United States Patent	12392370
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Smith; Keanan R.

Selectively lockable ball and socket joint

Abstract

A ball and socket joint assembly is disclosed that includes a body defining a cavity, a collet disposed in the cavity to receive a ball of a connector, and an actuator shaft coupled to the collet for rotating and translating the collet in the cavity. The cavity has a distal opening to accept the ball and an engagement feature extending into the cavity. The collet has an outer diameter larger than the opening in the body when the ball is disposed in the collet, and the collet has a corresponding engagement feature around at least a portion of the outer surface for receiving the engagement feature and converting rotation of the compression member into translation of the compression member along a proximal-distal axis of the body. The collet is compressed against the opening of the cavity when the collet is advanced distally against the opening.

Inventors: **Smith; Keanan R. (Quincy, MA)**

Applicant: **Medos International Sarl** (Le Locle, CH)

Family ID: **1000008765618**

Assignee: **Medos International Sàrl (Le Locle, CH)**

Appl. No.: **18/748955**

Filed: **June 20, 2024**

Prior Publication Data

Document Identifier	Publication Date
US 20240344554 A1	Oct. 17, 2024

Related U.S. Application Data

continuation parent-doc US 18314134 20230509 US 12038041 child-doc US 18748955
continuation parent-doc US 17548273 20211210 US 11668340 20230606 child-doc US 18314134
continuation parent-doc US 16698433 20191127 US 11204060 20211221 child-doc US 17548273

Publication Classification

Int. Cl.: **F16C11/10** (20060101)

U.S. Cl.:

CPC **F16C11/106** (20130101); F16C2316/10 (20130101)

Field of Classification Search

CPC: Y10T (403/32762); Y10T (403/32737); F16C (11/06); F16C (11/0604); F16C (11/0642); F16C (11/0652); F16C (11/106)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
4874375	12/1988	Ellison	N/A	N/A
5728046	12/1997	Mayer et al.	N/A	N/A
5876332	12/1998	Looney	N/A	N/A
5899627	12/1998	Dobrovolny	N/A	N/A
5931777	12/1998	Sava	N/A	N/A
5944658	12/1998	Koros et al.	N/A	N/A
6083154	12/1999	Liu et al.	N/A	N/A
6234961	12/2000	Gray	N/A	N/A
6254532	12/2000	Paolitto et al.	N/A	N/A
6322500	12/2000	Sikora et al.	N/A	N/A
6602190	12/2002	Dobrovolny	N/A	N/A
6951538	12/2004	Ritland	N/A	N/A
7179261	12/2006	Sicvol et al.	N/A	N/A
7491168	12/2008	Raymond et al.	N/A	N/A
7611460	12/2008	Dobrovolny	N/A	N/A
7918792	12/2010	Drzyzga et al.	N/A	N/A
7959564	12/2010	Ritland	N/A	N/A
8162827	12/2011	Abdelgany et al.	N/A	N/A
8202216	12/2011	Melkent et al.	N/A	N/A
8394109	12/2012	Hutton et al.	N/A	N/A
8409087	12/2012	Ames et al.	N/A	N/A
8469960	12/2012	Hutton et al.	N/A	N/A
8535320	12/2012	Woolley et al.	N/A	N/A
8636655	12/2013	Childs	N/A	N/A
8668715	12/2013	Sandhu	N/A	N/A
8715175	12/2013	Assaker et al.	N/A	N/A
8882661	12/2013	Hutton et al.	N/A	N/A
8894573	12/2013	Loftus et al.	N/A	N/A
8911442	12/2013	Wing et al.	N/A	N/A
8974381	12/2014	Lovell et al.	N/A	N/A
9050146	12/2014	Woolley et al.	N/A	N/A
9078635	12/2014	Menendez et al.	N/A	N/A

