502** has a first inter-stripe spacing, and the second cluster of stripes **512** has a second inter-stripe spacing larger than the first inter-stripe spacing.

[0060] Each object may be marked at a plurality of locations. For example, the first cluster of stripes **502** is present in two different locations of the first object **500**, and the second cluster of stripes **512** is present in two different locations of the second object **510**. In some examples, the computer **430** may be configured to discern between objects (e.g., first object **500**, second object **510**) by distinguishing marker types and inter-cluster spacing (e.g., longitudinal spacing between clusters). For example, the first object **500** has a first inter-cluster spacing, and the second object **510** has a second inter-cluster spacing larger than the first inter-cluster spacing.

[0061] The first cluster of stripes **502** and second cluster of stripes **512** may each be configured to uniquely identify a respective object (e.g., first object **500** and second object **510**, respectively). For example, the computer **430** may be configured to recognize the first object **500** based on the first cluster of stripes **502** and/or the second object **510** based on the second cluster of stripes **512**.

[0062] When searching tracked frames for tracking markers **420**, the computer **430** may compare the tracked frames to a geometrical model of the cluster of stripes (e.g., first cluster of stripes **502**, second cluster of stripes **512**), treating the cluster of stripes as a unique marker. Because the computer **430** is searching for a match to a plurality of parameters including cylindrical shape of predetermined diameter and stripes of a predetermined curvature in a sequence of a predetermined number (e.g., five) spanning a predetermined longitudinal length, the computer **430** may find a match and locate its center even if a portion of the object is partially blocked as shown in FIG. **17**. That is, the different inter-stripe spacing and/or inter-cluster spacing allows the computer **430** to easily discern between tracking markers **420** and/or objects while also finding accurate locations. For example, on second object **510** as shown in FIG. **17**, the comparison to the geometrical model may consider the curvature of the visible stripes and determine that the visible portion of the tracking markers **420** represents the right half of the tracking markers **420**. In this manner, example approaches described herein may allow different elements to be distinguished from each other, despite close proximity or partial overlap.

[0063] In some examples, a plurality of trackable objects (e.g., first object **500** and second object **510**) may be used to form a dynamic reference base (DRB) that is attached to a patient and/or serves as a reference to which other tracked objects are related. To make an object into a navigated element, it may be shaped or marked in unique ways. In one embodiment, an object may have contrasting (e.g., black and white) stripes painted on its shaft, or have slight variances in diameter such that sections are elevated or recessed and appear as stripes, with spacing between stripes being a consistent amount. For example, the spacing between stripes may be 1 millimeter (mm) in one element and 2 mm in another element. A section or group of stripes may have a predetermined number of total stripes so that the computer **430** may localize an exact longitudinal position of the stripe cluster, providing accuracy along and normal to the shaft of the element. If position sensors **410** track a plurality of elements simultaneously, the different stripe spacing allows the computer **430** to distinguish between elements. In other words, the frequency of the stripes may identify a tracking marker **420** from other tracking markers **420** and the cluster of stripes may provide the coordinates of the tracking marker **420**.

[0064] FIG. **19** shows an object **520** with stripes **522** of different thicknesses, a single stripe **524** between clusters of stripes **522**, and a contrast of a dark object **520** against white or silver stripes **522** and **524** (e.g., retro-reflective tape). In some embodiments, unique identification of objects **520** may be a function of stripe frequency and/or stripe thickness. Additionally or alternatively, a stripe **524** between clusters may facilitate improving tracking accuracy and/or localization robustness. The color configuration shown in FIG. **19** may facilitate increasing contrast in surgical environments while visually separating the object **520** from the background. Applying localized colors such as red, green, and/or blue to an object **520** may also provide additional feedback to surgeons and/or systems. The example approaches described herein have the advantage of encoding more information and being compatible with existing discrete and continuous linear barcode design principles. Additionally, the example approaches allow implanted hardware (e.g., screw tower **100**, instrument **200**, housing **300**) to serve as a navigated array, allowing registration to be transferred sequentially as additional screws as placed and maintaining better accuracy.

