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Inventor(s)	Beery; Zach et al.

Compressor/distractor with tower traversal

Abstract

A surgical instrument includes a rack, a first arm coupled to the rack, a second arm coupled to the rack, a first tower coupled to the first arm, and a second tower coupled to the second arm. The first tower comprises an upper end, a lower end, and a track between the upper end and the lower end. A channel of the first arm is configured to receive the track of the first tower and selectively position the first arm along the track of the first tower. The lower end of the first tower is configured to snap onto a pedicle screw and to disengage from the pedicle screw in response to a removal tool being inserted into the first tower.

Inventors: **Beery; Zach (Traverse City, MI), White; William (Traverse City, MI)**

Applicant: **Thompson Surgical Instruments, Inc.** (Traverse City, MI)

Family ID: **1000008763651**

Assignee: **THOMPSON SURGICAL INSTRUMENTS, INC. (Traverse City, MI)**

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Primary Examiner: Robert; Eduardo C

Assistant Examiner: Lane; Holly Joanna

Attorney, Agent or Firm: McAndrews, Held & Malloy, Ltd.

Background/Summary

BACKGROUND

(1) The present disclosure relates to a surgical apparatus and in particular to a compressor/distractor instrument that applies compression forces and/or distraction forces on anatomical structures.

(2) For example, pedicle screws may be inserted into vertebrae of a defective region. Spinal fixation rods may rigidly fix the vertebrae relative to one another between the pedicle screws. A compressor/distractor instrument may be coupled to the pedicle screws and may apply compression forces and/or distraction forces to the vertebrae via the pedicle screws. Via such compression forces and/or distraction forces the attached vertebrae may be appropriately positioned.

(3) Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such approaches with the present disclosure as set forth in the remainder of the present application with reference to the drawings.

SUMMARY

(4) Various aspects of this disclosure provide a surgical instrument, such as a compressor/distractor instrument, that may apply compression forces and/or distraction forces to anatomical structures. For example and without limitation, various aspects of the disclosure are directed to a surgical instrument comprising a rack, arms coupled to the rack, and towers coupled to the arms. Each tower may comprise a longitudinal track that extends between an upper end of the tower and a lower end of the tower. An arm may be coupled to a tower via its respective longitudinal track. The

longitudinal track may permit the arm to traverse or translate longitudinally along the tower. In various embodiments, the longitudinal track permits the arm to be selectively positioned along the tower and locked into such selected position.
(5) Furthermore, a lower end of each tower may snap onto a head of a pedicle screw that has been affixed to an anatomical structure. Thus, the tower may permit a simple manner for attaching the surgical instrument to the anatomical structure via affixed pedicle screws. Moreover, while the tower may simply snap onto a pedicle screw without the aid of a tool, the tower may require the use of a tool to detach the tower from the pedicle screw. Such configuration reduces the likelihood of the tower being accidentally detached from the pedicle screw.
(6) Further aspects will become apparent to one of skill in the art through review of the present disclosure and referenced drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** provides a perspective view of a surgical instrument in accordance with various aspects of the present disclosure.
(2) FIG. **2** depicts an arm connector of the surgical instrument depicted in FIG. **1**.
(3) FIG. **3** depicts an arm carriage of the surgical instrument depicted in FIG. **1**.
(4) FIG. **4** provides a top view of the surgical instrument depicted in FIG. **1**.
(5) FIG. **5** provides a front view and correspond cross-section of an arm and tower of the surgical instrument depicted in FIG. **1**.
(6) FIG. **6** provides perspective views of an arm and tower of the surgical instrument depicted in FIG. **1**.
(7) FIG. **7** provides a perspective view of the surgical instrument depicted in FIG. **1** with its arms in a lowered position.
(8) FIG. **8** provides a side view of the surgical instrument depicted in FIG. **1** with its arms in a lowered position.
(9) FIG. **9** provides a perspective view of the surgical instrument depicted in FIG. **1** with its arms angled inwards.
(10) FIG. **10** provides a perspective view of the surgical instrument depicted in FIG. **1** with its arms angled outwards.
(11) FIGS. **11**A-**11**E provide various views of a pivot joint that permits angling of arms per FIGS. **9** and **10**.
(12) FIGS. **12**A-**12**F provide various views of another embodiment of a pivot joint that permits angling of such arm per FIGS. **9** and **10**.
(13) FIG. **13** provides a perspective view and corresponding cross-section of a tower of the surgical instrument depicted in FIG. **1** coupled to a pedicle screw.
(14) FIG. **14** provides a magnified view of the tower and pedicle screw of FIG. **11**.
(15) FIG. **15**A-**15**E depict a removal tool and a process of using the removal tool to disengage a tower of the surgical instrument of FIG. **1** from a pedicle screw.
(16) FIGS. **16**A-**16**C depict the removal tool disengaging a tower of the surgical instrument of FIG. **1** from a pedicle screw.
(17) FIG. **17** provides a lateral cross-section and longitudinal cross-section depicting the removal tool seated in the tower of the surgical instrument of FIG. **1**.
(18) FIG. **18** provides a lateral cross-section and longitudinal cross-section depicting the removal tool disengaging the tower of the surgical instrument of FIG. **1** from a pedicle screw.
(19) FIG. **19** provides a perspective view of counter torque tools engaged with upper ends of towers of the surgical instrument of FIG. **1**.

(20) FIG. **20** provides a top view of counter torque tools engaged with upper ends of towers of the surgical instrument of FIG. **1**.
(21) FIG. **21** provides a perspective view of a surgical instrument similar to the surgical instrument of FIG. **1** in which each tower has a second track to which an accessory is attached.
(22) FIG. **22** provides a top of the surgical instrument of FIG. **21** in which towers have a second track to which accessories may be attached.
(23) FIGS. **23**A-**23**C provide various views depicting the multiple tracks of the towers shown in FIGS. **21** and **22**.