9216016	12/2014	Fiechter et al.	N/A	N/A
9307972	12/2015	Lovell et al.	N/A	N/A
9386971	12/2015	Casey et al.	N/A	N/A
9414828	12/2015	Abidin et al.	N/A	N/A
9545250	12/2016	Pfabe et al.	N/A	N/A
9572560	12/2016	Mast et al.	N/A	N/A
9649099	12/2016	Casey et al.	N/A	N/A
9693762	12/2016	Reimels	N/A	N/A
9700293	12/2016	Cryder et al.	N/A	N/A
9801667	12/2016	Hawkes et al.	N/A	N/A
9844400	12/2016	Stevenson et al.	N/A	N/A
9907583	12/2017	Hayes	N/A	N/A
9962147	12/2017	Casey	N/A	N/A
10076320	12/2017	Mast et al.	N/A	N/A
10463402	12/2018	Biester et al.	N/A	N/A
10792168	12/2019	Malcolmson et al.	N/A	N/A
11204060	12/2020	Smith	N/A	F16C 11/106
11668340	12/2022	Smith	N/A	N/A
12038041	12/2023	Smith	N/A	N/A
2005/0131408	12/2004	Sicvol et al.	N/A	N/A
2005/0228400	12/2004	Chao et al.	N/A	N/A
2005/0245929	12/2004	Winslow et al.	N/A	N/A
2006/0052671	12/2005	McCarthy	N/A	N/A
2007/0093823	12/2006	Booth et al.	N/A	N/A
2007/0213715	12/2006	Bridwell et al.	N/A	N/A
2008/0021285	12/2007	Drzyzga et al.	N/A	N/A
2009/0093684	12/2008	Schorer	N/A	N/A
2009/0105547	12/2008	Vayser et al.	N/A	N/A
2009/0149885	12/2008	Durward et al.	N/A	N/A
2009/0187080	12/2008	Seex	N/A	N/A
2009/0216087	12/2008	Bjork	N/A	N/A
2009/0254187	12/2008	Bjork	N/A	N/A
2010/0160975	12/2009	Biedermann et al.	N/A	N/A
2010/0317928	12/2009	Subramaniam	N/A	N/A
2011/0004248	12/2010	Abdou	N/A	N/A
2011/0034779	12/2010	Louftus et al.	N/A	N/A
2011/0137345	12/2010	Stoll et al.	N/A	N/A
2012/0089150	12/2011	Smith	N/A	N/A
2012/0179211	12/2011	Biedermann et al.	N/A	N/A
2012/0232350	12/2011	Seex	N/A	N/A
2014/0074166	12/2013	Scarrow et al.	N/A	N/A
2014/0194697	12/2013	Seex	N/A	N/A
2014/0277163	12/2013	Kretzer et al.	N/A	N/A
2014/0296917	12/2013	Donner et al.	N/A	N/A
2015/0148853	12/2014	Hawkes et al.	N/A	N/A
2015/0313585	12/2014	Abidin et al.	N/A	N/A
2016/0074029	12/2015	O'Connell et al.	N/A	N/A
2016/0106408	12/2015	Ponmudi et al.	N/A	N/A
2016/0296220	12/2015	Mast et al.	N/A	N/A
2016/0354073	12/2015	Nel et al.	N/A	N/A

2017/0014117	12/2016	Capote	N/A	N/A
2017/0014118	12/2016	Capote	N/A	N/A
2017/0014119	12/2016	Capote et al.	N/A	N/A
2017/0105770	12/2016	Woolley et al.	N/A	N/A
2017/0135735	12/2016	Hawkes et al.	N/A	N/A
2018/0116758	12/2017	Schlosser et al.	N/A	N/A
2018/0303473	12/2017	Spann et al.	N/A	N/A
2019/0090864	12/2018	Medeiros et al.	N/A	N/A
2019/0090979	12/2018	Medeiros et al.	N/A	N/A
2021/0156418	12/2020	Smith	N/A	N/A
2022/0099137	12/2021	Smith	N/A	N/A
2023/0272818	12/2022	Smith	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2010121291	12/2009	WO	N/A
2016131077	12/2015	WO	N/A

OTHER PUBLICATIONS

U.S. Appl. No. 16/698,433, filed Nov. 27, 2019, Selectively Lockable Ball and Socket Joint, Medos International Sàrl. cited by applicant
U.S. Appl. No. 17/548,273, filed Dec. 10, 2021, Selectively Lockable Ball and Socket Joint, Medos International Sàrl. cited by applicant
U.S. Appl. No. 18/314,134, filed May 9, 2023, Selectively Lockable Ball and Socket Joint, Medos International Sàrl. cited by applicant
[No Author Listed] MIT Lateral Platform, “Surgical Technique Guide,” DePuy Spine Inc., 2012. cited by applicant
[No Author Listed] [No Date Given] “NuVasive MAS TLIF Surgical Technique,” (25 pages). cited by applicant
[No Author Listed] “NuVasive MAS TLIF 2 Surgical Technique,” NuVasive Inc., 2016 (48 pages). cited by applicant
[No. Author Listed] Pipeline Access System and CONCORDE, “Surgical Technique—Guide and Protect Catalogue,” DePuy Spine Inc., 2011. cited by applicant

---

Primary Examiner: Wiley; Daniel J

Attorney, Agent or Firm: Barnes & Thornburg LLP

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. application Ser. No. 18/314,134, filed May 9, 2023. U.S. application Ser. No. 18/314,134 is a continuation of U.S. application Ser. No. 17/548,273, filed Dec. 10, 2021, and now issued as U.S. Pat. No. 11,668,340. U.S. application Ser. No. 17/548,273 is a continuation of U.S. application Ser. No. 16/698,433, filed Nov. 27, 2019, and now issued as U.S. Pat. No. 11,204,060. The entire contents of each of these applications is incorporated by reference herein.

FIELD
(1) This disclosure relates generally to surgical instruments, systems, and methods, and more particularly to instruments, systems, and methods including a ball and socket joint with a quick-

locking and quick-releasing mechanism. Such instruments, systems, and methods can be used in various procedures, e.g., orthopedic or neurologic surgical procedures such as spinal fusion surgery.