[0065] FIG. **20** shows an example computing system **600** configured to perform one or more computing operations. While some examples of the disclosure are illustrated and described herein with reference to the computing system **600** being a computer **430** (shown in FIG. **15**) and/or being used with a computer **430**, aspects of the disclosure are operable with any computing system (e.g., position sensor **410**) that executes instructions to implement the operations and functionality associated with the computing system **600**. The computing system **600** shows only one example of a computing environment for performing one or more computing operations and is not intended to suggest any limitation as to the scope of use or functionality of the disclosure.

[0066] In some examples, the computing system **600** includes a system memory **610** (e.g., computer storage media) and a processor **620** coupled to the system memory **610**. The processor **620** may include one or more processing units (e.g., in a multi-core configuration). Although the processor **620** is shown separate from the system memory **610**, examples of the disclosure contemplate that the system memory **610** may be onboard the processor **620**, such as in some embedded systems.

[0067] The system memory **610** stores data associated with one or more users, tracked objects, position sensors **410**, and/or tracking markers **420**, and computer-executable instructions, and the processor **620** is programmed or configured to execute the computer-executable instructions for implementing aspects of the disclosure using, for example, the computer **430**. The system memory **610** includes one or more computer-readable media that allow information, such as the computer-executable instructions and other data, to be stored and/or retrieved by the processor **620**.

[0068] By way of example, and not limitation, computer-readable media may include computer storage media and communication media. Computer storage media are tangible and mutually exclusive to communication media. For example, the system memory **610** may include computer storage media in the form of volatile and/or nonvolatile memory, such as read only memory (ROM) or random access memory (RAM), electrically erasable programmable read-only memory (EEPROM), solid-state storage (SSS), flash memory, a hard disk, a floppy disk, a compact disc (CD), a digital versatile disc (DVD), magnetic tape, or any other medium that may be used to store desired information that may be accessed by the processor **620**. Computer storage media are implemented in hardware and exclude carrier waves and propagated signals. That is, computer storage media for purposes of this disclosure are not signals per se.

[0069] A user or operator may enter commands and other input into the computing system **600** through one or more input devices **630** coupled to the processor **620**. The input devices **630** are configured to receive information. Example input device **630** include, without limitation, a pointing device (e.g., mouse, trackball, touch pad, joystick), a keyboard, a game pad, a controller, a microphone, a camera, a gyroscope, an accelerometer, a position detector, and an electronic digitizer (e.g., on a touchscreen). Information, such as text, images, video, audio, and the like, may be presented to a user via one or more output devices **640** coupled to the processor **620**. The output devices **640** are configured to convey information. Example, output devices **640** include, without limitation, a monitor, a projector, a printer, a speaker, a vibrating component. In some examples, an output device **640** is integrated with an input device **630** (e.g., a capacitive touch-screen panel, a controller including a vibrating component).
[0070] One or more network components **650** may be used to operate the computing system **600** in a networked environment using one or more logical connections. Logical connections include, for example, local area networks, wide area networks, and the Internet. The network components **650** allow the processor **620**, for example, to convey information to and/or receive information from one or more remote devices, such as another computing system or one or more remote computer storage media. Network components **650** may include a network adapter, such as a wired or wireless network adapter or a wireless data transceiver.
[0071] The examples described herein facilitate reducing the amount of soft tissue damage during surgery (e.g., orthopedic spine and neurosurgery), which may lead to less pain, quicker recovery times, and/or lower likelihoods of infection. For example, FIG. **21** shows percutaneous screws
[0072] FIGS. **21** and **22** show an example tracking array **700** and a navigation array-equipped rod **710** extending transversely across an upper portion of one or more screws **712** (e.g., a tulip of a pedicle screw) and one or more screw towers (e.g., screw tower **100** or **160**) coupled to the upper portion of the screws **712**. As shown in FIG. **21**, the tracking array **700** may be coupled to a first screw tower **714** in a first phase. Once the rod **710** is extended through the first screw tower **714**, the tracking array **700** may be uncoupled from the first screw tower **714** and coupled to a second screw tower **716** in a second phase as shown in FIG. **22**.
[0073] The tracking array **700** and rod **710** each include a plurality of markers **720** that may be tracked (e.g., using position sensors **410**) during the first and second phases to enable the relative positions of the rod **710** and first screw tower **714** to be determined (e.g., using the computer **430**). In this manner, the rod **710** may be extended through the first screw tower **714** and second screw tower **716** using feedback from the tracking system **400**. For example, as shown in FIG. **23**, the display **432** may aid in positioning the rod **710** by showing a distance **722** to the first screw tower **714** or second screw tower **716** and an alignment **724** of the rod **710** relative to an opening defined in the first screw tower **714** or second screw tower **716** (e.g., longitudinal channel **138**). While FIGS. **21-22** show the tracking array **700** and rod **710** each including a plurality of arms and a spherical marker at an end portion of each arm, the tracking array **700** and/or rod **710** may include one or more tracking markers **420** for tracking the rod **710**, screws **712**, first screw tower **714**, and/or second screw tower **716**.
[0074] FIG. **24** shows an example method **800** of providing a rod reduction tool. As shown in FIGS. **21** and **22**, the rod **710** may extend transversely across an upper portion of a screw **712** and a screw tower (e.g., screw tower **100** or **160**) coupled to the upper portion of the screw **712**. As shown in FIGS. **25-27**, the screw tower **100** may be rigidly and/or robustly coupled to the screw **712** to allow for screw manipulation or compression/distraction. In some examples, a driver shaft (e.g., inner shaft **210**) is extended longitudinally through the screw tower **100** at operation **810**. For example, a distal end **104** of the driver shaft may be inserted into the proximal opening **106** of the screw tower **100** and moved in the distal direction. A threaded sleeve **220** may be mounted on a proximal portion of the driver shaft at operation **820** to form the instrument **200**.
[0075] A housing **300** may be coupled to the screw tower **100** using one or more retention members