DETAILED DESCRIPTION

(24) The following discussion presents various aspects of the present disclosure by providing examples thereof. Such examples are non-limiting, and thus the scope of various aspects of the present disclosure should not necessarily be limited by any particular characteristics of the provided examples. In the following discussion, the phrases "for example," "e.g.," and "exemplary" are non-limiting and are generally synonymous with "by way of example and not limitation," "for example and not limitation," and the like.
(25) As utilized herein, "and/or" means any one or more of the items in the list joined by "and/or". As an example, "x and/or y" means any element of the three-element set {(x), (y), (x, y)}. In other words, "x and/or y" means "one or both of x and y." As another example, "x, y, and/or z" means any element of the seven-element set {(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)}. In other words, "x, y and/or z" means "one or more of x, y, and z."
(26) The terminology used herein is for the purpose of describing particular examples only and is not intended to be limiting of the disclosure. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "includes," "comprising," "including," "has," "have," "having," and the like when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.
(27) It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. Thus, for example, a first element, a first component or a first section discussed below could be termed a second element, a second component or a second section without departing from the teachings of the present disclosure. Similarly, various spatial terms, such as "upper," "lower," "side," and the like, may be used in distinguishing one element from another element in a relative manner. It should be understood, however, that components may be oriented in different manners, for example a semiconductor device may be turned sideways so that its "top" surface is facing horizontally and its "side" surface is facing vertically, without departing from the teachings of the present disclosure.
(28) In the drawings, various dimensions (e.g., layer thickness, width, etc.) may be exaggerated for illustrative clarity. Additionally, like reference numbers are utilized to refer to like elements through the discussions of various examples.
(29) The discussion will now refer to various example illustrations provided to enhance the understanding of the various aspects of the present disclosure. It should be understood that the scope of this disclosure is not limited by the specific characteristics of the examples provided and discussed herein.
(30) FIGS. **1-14** provide different views of a surgical instrument **10** and how the surgical instrument **10** may interact with pedicle screws **30** that may be affixed to anatomical structures. FIGS. **15-18** depict a removal tool **20** and how the removal tool **20** may interact with towers **300** of the surgical instrument **10** so as to detach or unlock the towers **300** from pedicle screws **30**. In various embodiments, the surgical instrument **10** may be implemented as a compressor/distractor

instrument, which may be attached to anatomical structures via pedicle screws **30** in order to selectively apply a compression force or a distraction force to such anatomical structures. However, aspects of the surgical instrument **10** may be embodied in a compressor instrument configured to provide a compression force but not a distraction force. Similarly, aspects of the surgical instrument **10** may be embodied in a distractor instrument configured to provide a distraction force but not a compression force.

(31) Referring now to FIG. **1**, a perspective view of the surgical instrument **10** is provided. As shown, the surgical instrument **10** may include a rack **110**, an arm connector **120**, an arm carriage **130**, a first arm **200**, a second arm **250**, and towers **300**. A proximal portion **210** of the first arm **200** is coupled to the rack **110** via the arm connector **120**. Further, a distal portion **220** of the first arm **200** is coupled to a first tower **300**. Similarly, a proximal portion **260** of the second arm **250** is coupled to the rack **110** via the arm carriage **130**. A distal portion **270** of the second arm **250** is coupled to a second tower **300**. In various embodiments, the first tower **300** is identical to the second tower **300** and thus interchangeable during use. Moreover, one or more parts of the surgical instrument **10** may be formed from surgical stainless steel. Other embodiments may utilize various alternative materials to form all or part of surgical instrument **10**.

(32) As further shown in FIG. **1**, lower ends of the towers **300** may engage pedicle screws **30** in order to impart compression forces and/or distraction forces to affixed anatomical structures. As explained in greater detail below, the towers **300** are effectively locked to the pedicle screws **30**. In order to disengage the towers **300** from the pedicle screws **30**, a person uses a separate removal tool **20** to release the towers **300** from their respective pedicle screws **30**. By requiring a separate removal tool **20**, the towers **300** may effectively prevent inadvertent disengagement from the pedicle screws **30** and corresponding anatomical structures during a surgical procedure.

(33) As shown in FIG. **4**, the rack **110** may comprise a cylindrical rod or rail **112** having a rectangular cross section. Moreover, the rail **112** may include teeth **114** spanning a longitudinal rear surface of the rail **112** and a stop **116** toward a free end of the rail **112**. In various embodiments, an internal spring (not shown) biases the stop **116** such that the stop **116** protrudes from a front surface of the rail **112**. The protruding stop **116** may prevent the arm carriage **130** from falling off the free end of the rail **112**. In particular, the internal spring may apply a biasing force to the stop **116** that is sufficient to prevent the arm carriage **130** from sliding past the stop **116** and off the free end of the rail **112** under its own weight. However, the biasing force provided by the spring may be overcome by a person imparting additional force to arm carriage **130** which causes retraction of the stop **116** into the rack **110**, thus permitting the person to slide the arm carriage **130** past the stop **116** and off the free end of the rack **110**.

(34) Referring now to FIGS. **1** and **2**, the arm connector **120** may be affixed to an end of the rack **110** in a stationary manner. However, in some embodiments, the arm connector **120** may be replaced with an arm carriage similar to the arm carriage **130** so as to permit translation of both the first arm **200** and the second arm **250** along the rack **110**. As shown, the arm connector **120** may include a port **122**. The port **122** may have a non-circular cross section that closely mates with a post **230** of the first arm **200**. As shown, one or more walls of the port **122** may have a recess **124** configured to receive a detent of the post **230**.

(35) Similarly, as shown in FIG. **3**, the arm carriage **130** may include a port **132**. The port **132** may have a non-circular cross section that closely mates with a post **280** of the second arm **250**. One or more walls of the port **132** may have a recess **134** configured to receive a detent of the post **280**.