BACKGROUND

(2) Surgical procedures are used to treat and cure a wide range of diseases, conditions, and injuries. Surgery often requires access to internal tissue through open or minimally invasive surgical procedures. The term “minimally invasive” refers to all types of minimally invasive surgical procedures, including endoscopic, laparoscopic, arthroscopic, natural orifice intraluminal, and natural orifice transluminal procedures. Minimally invasive surgery can have numerous advantages compared to traditional open surgical procedures, including reduced trauma, faster recovery, reduced risk of infection, and reduced scarring.

(3) Whether minimally invasive or not, there are a number of surgical procedures in which it can be desirable to form a working channel in a patient to provide access to a surgical site within the patient. One such example is orthopedic or neurologic surgical procedures, including, e.g., spinal fusion procedures where it can be desirable to form a working channel through a patient's tissue to access their vertebrae and/or the intervertebral discs disposed between adjacent vertebrae.

(4) A variety of methods for providing such a working channel are known, including various devices that are anchored to a surgical table upon which a patient is disposed, devices that penetrate tissue without being anchored to any other structure, or devices that anchor to one or more anchors implanted in a patient's bone. In some arrangements a modular tissue retractor system can be employed in which one or more tissue retracting implements can be selectively coupled to a modular retractor body that is itself coupled to, for example, an implanted bone anchor.

(5) Prior mechanisms for permitting polyaxial adjustment of tissue retracting implements relative to the retractor body can present challenges. For example, in some arrangements an expandable element coupled to the tissue retractor implement can be received within a socket formed in the retractor body. Such an arrangement can permit adjustment of the expandable element relative to the socket and selective locking of a particular orientation by actuation of the expandable element to interface with the walls of the socket. Actuation of the expandable element can be by rotation of a screw in some cases, and this can present challenges in that multiple rotations of the screw can be required to achieve acceptable locking levels that resist the forces imparted to the tissue retracting implements by abutting tissue. Further, in some cases the actuating screw can be coupled to the tissue retracting implement, such that a user might move the implement during actuation. Still further, operation of such an arrangement can be complex, e.g., actuation of the screw can be required to achieve any degree of locking, even provisional locking force that still allows some adjustment of tissue retracting implement positioning by a user.

(6) Accordingly, there is a need for improved access devices, systems, and methods that can streamline the instrumentation and methodology of various surgical procedures. For example, there is a need for improved polyaxial restraint and locking of components of surgical retractor assemblies. Additionally, there is a need for locking assemblies that both enable easy assembly and polyaxial retention of retractor components while achieving acceptable lockout levels with simple operation.

SUMMARY

(7) Surgical instruments, systems, and methods are disclosed herein that provide improved polyaxial restraint and locking of components of surgical retractor assemblies. For example, the embodiments described herein provide selectively lockable ball-and-socket joints that can be used to couple, for example, tissue retracting implements to modular retractor bodies. The embodiments described herein can provide a number of advantages over prior approaches. This can include, for example, the ability to quickly couple and decouple tissue retracting implements to a retractor body, the ability to impart a provisional locking or drag force to a coupled tissue retracting implement without requiring actuation of a locking element, e.g., a screw, and ability to achieve selective locking with sufficient locking strength with minimum movement, e.g., less than one

rotation of a locking actuator.
(8) In one aspect a ball and socket joint assembly includes a body defining a cavity and a distal opening to the cavity, a compression member disposed in the cavity, and an actuator shaft extending through a proximal end of the housing, the actuator shaft coupled to the compression member and permitting rotation and translation of the compression member in the cavity.
(9) The distal opening can have a diameter larger than a diameter of a spherical portion of a connector and less than a diameter of an inner wall of the cavity proximal to the opening. The body can include an engagement feature extending into the cavity. A distal end of the compression member can include a collet configured to accept the spherical portion of the connector, and the collet can define an outer diameter that is configured to be larger than the diameter of the opening in the body when the spherical portion is disposed in the collet. The compression member can include an outer surface defining a corresponding engagement feature around at least a portion of the outer surface for receiving the engagement feature of the body for converting rotation of the compression member into translation of the compression member along a longitudinal axis of the body. The collet can be configured to be compressed against the opening of the cavity when the receiver is advanced distally against the opening.
(10) In some instances, after inserting the spherical portion of the connector into the collet, rotation of the actuator shaft in a first direction rotates the compression member and engagement between the engagement feature and the locking channel advances the compression member distally, and, when advanced distally, the collet engages the opening of the cavity and locks the collet about the spherical portion. The cavity can define an outwardly tapered inner wall region extending proximally from the distal opening.
(11) A distal end of the collet can define a plurality of resilient fingers each having a tapered exterior surface configured to interface with the outwardly tapered inner wall region of the cavity when the receiver is advanced distally such that the outwardly tapered inner wall region constricts the plurality of resilient fingers.
(12) The engagement feature can be a cam pin and the corresponding engagement feature can include an angled locking channel sized and shaped to receive the cam pin. The angled locking channel can define a variable pitch to provide a variable mechanical advantage during rotation of the compression member with respect to the cam pin, when the cam pin is disposed in the angled locking channel.
(13) The outer surface of the compression member can include an axial channel for receiving the cam pin and allowing the compression member to translate freely along the proximal-distal axis in the cavity, and the locking channel can extend from the axial channel and be angled proximally from the axial channel.
(14) The assembly can include a spring disposed in the housing, the spring being coupled to the body and the receiving member for biasing the compression member towards the distal opening. In some instances, the spring is configured to urge the collet against the distal opening and impart a drag force on the spherical portion for resisting polyaxial movement of the spherical portion about the collet. The spring can be configured to urge the collet against the distal opening and impart a retaining force on the spherical portion.
(15) In some instances, the engagement feature includes a threaded portion of the inner wall of the cavity, and the angled locking channel includes a corresponding threaded portion of the outer wall of the compression member, where the compression member is in threaded engagement with the body.
(16) The collet can be configured to passively secure the spherical portion of the connector without engaging the opening of the body. In some instances, the collet is configured to extend distally beyond a maximum diameter location of the spherical portion of the connector. In some instances, the collet defines a distal opening having an inner diameter less than a maximum inner diameter of the collet. In some instances, the collet includes a central through-hole adapted to receive the