(e.g., tower clips **310**) at operation **830**. The housing **300** may be threadably coupled to the threaded sleeve **220** using a threaded button **320** at operation **840**. The threaded sleeve **220** is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower **100**. The driver shaft being able to protrude through a locking cap allows the instrument **200** to achieve rod reduction without putting extraneous force on the locking cap, thereby mitigating a likelihood of premature damage to the locking cap and/or tulip. In some examples, the screw tower **100**, instrument **200**, and/or housing **300** may be marked and used as locating and/or guidance devices for inserting interconnecting rods.

[0076] The previously mentioned examples allow for quick and robust connection to a bone screw and tulip and also allows for reduction instrumentation to connect within a small footprint. The internal variable reduction is not only robust, but also does keeps the outer diameter of the screw tower slim, minimizing the incision size. The following instrumentation may also function with other instrumentation to allow for other technique related steps including but not limited to: rod measuring, rod passage, rod reduction, locking cap attachment and tightening, compression, and distraction. The following embodiments represent an approach that may be used to hold a pedicle screw to a tower-based instrument; a tube-based device allowing rod passage, rod reduction, and locking cap delivery and tightening following screw implantation. Reduction embodiments may allow for free moving reduction followed by mechanically assisted reduction to save time by allowing particular orientations or intermittent functionality of certain internal components not possible in all minimally invasive screw instrumentation systems. Additionally, the potential ability to use instrumentation from other currently available Globus systems may reduce the number of sets required in the operating room, may streamline the procedure, and may also reduce operating room time due to a potentially more streamlined technique.

[0077] This written description uses examples to disclose aspects of the disclosure and also to enable a person skilled in the art to practice the aspects, including making or using the above-described systems and executing or performing the above-described methods. Having described aspects of the disclosure in terms of various examples with their associated operations, it will be apparent that modifications and variations are possible without departing from the scope of the disclosure as defined in the appended claims. That is, aspects of the disclosure are not limited to the specific examples described herein, and all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense. For example, the examples described herein may be implemented and utilized in connection with or applied to other examples and applications without departing from the scope of the disclosure. Thus, the aspects of the disclosure are not intended to be limited to the above description and/or accompanying drawings, but are to be accorded the broadest scope consistent with the principles and features disclosed herein.