(36) The arm carriage **130** may include a pinion **136**. The pinion **136** may include a head **137** and teeth that engage the teeth **114** of the rack **110**. The head **137** may include a socket **139** to receive a tool, which may rotate the pinion **136**. Through rotation of the pinion **136** and its engagement with teeth **114**, the pinion **136** may impart ratcheted-movement of the arm carriage **130** along the rack **110**. In particular, rotation of the pinion **136** in a first direction may cause the arm carriage **130** to traverse along the rack **110** toward the stationary arm connector **120** and impart a compression

force between the arms **200**, **250** coupled to the arm connector **120** and the arm carriage **130**. Conversely, rotation of the pinion **136** in a second direction opposite the first direction may cause the arm carriage **130** to traverse along the rack **110** away from the arm connector **120** and impart a distraction force between the arms **200**, **250** coupled to the arm connector **120** and the arm carriage **130**. To this end, the rack **110** may pass through a longitudinal aperture **138** of the arm carriage **130**.

(37) As shown, the arm carriage **130** may further include a lever **140** that may be selectively moved among a compression position, a distraction position, and a disengaged position. When placed in the compression position, the lever **140** positions a first pawl such that the first pawl is moved toward and engages teeth **114** of the rack **110** and positions the second pawl such that the second pawl is moved away from and disengages the teeth **114** of the rack **110**. Conversely, when placed in the distraction position, the lever **140** positions the first pawl such that the first pawl is moved away from and disengages teeth **114** of the rack **110** and positions the second pawl such that the second pawl is moved toward and engages the teeth **114** of the rack **110**. Further, when placed in the disengaged position, the lever **140** positions the first pawl such that the first pawl is moved away from and disengages teeth **114** of the rack **110** and positions the second pawl such that the second pawl is moved away from and disengages the teeth **114** of the rack **110**. Due to such disengagement of the pawls, the arm carriage **130** in various embodiments may freely slide along the rack **110** when the lever **140** is in placed in the disengaged position.

(38) In various embodiments, the first pawl and teeth **114** permit ratcheted movement in the compression direction when the first pawl is engaged with the teeth **114**. Moreover, while engaged, the first pawl and teeth **114** may prevent movement in the opposite distraction direction. To this end, the teeth **114** of the rack **110** in various embodiments are uniformly-shaped and symmetrically-sloped, with leading and trailing edges having the same slope. However, the first pawl is not symmetrically sloped. Instead, the leading edge (i.e., edge toward the compression direction of ratcheted movement) is more moderately-sloped than the opposite trailing edge. As a result of the more moderately-sloped or less steeply-sloped leading edge, lateral movement of the arm carriage **130** with respect to the rack **110** in the compression direction imparts an upward force upon the first pawl that is sufficient to overcome the biasing force of an associated spring and permit the first pawl to travel over the teeth **114**. Conversely, as a result of the more steeply-sloped trailing edge, lateral movement of the arm carriage **130** with respect to the rack **110** in the distraction direction fails to impart an upward force upon the first pawl that is sufficient to overcome the biasing force of the spring, thus preventing the first pawl from traveling over the teeth **114**. In this manner, the arm carriage **130** may lock or retain its attached retractor arm **250** to a particular location along the rack **110**, thereby maintaining a desired compression force between the arms **200**, **250**.

(39) In various embodiments, the second pawl and teeth **114** may permit ratcheted movement in the distraction direction when engaged. Moreover, while engaged, the second pawl and teeth **114** may prevent movement in the opposite compression direction. To this end, the second pawl may be implemented in a similar manner as the first pawl. Namely, the leading edge (i.e., edge toward the distraction direction of ratcheted movement) is more moderately-sloped than the opposite trailing edge.

(40) Referring now to FIGS. **4-6**, aspects of the arms **200**, **250** will be described. In various embodiments, the only substantive difference between the first arm **200** and second arm **250** is the angle or offset of the distal portion **220**, **270** of the respective arm **200**, **250** with respect to its proximal portion **210**, **260**. Namely, the distal portion **220** of the first arm **200** is angled or offset from its proximal portion **210** toward the free end of the rack **110** whereas the distal portion **270** of the second arm **250** is angled or offset from its proximal portion **260** toward the opposite end of the rack **110**. Thus, in various embodiments, the first arm **200** essentially mirrors the second arm **250**. As such, the following discussion focuses mainly on the second arm **250** as depicted in FIGS. **5** and

6. However, the first arm **200** may be implemented in a similar manner.

(41) As shown, the proximal portion **260** of the arm **250** may include a post **280** that protrudes above a top surface **262** of the proximal portion **260**. The post **280** may have a non-circular cross section that closely mates with a port **122** of the arm connector **120** or the port **132** of the arm carriage **130**. Moreover, the post **280** may be implemented as a push button comprising an internal spring (not shown) and one or more detents **282**. The spring may bias the post **280** away from the top surface **262** and toward a locked position, in which the post **280** causes the one or more detents **282** to extend outwardly from a surface of the post **280**. Such extended detents **282** may engage the recess **124** of port **122** or the recess **134** of port **132** when the post **280** is placed in the respective port **122**, **132**. Such engagement may prevent sliding the post **280** from the respective port **122**, **132** and may prevent removal of the arm **250** from the rack **110**. However, in various embodiments, a person may push the post **280** toward the top surface **262** to overcome the biasing force of the spring and place the post **280** into a released position. In the released position, the post **280** may permit inward deflection of the detents **282** by the wall of the ports **122**, **132** and may permit sliding the arm **250** off the post **280**. Thus, the post **280** permits easy attachment of the arm **250** to the rack **110** since a person needs to merely slide the port **122**, **132** over the post **280** in order to snap the arm **250** to the rack **110**. Similarly, the post **280** permits easy detachment of the arm **250** from the rack **110** since a person needs to merely press the post **280** in order to release the detents **282** and permit the arm **250** to be slid off the post **280**.