actuator shaft.
(17) Another example of the present disclosure is a surgical instrument having a retractor body configured to couple to an implantable anchor, with the retractor body including a first connector and a second connector each having a spherical portion, a first tissue manipulating implement coupled to the first connector of the retractor body and capable of polyaxial movement relative thereto, and a second tissue manipulating implement coupled to the second connector retractor body and capable of polyaxial movement relative thereto. Where each of the first and second tissue manipulating implements couples to the corresponding connector via a ball and socket joint assembly having aspects of the present disclosure, where each tissue manipulating implement includes the body of the ball and socket joint assembly. In some instances, the connector includes an extension post coupled to the retractor body. In some instances, the extension post pivots relative to the body.
(18) Yet another example of the present disclosure is a method of assembling a surgical instrument including inserting a spherical portion of a connector into a collet of a compression member disposed within a cavity of a body, the connector being attached to an arm of a surgical retractor, the ball-shaped end passing through a distal opening to the cavity that has a diameter larger than a diameter of a spherical portion of a connector and less than a diameter of an inner wall of the cavity proximal to the opening, rotating an actuator shaft that is coupled to the compression member in a first direction, the actuator shaft rotating the compression member with respect to an engagement feature of the body that extends into the cavity, the engagement feature interfacing with the compression member such that the rotation of the compression member urges the compression member distally in the cavity, and continuing to rotate the actuator shaft until an outer surface of the collet is compressed against the opening of the cavity and an inner surface of the collet is compressed around the spherical portion to retain the spherical portion in the collet.
(19) In some instances, inserting the spherical portion into the collet includes urging the compression member proximally against a spring force, where the spring force urges the compression member distally towards the opening after the inserting. In some instances, the spring force urges the collet distally against the distal opening and imparts a provisional retaining force to the spherical portion. In some instances, the provisional retaining force serves to impart a drag force on the spherical portion to resist polyaxial movement of the spherical portion about the collet.
(20) Rotating the actuator shaft can include threading the compression member inside the cavity. In some instances, continuing to rotate the actuator shaft includes adjusting a degree of frictional resistance to polyaxial movement of the spherical portion in the collet. In some instances, the method further includes rotating the actuator shaft in a second direction to urge the compression member proximally in the cavity until the spherical portion can be removed from the collet and pass through the opening of the cavity.
(21) Any of the features or variations described above can be applied to any particular aspect or embodiment of the present disclosure in a number of different combinations. The absence of explicit recitation of any particular combination is due solely to the avoidance of repetition in this summary.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) This disclosure will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:
(2) FIG. **1** is an illustration of one embodiment of a surgical instrument assembly according to the teachings provided herein;
(3) FIG. **2** is a detail view of a retractor of the assembly of FIG. **1**;

(4) FIG. **3** is an exploded view of the assembly of FIG. **1**;
(5) FIG. **4** is an exploded view of the retractor of FIG. **2**;
(6) FIG. **5**A is a partially-transparent detail view of one embodiment of a selectively lockable ball and socket joint assembly representing an alternate design for the polyaxial joints of the retractor of FIG. **2**;
(7) FIG. **5**B is a partially-transparent detail view of the ball and socket joint assembly of FIG. **5**A, showing the ball connector coupled to a collet of the assembly;
(8) FIG. **6** is a cross-sectional view of the ball and socket assembly of FIGS. **5**A and **5**B;
(9) FIG. **7**A is a partially-transparent detail view of the ball and socket joint assembly of FIGS. **5**A and **5**B showing the initiation of a locking operation;
(10) FIG. **7**B is a partially-transparent detail view of the ball and socket joint assembly of FIG. **7**B illustrating the assembly in a locked position;
(11) FIG. **7**C is an illustration of the angled channel of FIGS. **7**A and **7**B having a straight section;
(12) FIG. **7**D is an illustration of the angled channel of FIGS. **7**A and **7**B having a divot;
(13) FIG. **8** is a perspective view of the of the polyaxial joint assembly of FIGS. **5**A and **5**B;
(14) FIG. **9**A is an illustration of one embodiment of a retractor body and tissue retracting implements of a surgical instrument assembly being connected by embodiments of the ball and socket joints disclosed herein; and
(15) FIG. **9**B is an illustration of another embodiment of a retractor body and tissue retracting implements of a surgical instrument assembly being connected by embodiments of the ball and socket joints disclosed herein.