[0078] It is to be understood that the present disclosure is not limited in its application to the details of construction and/or the arrangement of components set forth in the description herein or illustrated in the drawings. For example, in accordance with the principles of the disclosure, any feature described herein and/or shown in the drawings may be referenced and/or claimed in combination with any other feature described herein and/or shown in the drawings. Skilled artisans will recognize the examples provided herein have many useful alternatives and fall within the scope of the disclosure.

[0079] The teachings of the present disclosure may be used and practiced in other embodiments and practiced or carried out in various ways. For example, components of the systems and/or operations of the methods described herein may be utilized independently and separately from other components and/or operations described herein. Moreover, the methods described herein may include additional or fewer operations than those disclosed, and the order of execution or performance of the operations described herein is not essential unless otherwise specified. That is, the operations may be executed or performed in any order, unless otherwise specified, and it is contemplated that executing or performing a particular operation before, contemporaneously with, or after another operation is within the scope of the disclosure. Moreover, the functionality of a given block of the flowcharts and/or block diagrams may be separated into multiple blocks, and/or the functionality of two or more blocks of the flowcharts and/or block diagrams may be at least partially integrated. Furthermore, although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction to the depicted arrows.

[0080] It should be apparent from the foregoing description that one or more block diagrams described herein may represent conceptual views of illustrative circuitry embodying the principles of the disclosure and that various examples may be implemented in hardware and/or as computer program instructions stored on a non-transitory machine-readable storage medium. Computer program instructions may be provided to a processor of a general purpose computer circuit, a special purpose computer circuit, and/or other programmable data processing circuit to produce a machine, such that the instructions, which execute via the processor, transform and control transistors, values stored in memory locations, and other hardware components within such circuitry to perform the operations described in detail herein, including the functions/acts associated with the blocks of the flowcharts and/or block diagrams, and thereby create means (functionality) and/or structure for performing such operations. It will be appreciated by those skilled in the art that any flowcharts, sequence diagrams, state transition diagrams, pseudo code, and the like represent various processes that may be substantially represented in machine-readable storage media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0081] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which present inventive concepts belong. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0082] When introducing aspects of the disclosure or the examples thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements, unless the context clearly indicates otherwise. References to an “embodiment” or an “example” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments or examples that also incorporate the recited features. The phrase “one or more of the following: A, B, and C” means “at least one of A and/or at least one of B and/or at least one of C.” The term “and/or” includes any and all combinations of one or more of the associated listed items. It will be understood that although ordinal terms (e.g., “first,” “second,” “third,” etc.) may be used herein to describe various elements/operations, these elements/operations should not be limited by these terms. These terms are only used to distinguish one element/operation from another element/operation. Thus, a first element/operation in some embodiments could be termed a second element/operation in other embodiments without departing from the teachings of present inventive concepts. Furthermore, as used herein, the common abbreviation “e.g.”, which derives from the Latin phrase “exempli gratia,” may be used to introduce or specify a general example or examples of a previously mentioned item, and is not intended to be limiting of such item. The common abbreviation “i.e.”, which derives from the Latin phrase “id est,” may be used to specify a particular item from a more general recitation.

[0083] Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. Use of the terms “including,” “comprising,” or “having,” and variations thereof, herein is meant to encompass the items listed thereafter and equivalents thereof, as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled,” and variations thereof,

are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings. Moreover, when an element is referred to as being “connected,” “coupled,” or “responsive,” and variations thereof, to another element, it can be directly connected, coupled, or responsive to the other element or intervening elements may be present. In contrast, when an element is referred to as being “directly connected,” “directly coupled,” or “directly responsive,” and variations thereof, to another element, there are no intervening elements present. Furthermore, “connected,” “coupled,” “responsive,” or variants thereof as used herein may include wirelessly coupled, connected, or responsive.
[0084] The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