(42) As shown in the cross-section of FIG. **5**, the distal portion **270** of the second arm **250** may further include a button **290**, a pivot pin **292**, retaining pin **294**, and a spring **296**. The pivot pin **292** may extend through lateral sides of the distal portion **270** and through a pivot hole **291** of the button **290**. The pivot hole **291** may closely mate with a longitudinal surface of the pivot pin **292** in order to provide an axis about which the button **290** may pivot or rock. Similarly, the retaining pin **294** may extend through lateral sides **272** of the distal portion **270** and through a retaining hole **293** of the button **290**. The retaining hole **293** may be larger than longitudinal surfaces of the retaining pin **294** in order to provide the button **290** with a range of movement about the axis of the pivot pin **292**. In this manner, the button **290** may pivot about the pivot pin **292**, but the retaining pin **294** may cooperate with the retaining hole **293** to limit movement of the button **290** between a fully engaged position and a fully disengaged position.

(43) The spring **296** may be positioned between a proximal end **295** of the button **290** and a seat **273** of the distal portion **270**. In various embodiments, the spring **296** comprises a compression spring that supplies a biasing force that biases the proximal end **295** upward and toward the fully engaged position. In the fully engaged position, a distal end **297** of the button **290** may extend into a channel **274** of the distal portion **270**. In such an engaged position, the distal end **297** of the button **290** may engage teeth **310** of the tower **300** and retain the tower **300** at a specific position. A person, however, may press the proximal end **295** of the button **290** to move the button **290** toward the fully disengaged position. In the fully disengaged position, the distal end **297** of the button **290** may move away from the teeth **310** of the tower **300** so as to permit sliding the tower **300** along the channel **274**.

(44) As shown in FIG. **6**, the tower **300** may be fully disengaged from the arm **250** by simply pressing the button **290** and sliding the tower **300** downward and/or the arm **250** upward. Conversely, a person may press the button **290** in order to slid the arms **200**, **250** down respective towers **300** in order to place the arms **200**, **250** closer to anatomical structures to which the arms **200**, **250** are coupled via their respective towers **300** as shown in FIGS. **7** and **8**. Such a lowered position may provide at least two advantages. One, the lowered position may position the arms **200**, **250** out of surgeon's line of sight thus improving the surgeon's view of the operative site. Two, the lower position may improve the arms **200**, **250** ability to impart compression forces and/or distraction forces upon the anatomical structures to which they are attached since the lower position effectively places the arms **200**, **250** closer to the anatomical structures.

(45) Referring back to FIGS. **5** and **6**, the tower **300** may comprise a generally-cylindrical tube shape body **301** with a central longitudinal bore **302** between an upper end and a lower end of the body **301**. Further, the tower **300** may comprise a track **305** that runs longitudinally down a proximal side of the body **301**, a first vertical slit **331** runs longitudinally down a first lateral side of the body **301**, and a second slit **331** runs longitudinally down a second lateral side of the body **301** and opposite the first slit **331**.
(46) The two vertical slits **331** may extend through the lower end of the body **301** and their respective lateral sides of the body **301**. However, as shown, the two vertical slits **331** do not extend all of the way to the upper end of the body **301**. As such, the vertical slits **331** effectively split the body **301** into two cantilevered fingers **333**. As explained in greater detail below, the lower ends of the fingers **333** may be configured to grasp a pedicle screw **30** and lock the pedicle screw **30** to the tower **300**.
(47) A shown, the track **305** comprises teeth **310** that are flanked by rails **320**. In various embodiments, the rails **320** are formed by longitudinal recesses **321** into the body **301**. In particular, each recess **321** may extend into the outer surface of the body **301** at an angle such that a distance between the opposing recesses is greater at an outer surface of the body **301** than at their depths. Moreover, each recess **321** may comprise an upper end **322** and a lower end **324**. The upper ends **322** may provide openings for the arms **200**, **250** to enter and grasp the rails **320**. In particular, such openings may be sized and spaced to receive respective flanges or fingers **276** of the channel **274** that runs through the distal portion **270** of the arm **250**.
(48) The fingers **276** of the distal portion **270** may be angled inward toward the channel **274** so as to closely mate with and engage the rails **320** via the recesses **321** when the channel **274** receives the track **305**. In this manner, the fingers **276** may capture the rails **320** and position the track **305** in its channel **274**. In various embodiments, the opening of the upper ends **322** may be tapered such that the opening provided at the upper end **322** is larger than the opening or groove provided by the recess **321**. Such tapering may make it easier for a person to slide the fingers **276** into the recesses **321** and engage the rails **320** with the fingers **276** of the arm **250**.
(49) In various embodiments, the lower end **324** of each recess **321** is closed. Such closing of the lower end **324** effectively provides a lower stop that prevents sliding the fingers **276** off the lower end of the rails **320** and disengaging the fingers **276** from the rails **320** in the process. In this manner, a person does not need to be concerned about inadvertently disengaging the arms **200**, **250** from the towers **300** when sliding the arms **200**, **250** toward a lower position closer to the attached anatomical structures.
(50) As described above, the arms **200**, **250** may engage rails **320** of respective towers **300** in a manner that permits the arms **200**, **250** to translate longitudinally along the respective tower **300** while firmly coupling the tower **300** to the rack **110**. However, in other embodiments, the arms **200**, **250** may be implemented to utilize different techniques and/or mechanisms to couple the tower **300** to rack **110**.
(51) For example, the arms **200**, **250** may engage the towers **300** via a male/female T-slot connection in which the arms **200**, **250** comprise a male T-shaped member that engages a female T-shaped slot of the tower **300**. Conversely, the tower **300** may comprise a male T-shaped member that engages a female T-shape slot of the arms **200**, **250**.
(52) Alternatively, the arms **200**, **250** may engage the towers **300** via a cam lock mechanism that grips an outer diameter of the towers **300**. Such a cam lock mechanism would not need to completely circumscribe the outer diameter. For example, the cam lock mechanism may comprise a cam that pulls fingers of the arms **200**, **250** toward each other to grasp the tower or rails of the tower in a manner similar to the above described fingers.
(53) In yet another embodiment, the tower **300** may include holes spaced along its longitudinal length. Actuation of a lever, button, or other mechanism of the arm **200**, **250** may control extension/retraction of pin of the arm **200**, **250**. Extension of the pin into one of the holes of the