DETAILED DESCRIPTION

(16) Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those skilled in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the present disclosure is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present disclosure.
(17) Additionally, to the extent that linear or circular dimensions are used in the description of the disclosed devices and methods, such dimensions are not intended to limit the types of shapes that can be used in conjunction with such devices and methods. Equivalents to such linear and circular dimensions can be determined for any geometric shape. Further, in the present disclosure, like-numbered components of the embodiments generally have similar features. Still further, sizes and shapes of the devices, and the components thereof, can depend at least on the anatomy of the subject in which the devices will be used, the size and shape of components with which the devices will be used, and the methods and procedures in which the devices will be used.
(18) FIGS. **1-4** illustrate an exemplary surgical instrument assembly **100** according to the teachings provided herein. The assembly **100** can be used in various surgical procedures, including spinal surgeries such as microsurgical bone resection, spinal decompression, spinal fusion, and the like. In general, the assembly **100** can include a support instrument **102** that couples to an implanted anchor **104**, such as a pedicle or other bone screw. The assembly **100** can further include a retractor **106** coupled to the support instrument **102**. Other components not illustrated here can be included or coupled to the assembly **100**. Such components can include, for example, any of a variety of cameras or visualization systems, and any of a variety of other surgical instruments.
(19) An exemplary method of using the assembly **100** of FIGS. **1-4** can include any one or more of the following steps, performed in any of a variety of sequences: a) making an incision in a skin of a patient; b) percutaneously inserting through the incision an implantable anchor, such as a pedicle or

other bone screw; c) coupling the support instrument **102** to the implanted anchor (e.g., a pedicle anchor); d) coupling a tissue retractor to the instrument; e) providing medial-lateral retraction of tissue surrounding an incision; f) coupling an optical visualization instrument to the tissue retractor and/or instrument; g) resecting a portion of the superior articular process, and/or performing a microsurgical decompression procedure; h) extracting intervertebral disc material including removing cartilaginous material from the vertebral endplates; i) inserting an interbody device; and j) deploying a mechanism of stabilization to stabilize the intervertebral segment.

(20) The above described retractor assembly **106**, in combination with the support instrument or anchor extension **102** and implanted anchor **104**, can be used to, for example, widen an incision formed in a patient's skin and tissue to enable better access to a surgical site. By way of further example, in some embodiments these components can form an assembly that is anchored to a single implanted screw or anchor and provides medial-lateral tissue retraction to increase access for a variety of surgical procedures. Medially and laterally retracting skin and underlying tissue surrounding an incision can provide a wider opening and working channel between the tissue manipulating implements to access the patient's spine or intervertebral space. In some embodiments, the working channel can extend to encompass an adjacent anchor implanted in an adjacent vertebra. Once the tissue of the incision walls is retracted to form the working channel, any of a variety of surgical procedures can be performed by introducing one or more instruments through the working channel defined by the tissue manipulating implements of the retractor assembly. For example, procedures on the intervertebral disc space, such as disc replacement, discectomy, endplate preparation, fusion cage insertion, bone graft delivery, and the like can be performed by passing instruments or implants through the working channel.

(21) Returning to FIGS. **1**-**4**, FIG. **1** illustrates one embodiment of a surgical instrument assembly **100** that includes a support instrument **102** coupled to an implantable anchor **104** and a tissue retractor **106**. Further details regarding embodiments of the assembly **100** can be found in U.S. application Ser. No. 16/139,409, entitled “PATIENT-MOUNTED SURGICAL SUPPORT,” now issued as U.S. Pat. No. 10,945,773, as well as U.S. application Ser. No. 16/139,434 entitled “PATIENT-MOUNTED SURGICAL RETRACTOR,” now published as US-2019-0090864-A1, both of which were filed on Sep. 24, 2018. Further details regarding embodiments of the implantable anchor **104** can be found in U.S. application Ser. No. 15/208,872, filed on Jul. 13, 2016, and entitled “BONE ANCHOR ASSEMBLIES AND RELATED INSTRUMENTATION,” now issued as U.S. Pat. No. 10,463,402. Furthermore, details regarding certain embodiments of retractors that can be used in the surgical assembly **100** can be found below and in U.S. Pat. No. 7,491,168. The entire contents of each of these references are incorporated by reference herein.