Claims

1. A rod reduction system for use with a tracking system comprising: a screw tower having: an outer sleeve having distal ends adapted to mate to an exterior feature of a tulip of a bone screw, the outer sleeve further having extensions extending radially inwardly; and an inner sleeve configured to be slidably coupled to the outer sleeve and configured to secure the bone screw to the outer sleeve, the inner sleeve having longitudinal slots for receiving the extensions of the outer sleeve to prevent rotation of the inner sleeve relative to the outer sleeve; a driver having a shaft extendable longitudinally through the screw tower, the shaft having a threaded sleeve disposed around a proximal portion of the shaft; and a housing configured to attach to the screw tower and holding a threaded insert configured to threadably couple to the threaded sleeve of the shaft, wherein the threaded sleeve is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower to reduce a rod disposed in the tulip, a tracking system for use with a robot including: a computer, a display in communication with the computer; a position sensor in communication with the computer; one or more tracking markers disposed on the screw tower; wherein the position sensor is configured to detect the one or more tracking markers to determine position sensor data of the one or more tracking markets; wherein the computer is configured to receive the position sensor data and present the position of the screw tower via the display in relation to an image of an anatomical structure of a patient.
2. The system of claim 1, wherein the housing includes retention clips configured to clamp to external features disposed in a proximal portion of the screw tower.
3. The system of claim 2, wherein each retention clip includes a spring loaded pivoting clip biased to a clamped position.
4. The system of claim 1, wherein the threaded insert includes a threaded button having a threaded hole configured to threadably couple to the threaded sleeve, the button switchable between an engaged position for engaging with the threaded sleeve and a disengaged position.
5. The system of claim 4, wherein the threaded button is a spring loaded threaded button biased to the engaged position.
6. The system of claim 4, wherein the threaded button is a transversely movable spring loaded threaded button biased to the engaged position, wherein transverse movement of the threaded button against the bias releases the threaded engagement with the threaded sleeve.
7. The system of claim 1, wherein the system includes a second screw tower positioned on a second location on the patient, and one or more tracking markers disposed on the second screw tower.
8. The system of claim 1, wherein the one or more tracking markers are passive tracking markers.
9. The system of claim 1, further comprising a robot trackable by the position sensor.

10. The system of claim 1, further comprising a surgical tool trackable by the position sensor.

11. A rod reduction system for use with a tracking system comprising: a computer; a screw tower positioned at a first location on a patient during the surgical procedure; a position sensor in electronic communication with the computer; one or more tracking markers positioned on the screw tower; wherein the screw tower includes: an outer sleeve having distal ends adapted to mate to an exterior feature of a tulip of a bone screw, the outer sleeve further having extensions extending radially inwardly; and an inner sleeve configured to be slidably coupled to the outer sleeve and having a pair of mating extensions configured to be positioned inside the tulip to sandwich the tulip between the outer sleeve and the inner sleeve, thereby locking the bone screw to the outer sleeve, the inner sleeve having longitudinal slots for receiving the extensions of the outer sleeve to prevent rotation of the inner sleeve relative to the outer sleeve; a driver having a shaft extendable longitudinally through the screw tower, the shaft having a threaded sleeve disposed around a proximal portion of the shaft; and a housing configured to attach to the screw tower and holding a threaded insert configured to threadably couple to the threaded sleeve of the shaft, wherein the threaded sleeve is rotatable about a longitudinal axis to urge the driver shaft longitudinally relative to the screw tower to reduce a rod disposed in the tulip, wherein the position sensor is configured to detect the one or more first tracking markers to determine position sensor data of the one or more first tracking markers and provide the position sensor data to the computer.

12. The system of claim 11, wherein the housing includes retention clips configured to clamp to external features disposed in a proximal portion of the screw tower.

13. The system of claim 12, wherein each retention clip includes a spring loaded pivoting clip biased to a clamped position.

14. The system of claim 11, further comprising: a second screw tower positioned at a second location on the patient; and one or more second tracking markers disposed on the second screw tower.

15. The system of claim 14, wherein the one or more first tracking markers and the second one or more tracking markers are passive tracking markers.

16. The system of claim 11, further comprising a robot trackable by the position sensor.

17. The system of claim 11, further comprising a surgical tool trackable by the position sensor.