tower **300** may restrict further translation of the arm **200**, **250** along the tower **300** until the lever, button, other mechanism is actuated to retract the pin from the hole. In a further embodiment, the arms **200**, **250** may operate as a crab clamp in which rotation of screw in a first direction may cause fingers or other members of the arms **200**, **250** to grasp the tower **300** and rotation of the screw in a second direction may cause the fingers or other members of the arms **200**, **250** to release the tower **300**.

(54) As shown in FIG. **6**, the proximal portion **260** of the second arm **250** may be pivotally coupled to its distal portion **270** via a pin **264**. In particular, the pin **264** may provide an axis of rotation that runs longitudinally through the second arm **250**. Thus, the axis of rotation provided by the pin **264** may be perpendicular to, intersect, or otherwise cross a longitudinal axis of the rack **110** when attached to the rack **110**. See, e.g., FIGS. **9** and **10**. In particular, FIG. **9** depicts the distal portions **220**, **270** of the arms **200**, **250** angled such that lower ends of their respective towers **330** are angled toward each other. Conversely, FIG. **10** depicts the distal portions **220**, **270** of the arms **200**, **250** angled such that the lower ends of their respective towers **300** are angled away from each other.

(55) Details of a pivot joint between the proximal portion **260** and distal portion **270** of the second arm **250** are shown in FIGS. **11**A-**11**E. As shown, the distal portion **270** of the arm **250** may include a track or recess **271** in a proximal surface of the distal portion **270**. The track **271** may laterally traverse the proximal surface between a first end or stop **271***a* and a second end or stop **271***b* of the track **271**. Conversely, the proximal portion **260** of the arm **250** may include a projection, member, or tab **261** that extends or protrudes from a distal surface of the proximal portion **260**. The tab **261** may engage the track **271**. In one embodiment, the distal portion **270** may rotate with respect to the proximal portion **260** of the arm **250** about the pin **264**. However, the ends **271***a*, **271***b* of the track **271** may engage the tab **261** and limit rotation to a predetermined range of rotation (e.g., ±20°, ±15°, etc.). FIGS. **11**A-**11**E depict the track **271** in the distal portion **270** and the tab **261** in the proximal portion **260**. However, in other embodiments, the distal portion **270** may have the tab and the proximal portion **260** may have the track.

(56) The pivot join of FIGS. **11**A-**11**E generally permits free rotation within the predetermined range. The pivot joint of FIGS. **12**A-**12**F depicts an alternative in which the rotation between the distal portion **270** and the proximal portion **260** may be adjusted and locked to a desired angle. To this end, an angling mechanism **240** may adjust an angle of rotation between the distal portion **270** and the proximal portion **260**. In particular, the angling mechanism **240** may include an adjustment screw **242** that passes vertically through the proximal portion **260** of the arm **250**. In the depicted embodiment, the adjustment screw **242** comprises a shaft **243** having a threaded upper portion **244** and a lower portion **245**. A bobbin **246** is coupled to the lower portion **245** of the shaft **243**. A head **247** is coupled to an upper end of the shaft **243**. Due to the threaded portion **244**, rotation of the head **247** in a first direction extends the bobbin **246** in a downward direction and rotation of the head **247** in an opposite second direction retracts the bobbin **246** in upward direction.

(57) The angling mechanism **240** further includes members or tines **248** that protrude from the distal portion **270** of the arm **250** and engage tapered surfaces **249** of the bobbin **246**. Due to such engagement, as the the bobbin **246** is moved downward due to rotation of head **247**, the distal portion **270** is rotated in a first direction with respect to the proximal portion **260** of the arm **250**. Conversely, as the the bobbin **246** is moved upward due to rotation of head **247**, the distal portion **270** is rotated in a second direction that is opposite to the first direction. Via rotation of the head **247**, a person may adjust a rotation of the distal portion **270** with respect to the proximal portion **260**.

(58) Referring now to FIGS. **13** and **14**, aspects of a pedicle screw **30** will be explained. As shown, the pedicle screw **30** may include a head **410** and a threaded shaft **420**. The head **410** may comprise a generally cylindrical base **412** coupled to a proximal end of the threaded shaft **420**. In various embodiments, the base **412** is coupled to the shaft **420** such that a longitudinal axis of the base **412** and a longitudinal axis of the shaft **420** are coaxially aligned. As such, rotation of the head **410**

about the longitudinal axis of the base **412** imparts rotation of the threaded shaft **420** about its longitudinal axis. In this manner, a distal end of the threaded shaft **420** may be driven into an anatomical structure such as a vertebrae.

(59) As further shown, the head **410** may comprise wings or tabs **414** that vertically extend above the base **412**. As shown, a lower end of each tab **414** is coupled to the base **412**. Moreover, each tab **414** includes an outer vertical surface **416** between the lower end and the upper end of the respective tab **414**. As further shown, the outer vertical surface **416** includes a hole or recess **418** which is configured to receive a detent **366** of the tower **300**.

(60) As noted above, the cantilevered fingers **333** may lock the tower **300** to the pedicle screw **30**. In general, each cantilevered finger **333** may include structures for grasping and locking to a pedicle screw **30**. Moreover, each cantilevered finger **333** may include structures that release the pedicle screw **30** in response to interactions with the removal tool **20**. In various embodiments, the fingers **333** may be implemented in a similar.