(22) Generally, the support instrument can include an elongate body **108** with a laterally-extending fork formed at a distal end thereof that can interface with a narrowed neck of the anchor **104**. The fork can include opposed projections that extend laterally from a distal portion of the elongate body and define a U-shaped or otherwise open-ended recess that can be sized to receive a portion of the implantable anchor **104**. For example, the projections can be configured to fit around a proximal portion of a bone anchor that can be part of a modular mono- or poly-axial pedicle screw. Such anchors can include a generally cylindrical distal shank portion with threads for tapping into bone, as well as a narrowed neck proximal of the shank portion and a wider proximal head. The proximal head can be generally spherical or semi-spherical in shape and can be configured to couple with a receiver head before or after implantation in a patient's bone. The elongate body can also include a lock configured to exert a drag force on the head of the anchor to control polyaxial movement of the instrument **102** relative to the anchor **104**. As shown in FIG. **3**, the lock can include a lock body **302** that is coupled to the elongate body **108** and translatable relative thereto along a longitudinal axis **304** of the elongate body. The lock body **302** can have a generally elongate shape to facilitate coupling with and translating or sliding along or relative to the elongate body **108**. The lock can be actuated by a lock screw **305** that can cause distal translation of the lock body **302** as the screw is

threaded further into the elongate body **108**. The lock body **302** can further include a laterally-extending ring-shaped projection **306** at a distal end thereof that can be configured to contact the proximal head of the anchor **104** and exert a drag force thereon. The ring-shaped projection **306** can define a lumen to maintain access to a drive feature formed on a proximal end of the head of the anchor **104**. This lumen, in combination with the lateral extension of the projection **306** and the fork formed at the distal end of the elongate body **108** can orient the instrument **100** such that a longitudinal axis of the instrument is laterally offset or non-coaxial with a longitudinal axis of the anchor **104**. Such a configuration can allow a driver or other instrument to access the drive feature of the anchor **104** even when the instrument **100** is coupled thereto. This can enable flexibility to implant the anchor **104** any of before and after coupling the instrument **100** thereto.

(23) Returning to FIG. **2**, a more detailed illustration of one embodiment of the tissue retractor **106** is provided. The retractor **106** can include a body **202** that can be configured to couple to the support instrument or anchor extension **102**. First and second tissue manipulating implements **204**, **206** can be coupled to the body **202** by, for example, rigid arms **208**, **210**, respectively. Each of the first and second tissue manipulating implements **204**, **206** can be capable of polyaxial movement relative to the body via a polyaxial joint **212**, **214**, such as a ball-and-socket joint. Such a joint can allow the tissue manipulating implements **204**, **206** to move relative to one another in a variety of manners. For example, the implements **204**, **206** can be pivoted toward or away from one another about an axis extending parallel to a longitudinal axis of a support instrument **102**, (e.g., an axis parallel to the axis **304** in FIG. **3**). The implements **204**, **206** can also be pivoted toward or away from one another about an axis transverse or oblique to, e.g., the axis **304**. For example, the implements **204**, **206** can be toed relative to one another, where distal ends of the implements are moved toward or away from one another by an amount greater than proximal ends of the implements. In some embodiments, toeing can include moving distal ends of the implements away from one another while proximal ends of the implements are either moved toward one another or do not move such that a distance between the proximal ends of the implements remains unchanged. Furthermore, each polyaxial joint **212**, **214** can include a lock **216**, **218** that can be used to selectively lock a position of the associated tissue manipulating implement **204**, **206** or impose a drag force to inhibit movement in the absence of at least a threshold level of force.

(24) As noted above, the tissue retractor **106** can be configured to couple to a support instrument or anchor extension **102** and can be configured to slide along a length of such an instrument to adjust a height of the retractor relative to the implanted anchor **104**. As shown in FIG. **2**, the body **202** of the retractor can include a closed or partially-open lumen or recess **220** configured to receive a portion of the support instrument **102**, such as a generally cylindrical elongate body **108** (see FIG. **1**). The retractor **106** can further include a feature to selectively lock a position of the retractor relative to the support instrument **102**, such as a spring-biased protrusion or pawl **222** that can engage a ratchet rack or other series of recesses or other surface features formed on the elongate body **108** of the support instrument. Furthermore, in some embodiments the locking feature **222** can be configured to prevent not only movement along a length of the support instrument **102**, but also rotation thereabout. An actuator **224**, such as the illustrated sliding or translating member, can be included to allow a user to easily withdraw the protrusion **222** against the biasing force of a spring or other biasing element disposed within the body **202** of the retractor **106**.

(25) In addition to adjusting a position of the retractor **106** along a length of the support instrument **102**, a length of each of the tissue manipulating implements **204**, **206** can also be adjusted. For example, in some embodiments the tissue manipulating implements **204**, **206** can each include an extension **226**, **228** that can be configured to translate relative to the tissue manipulating implements **204**, **206**. Proximally or distally translating either extension **226**, **228** relative to the associated implement **204**, **206** can change an overall length of the implement and, for example, can allow an implement to reach deeper into tissue even if the retractor **106** is mounted at a greater height above a patient's skin surface along a more proximal portion of the support instrument

elongate body **108**.
(26) FIG. **3** illustrates a partially exploded view showing how the retractor **106** can be coupled to the support instrument **102** by sliding the retractor down or distally over a proximal portion of the support instrument. For example, the recess or lumen **220** of the retractor **106** can be aligned with the generally cylindrical elongate body **108** of the support instrument and the retractor can be advanced down or distally along the axis **304**. While advancing the retractor relative to the support instrument, a user can manually retract the spring biased pawl or protrusion **222** using the sliding lever **224** to allow free movement of the retractor relative to the support instrument. When a desired position is reached, the user can release the lever **224** such that the protrusion **222** is advanced into engagement with a complementary recess or other feature formed on the elongate body **108** to maintain the relative positioning of the retractor and support instrument. In other embodiments, the complementary features formed on the elongate body **108** and the protrusion **222** can be formed as a biased ratchet where, e.g., distal advancement of the retractor can be achieved without actuating the lever **224**, but proximal withdrawal of the retractor **106** relative to the instrument **102** requires actuating the lever **224** to withdraw the biased protrusion **222**.
(27) FIG. **4** illustrate the retractor **106** in various exploded and partially transparent views to better explain the interaction of various components thereof. For example, the polyaxial joints **212**, **214** can be seen in greater detail. Each polyaxial joint **212**, **214** can include a socket **402**, **404** formed in the body **202** of the retractor **106**. Each of the arms **208**, **210** coupled to the tissue manipulating implements **204**, **206** can have a generally ball-shaped proximal end **406**, **408** that includes one or more relief slots formed therein such that various portions of the proximal end (e.g., petals **428**) can deform relative to other portions thereof. A lock **216**, **218** can be coupled to each arm **208**, **210** by cooperation between threads **410**, **412** formed on the lock and threads **414**, **416** formed on an inner surface of through-holes in the arms **208**, **210**. Further, an expanding member **420** can be disposed at a distal end of each lock **216**, **218** and arranged within the ball-shaped proximal end **408** such that adjustment of the lock **218** position by movement along the threads **412** can moves the expanding member **420** distally within the ball-shaped proximal end **408** such that it urges the petals **428** outward or the expanding member **420** can be retracted proximally such that it sits more in a curved inside surface of the petals **428** and does not urge them outward from a resting position.
(28) When assembled, with the expanding members **418**, **420** disposed within the generally ball-shaped proximal ends **406**, **408** in an un-locked (e.g., retracted or resting) position, the expanding members **418**, **420** can be disposed within one of the sockets **402**, **404** of the body **202** to enable a locking function. In use, as the locks **216**, **218** are rotated relative to the arms **208**, **210**, they can advance the expanding member **420** farther into the ball-shaped proximal end **408** due to the threaded coupling between the arms **208**, **210** and the locks **216**, **218**. Advancement of the locks **216**, **218** into the ball-shaped proximal end **408** can cause the expanding member **418**, **420** formed at a distal end of each lock to expand the petals **428** radially outward inside the sockets **402**, **404**. As the petals **428** of the ball-shaped proximal ends **406**, **408** expand radially, they are urged into contact with the sidewalls of the sockets **402**, **404**. This can cause an increase in frictional force between the sockets **402**, **404** and the ball-shaped proximal ends **406**, **408** of the arms **208**, **210**. Further, upon sufficient advancement of the locks **216**, **218**, the force of the expanding members **418**, **420** against the petals **428** can effectively lock the ball-shaped proximal ends **406**, **408** in a given position and thereby prevent any movement of the arms **208**, **210** or tissue manipulating implements **204**, **206** coupled thereto.
(29) The embodiment illustrated in FIGS. **1-4** can present certain challenges in use, however. For example, in some cases achieving sufficient frictional or lockout force to resist reaction forces imparted onto the tissue manipulating implements by retracted tissue can require multiple complete rotations of the locks **216**, **218**. Further, in some cases actuating the locks **216**, **218** that are coupled to the tissue manipulating implement arms can cause unintended movement of the tissue manipulating implement. Still further, in some cases achieving even a provisional level of locking

between the ball-shaped proximal ends **406**, **408** and the sockets **402**, **404** can require some actuation of the locks **216**, **218**, which can complicate a surgical procedure by requiring more steps and hands to position a tissue manipulating implement, provisionally lock its position such that it does not move unless a force is imparted by a user, possibly readjust positioning (perhaps many times), and finally fully lock positioning.

(30) A ball and socket joint is one method for positioning a screw mounted retractor. Examples of the present disclosure provide for a ball and socket joint that includes structure for capturing and locking the ball orientation with sufficient force to resist reaction forces imparted by muscle/tissue. Additionally, the examples of the ball and socket joints can be easily assembled and disassembled in order to allow positioning of the retractor for the surgeon. Accordingly, the above described retractor assembly **106** can be constructed with an alternate polyaxial joint design, which replaces the polyaxial joint assembly **499** shown in FIG. **4**. The polyaxial joint assembly **499** includes at least a portion of the arm **210** with the ball-shaped proximal end, the lock **218** and the ball-shaped expanding end **420**, and at least a portion of the body **202** with the socket **404**. One such alternate polyaxial joint assembly is the ball and socket joint assembly **500** illustrated in FIGS. **5**A-**8** and described below.