(61) As shown, the finger **333** may include a leaf spring **360**. In various embodiments, the leaf spring **360** may be integrally-formed from a side of the tower body **301**. Regardless of whether integrally-formed, the leaf spring **360** may include an upper end **362** coupled to the tower body **301** and a lower end **364** radially biased toward the bore **302** of the tower body **301**. Moreover, the lower end **364** of the leaf spring **360** comprises a detent **366** configured to engage the pedicle screw **30** and lock the tower **300** to the pedicle screw **30**. In various embodiments, the detent **366** is tapered such that the detent **366** gradually slopes from its lower end to its upper end inward toward the bore **302**. Such gradual slope may permit a pedicle screw **30** received via the lower end of the tower **300** to press against the sloped surface and overcome the biasing force of the leaf spring **360**. Conversely, the detent **366** may provide an upper end with an abrupt transition between a base of the detent **366** and a distal end. Such abrupt surface may prevent a pedicle screw **30** from overcoming the bias force of the leaf spring **360** when pressed against the abrupt surface through an attempt to extract the pedicle screw **30** from the tower **300**.

(62) As noted above, the leaf spring **360** biases the lower end **364** and its detent **366** toward the bore **302**. As such, when the lower end of the tower **300** is placed over the head **410** of the pedicle screw **30**, the tabs **414** may overcome the bias of the leaf spring **360** and force the lower end **364** away from the bore **302**. Once the recess **418** aligns with a detent **366**, the leaf spring **360** may move or snap the detent **366** back toward the bore **302** and into the recess **418**. Such snapping may be felt and heard by the person attaching the tower **300** to the pedicle screw **30**. Thus, the leaf spring **360** and detent **366** may provide both audible and tactile feedback regarding a proper coupling of the tower **300** to the pedicle screw **30**.

(63) The pedicle screw **30** is depicted with two opposing tabs **414**. However, various embodiments of the pedicle screw **30** may include a different number of tabs **414** and/or recesses **418**. For example, the head **410** may include a single tab **414** that circumscribes or mostly circumscribes the head **410**. Such a single tab **414** may include one or more recesses **418** to capture retaining detents **366** of the tower **300**. Furthermore, while the head **410** is depicted with two recesses **418** positioned to receive corresponding detents **366** of the tower **300**, some embodiments may not have a one-to-one correspondence between recesses **418** and detents **366**. For example, the head **410** may include a greater number of recesses **418** so as to permit locking the tower **300** to the pedicle screw **30** via multiple orientations.

(64) As explained above, a person may effectively snap the tower **300** onto the pedicle screw **30** without the aid of a tool. However, due to the abrupt upper surfaces of the detents **366**, a person may not simply snap the tower **300** off the pedicle screw **30** once attached. Instead, in various embodiments, a person uses a removal tool **20** to disengage the detents **366** from the pedicle screw **30** in order to remove the tower **300** from the pedicle screw **30**. As shown in FIGS. **15**A-**15**E, the removal tool **20** may include a handle **500** and a shaft **510**. The shaft **510** may include an upper end coupled to the handle **500**. The shaft **510** may further include a keyed lower end **520**. Furthermore,

the removal tool **20** may include a shoulder **530** toward the upper end of the shaft **510**.

(65) During removal, the removal tool **20** may be positioned above the tower **300** as shown in FIG. **15**A and inserted into the bore **302** of the tower **300** as shown in FIG. **15**B. The removal tool **20** may be further inserted into the bore **302** until the shoulder **530** engages an upper surface of the tower **300** as shown in FIG. **15**C. In various embodiments, the shoulder **530** is positioned along the shaft **510** such that the keyed lower end **520** is properly positioned within the bore **302** when the shoulder **530** engages the upper surface of the tower **300**.

(66) Once properly seated, the handle **500** may be rotated in order to rotate the keyed lower end **520** as shown in FIGS. **15**D, **16**B, **18**. As shown in FIGS. **16**B and **18**, the keyed lower end **520** may engage the leaf springs **360** and force them radially outward from the bore **302** of the tower **300**. Such outward movement of the leaf springs **360** may disengage the detents **366** from the recesses **418** of the pedicle screw **30**. With the recesses **418** disengaged, the tower **300** along with the removal tool **20** may be removed from the pedicle screw **30** as shown in FIGS. **15**E and **16**C.

(67) In various embodiments, the tower **300** may include stops **370** that prevent rotation of the keyed lower end **520** in a clockwise direction and grooves **372** that permit rotation of the keyed lower end **520** in counterclockwise direction. See, e.g., FIGS. **17** and **18**. Moreover, the tower **300** may include stops **374** that prevent over rotation of the removal tool **20** passed the desired 90° rotation.

(68) Referring now to FIGS. **19** and **20**, counter torque tools **600** coupled to towers **300** are shown. As shown, each counter torque tool **600** may include a handle **610** that extends from a connector **620**. The connector **620** may include a recess **622** shaped to mate with an upper end of the tower **300**. In particular, the recess **622** may have fingers **624** that engage rails **320** of the tower **300**. Due to such engagement of rails **320**, rotation of the tower **300** about its longitudinal axis translates into rotation of the handle **610** via its connector **620**. Thus, a person may prevent rotation of the tower **300** by holding the handle **610** in a stationary position and/or applying a proper counter torque to the handle **610** of the counter torque tool **600**. For example, a person may provide a proper counter torque to the tower **300** via tool **600** to prevent rotation of the tower **300** about its longitudinal axis when tightening a pedicle screw **30** to which the tower **300** is attached.

(69) As further shown, a sidewall of the connector **620** may not completely circumscribe the tower **300**. The opening **630** in the sidewall may permit viewing the upper end of the tower **300** while coupling the counter torque tool **600** to the tower **300**. Such viewing may aid when trying to properly aligning the connector **620** with the upper end of the tower **300**. However, in some embodiments, the connector **620** may be implemented without opening **630**.

(70) Moreover, FIGS. **19-20** depicted two counter torque tools **600** which appear to have different offsets of the handle **610** with respect to the connector **620**. However, per an embodiment, the two counter torque tools **600** are implemented in the same manner. The depicted difference between the two counter torque tools **600** is due to one being vertically flipped with respect to the other. In other words, the counter torque tool **600** coupled to the left-side tower **300** may be coupled to the right-side tower **300** in the same depicted configuration by merely flipping the tool **600** over. Thus, in one embodiment, there is not a right side tool and a left side tool, but a single tool that is suitable for engaging either tower **300**.

(71) Finally, as shown in FIGS. **21-23**, towers may include a plurality of tracks **305**. As shown, towers **300′** of FIGS. **21-23** may be implemented in the same manner as the towers **300** of FIG. **1**, but may include a second track **305** opposite the track **305**. The second track **305** may permit attaching various accessories to the towers **300′**. In FIGS. **21** and **22**, an additional rack **110** and arms **200**, **250** are attached to the towers **300′** via the second tracks **305**. Moreover, as shown, retractor blades may be attached to the racks **110** at locations that are laterally between attachment points of the arms **200**, **250**. However, tracks **305** are not limited to merely the attachment of additional racks **110**. Other accessories such as lights, smoke evacuation, retractor blades, etc. may be attached to towers **300′** via their respective second tracks **305**.

(72) While the present invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present invention without departing from its scope. Therefore, it is intended that the present invention not be limited to the particular embodiment or embodiments disclosed, but that the present invention encompasses all embodiments falling within the scope of the appended claims.

Claims

1. A surgical instrument, comprising: a rack comprising a rail having a rail first end and a rail second end; a first arm comprising a first arm proximal end, a first arm distal end, a first arm top side that extends from the first arm proximal end to the first arm distal end, a first arm bottom side that extends from the first arm proximal end to the first arm distal end, and a first arm channel in the first arm distal end, wherein the first arm proximal end is coupled to the rail toward the rail first end, and wherein the first arm channel passes through the first arm top side and the first arm bottom side; a second arm coupled to the rack via a second arm carriage, wherein the second arm carriage is configured to move the second arm along the rack; a spring-biased stop toward the rail second end, wherein a biasing force of the spring-biased stop is sufficient to prevent the second arm carriage from moving past the spring-biased stop based on a first force applied by weight of the second arm carriage but permits the second arm carriage to move past the spring-biased stop based on a second force that is greater than the first force; and a first tower comprising a first tower upper end, a first tower lower end, and a first tower track between the first tower upper end and the first tower lower end; wherein the first arm channel is configured to receive the first tower track and selectively position the first arm distal end along the first tower track; and wherein the first arm channel permits passage of the first tower into an upper end of the first arm channel, along the first arm channel, and out a lower end of the first arm channel such that the first tower track extends below the first arm bottom side.
2. The surgical instrument of claim 1, wherein the first tower lower end is configured to engage and snap onto a pedicle screw.
3. The surgical instrument of claim 2, wherein: the first tower comprises a bore that runs longitudinally between the first tower upper end and the first tower lower end; and the first tower is configured to disengage from the pedicle screw in response to a tool inserted into the bore of the first tower.
4. The surgical instrument of claim 2, wherein: the first tower comprises a bore that runs longitudinally between the first tower upper end and the first tower lower end; and the first tower is configured to disengage from the pedicle screw in response to rotation of a tool inserted into the bore of the first tower.
5. The surgical instrument of claim 1, wherein the first tower comprises a detent configured to secure a pedicle screw to the first tower when the pedicle screw is inserted into the first tower lower end.
6. The surgical instrument of claim 1, wherein: the first tower includes a detent and a spring, wherein the spring applies a biasing force that biases the detent radially inward; and the detent and the spring are configured to permit a pedicle screw to overcome the biasing force and move the detent radially outward as the pedicle screw is inserted into the first tower lower end.
7. The surgical instrument of claim 6, wherein the detent and the spring are configured to prevent the pedicle screw from overcoming the biasing force and moving the detent radially outward and out of a recess in the pedicle screw.
8. The surgical instrument of claim 1, wherein the second arm carriage comprises a pinion having teeth that engage teeth of the rack and move the second arm carriage along the rack based on

rotation of the pinion.
9. The surgical instrument of claim 8, wherein: the second arm carriage comprises a lever and a pawl; the lever selectively engages the pawl with the teeth of the rack; and the pawl, when engaged with the teeth of the rack, permits movement of the second arm carriage along the rack in a first direction but prevents movement of the second arm carriage along the rack in a second direction.
10. The surgical instrument of claim 1, wherein: the first arm comprises a first arm proximal portion, a first arm distal portion, a first arm pivot joint that couples a proximal end of the first arm distal portion to a distal end of the first arm proximal portion; and the first arm pivot joint permits rotation of the first arm distal portion about a first arm pivot axis that extends through the proximal end of the first arm distal portion and the distal end of the first arm proximal portion.
11. The surgical instrument of claim 10, wherein the first arm comprises one or more stops that limit rotation of the first arm distal portion about the first arm pivot axis.
12. The surgical instrument of claim 1, wherein the first tower comprises a first tower second track between the first tower upper end and the first tower lower end.
13. The surgical instrument of claim 12, comprising: a third arm comprising a third arm proximal end and a third arm distal end; wherein the third arm distal end comprises a third arm channel; and wherein the third arm channel is configured to receive the first tower second track and selectively position the third arm distal end along the first tower second track.
14. The surgical instrument of claim 12, comprising an accessory coupled to the first tower second track and configured to selectively position the accessory along the first tower second track.
15. A system, comprising: a removal tool comprising a handle and a shaft, wherein the shaft comprises an upper end coupled to the handle and a keyed lower end; and a surgical instrument comprising a rack comprising a rail having a rail first end and a rail second end, a first arm coupled to the rack, a second arm coupled to the rack via a second arm carriage, a spring-biased stop toward the rail second end, a first tower coupled to the first arm, and a second tower coupled to the second arm; wherein the first arm comprises a first arm proximal end, a first arm distal end, a first arm top side that extends from the first arm proximal end to the first arm distal end, a first arm bottom side that extends from the first arm proximal end to the first arm distal end, and a first arm channel in the first arm distal end, wherein the first arm channel passes through the first arm top side and the first arm bottom side; wherein the first tower comprises a first tower upper end, a first tower lower end, and a first tower track comprising a first tower track upper end and a first tower track lower end between the first tower upper end and the first tower lower end; wherein the first arm channel is configured to receive the first tower track and selectively position the first arm distal end along the first tower track; wherein the first arm channel permits passage of the first tower track lower end into an upper end of the first arm channel, along the first arm channel, and out a lower end of the first arm channel such that the first tower track lower end extends below the first arm bottom side; and wherein the first tower lower end is configured to directly engage a pedicle screw and is configured to disengage from the pedicle screw in response to the removal tool being inserted into the first tower; wherein the second arm carriage is configured to move the second arm along the rack; and wherein a biasing force of the spring-biased stop is sufficient to prevent the second arm carriage from moving past the spring-biased stop based on a first force applied by weight of the second arm carriage but permits the second arm carriage to move past the spring-biased stop based on a second force that is greater than the first force.
16. The system of claim 15, wherein: the first tower comprises a bore that runs longitudinally between the first tower upper end and the first tower lower end; and the first tower is configured to disengage from the pedicle screw in response to the removal tool being inserted into the bore of the first tower.
17. The system of claim 15, wherein: the first tower comprises a bore that runs longitudinally between the first tower upper end and the first tower lower end; and the first tower is configured to disengage from the pedicle screw in response to rotation of the removal tool in the bore of the first

tower.

18. The system of claim 17, wherein the removal tool comprises a shoulder positioned between the handle and the keyed lower end such that the keyed lower end of the removal tool is aligned with a keyed surface of the first tower when the shoulder engages an upper surface of the first tower and prevents further insertion of the removal tool into the bore.

19. The system of claim 18, wherein the keyed surface of the first tower and the keyed lower end cooperate to permit rotation of the removal tool in a first direction and prevent rotation of the removal tool in a second direction.

20. The system of claim 19, wherein the keyed surface comprises a stop that prevents rotation of the removal tool in the first direction beyond a screw removal position.

21. The system of claim 15, wherein the first tower comprises a detent configured to secure the pedicle screw to the first tower when the pedicle screw is inserted into the first tower lower end.

22. The system of claim 15, wherein: the first tower includes a detent and spring that applies a biasing force that biases the detent radially inward; and the detent is configured to permit the pedicle screw to overcome the biasing force and move the detent radially outward as the pedicle screw is inserted into the first tower lower end.

23. The system of claim 22, wherein the detent is configured to prevent the pedicle screw from overcoming the biasing force and moving the detent radially outward and out of a recess in the pedicle screw.

24. The system of claim 15, wherein the second arm carriage comprises a pinion having teeth that engage teeth of the rack and move the second arm carriage along the rack based on rotation of the pinion.

25. The system of claim 24, wherein: the second arm carriage comprises a lever and a pawl; the lever selectively engages the pawl with the teeth of the rack; and the pawl, when engaged with the teeth of the rack, permits movement of the second arm carriage along the rack in a first direction but prevents movement of the second arm carriage along the rack in a second direction.

26. The system of claim 15, comprising: a counter torque tool comprising a handle that extends from a connector; wherein the connector is configured to detachably couple the handle to the first tower and translate rotation of the first tower about a longitudinal axis of the first tower to the handle; and wherein the handle of the counter torque tool, when held in a stationary position while coupled to the first tower, prevents rotation of the first tower about the longitudinal axis.

27. A surgical instrument, comprising: a rack comprising a rail having a rail first end and a rail second end; a first tower comprising a first tower upper end, a first tower lower end, and a first tower track between the first tower upper end and the first tower lower end, wherein the first tower lower end is configured to engage and secure a pedicle screw to the first tower; and a first arm comprising a first arm proximal end, a first arm distal end, a first arm top side that extends from the first arm proximal end to the first arm distal end, and a first arm bottom side that extends from the first arm proximal end to the first arm distal end; a second arm coupled to the rack via a second arm carriage, wherein the second arm carriage is configured to move the second arm along the rack; and a spring-biased stop toward the rail second end; wherein a biasing force of the spring-biased stop is sufficient to prevent the second arm carriage from moving past the spring-biased stop based on a first force applied by weight of the second arm carriage but permits the second arm carriage to move past the spring-biased stop based on a second force that is greater than the first force; wherein a length of the first tower track between the first tower upper end and the first tower lower end is greater than a distance between the first arm top side and the first arm bottom side at the first arm distal end; and wherein the first arm distal end is configured to engage the first tower track and selectively position the first tower along the first arm distal end between the first tower upper end and the first tower lower end such that the first tower lower end protrudes beyond the first arm bottom side.

28. The surgical instrument of claim 27, wherein: the first tower comprises a bore that runs

longitudinally between the first tower upper end and the first tower lower end; and the first tower is configured to disengage from the pedicle screw in response to a tool inserted into the bore of the first tower.

29. The surgical instrument of claim 27, wherein: the first tower includes a detent and a spring, wherein the spring applies a biasing force that biases the detent radially inward; and the detent and the spring are configured to permit a pedicle screw to overcome the biasing force and move the detent radially outward as the pedicle screw is inserted into the first tower lower end.

30. The surgical instrument of claim 29, wherein the detent and the spring are configured to prevent the pedicle screw from overcoming the biasing force and moving the detent radially outward and out of a recess in the pedicle screw.