(31) FIGS. **5**A and **5**B are partially-transparent detail views of a ball and socket joint assembly **500** as an alternate design for the polyaxial joints of the retractor of FIG. **2**. The ball and socket joint assembly **500** includes a housing **501** that has an open distal end **509** and an internal cavity **505** containing a compression member **530** that is configured to move axially (i.e., along the proximal (P)-distal (D) axis) inside the cavity **505**. The compression member **530** includes a collet **508** that is configured to receive the ball-shaped end **520** of a connector **502**, as illustrated by arrow **591** in FIG. **5**A and subsequently shown disposed in the collet in FIG. **5**B. In operation, because the outer diameter of the collet **508** is larger than the diameter of a lip **504** of the inner wall of the cavity **505** when the ball-shaped end **520** of the connector **502** is disposed in the collet, when the compression member **530** is translated distally relative to the housing **501**, the outer surface of the collet **508** is engaged by the lip **504** to collapse the collet **508** around the ball-shaped end **520**, creating a friction fit. Accordingly, a proximal inner wall region **503** of the cavity **505** defines a larger diameter section than the lip **504** to allow the collet **508** to flex radially outward to accept the ball-shaped end **520** when the compression member is disposed proximally, as shown in FIG. **5**B.

(32) In some examples, the ball and socket joint assembly **500** includes a spring **560** disposed in the cavity **505** for distally biasing the compression member **530** against the lip **504** of the opening **509**, as illustrated in FIG. **5**A. In some examples, and as illustrated, the housing **501** includes an engagement feature or protrusion extending into the cavity **505**, such as a cam pin **550**. Additionally, the compression member **530** includes an axial track **538** for receiving the cam pin **550** and allowing axial translation of the compression member **530** in the cavity **505** of the housing **501**. In some examples, the compression member **530** further includes an angled track **539** for the cam pin **550** that extends from the axial track **538**, such that the angled track **539** enables rotation of the compression member **530** in the housing and the angle of the angled track **539** advances the compression member distally against the lip **504** when the cam pin **550** is rotated out of the axial track **538** and along the angled track **539**.

(33) FIG. **5**A shows the assembly **500** in a default position. While the cam pin **550** is aligned to the axial channel **548**, and the spring **560** has driven the collet **508** of the compression member **530** distally against the lip **504** of the housing **501**. In some examples, the only distal force on the collet **508** comes from the spring **560**, whereby insertion of the ball-shaped end **520** into the collet **508** can be achieved simply by pushing the ball-shaped end **520** proximally into the opening **509** of the housing **501** until the ball-shaped end **520** is received by the collet **508**. Thereafter, the spring **560** can urge the compression member **530** distally until the collet **508** is engaged with the lip **504**, which can provide a degree of frictional locking of the ball-shaped end **520** in the collet **508**. This frictional locking, or drag force, can provisionally lock a position of the ball-shaped end **520**

relative to the collet **508** and assembly **500** such that the two components maintain their relative position in the absence of a sufficient force imparted thereto, e.g., from a user forcing an adjustment of their relative positions.

(34) In some examples, the ball and socket joint assembly **500** includes an actuator shaft **518** extending proximally from the housing **501**, with the actuator shaft **518** extending into the cavity **505** and coupled to the compression member **530**. The actuator shaft **518** is able to rotate and translate with respect to the housing **501** and the actuator shaft **518** can be used to position the compression member **530** with respect to the cam pin **550**. For example, when the compression member **530** is sprung distally, torque applied to the actuator shaft **518** can rotate the compression member **530** to use the cam pin **550** as a thread in the angled channel **539** and advance the compression member **530** distally to collapse the collet **508** around the ball-shaped end **520**, creating a friction fit. This cam pin **539** and angled track **539** design can be replaced with a partial thread in some embodiments.

(35) FIG. **5**B shows the ball and socket joint assembly **500** in a loading/unloading position. During a loading or connecting operation, this position will be achieved by pushing the ball-shaped end **520** into the collet **508**, forcing it proximally until the fingers of the collet **508** are able to flex radially outwards (i.e., into the space provided by the proximal inner wall **503** of the cavity **505**) and accept the ball-shaped end **520**. During an unloading or disconnecting operation, the position of FIG. **5**B is achieved by pulling proximally on the actuator shaft **518** and overcoming the spring force. At this point the fingers of the collet **508** can flex radially outwards and the ball-shaped-end **520** can be pulled out of the compression member **530**.

(36) FIG. **6** is a cross-sectional view of the ball and socket joint assembly **500** of FIGS. **5**A and **5**B. The ball and socket joint assembly **500** is shown in cross-section in the loading/unloading position with the ball-shaped end **520** (shown in phantom by dotted line) of the connector **502** disposed in the collet **508**. The inner diameter of the cavity **505** is label d**3**, the outer diameter of the collet **508** is labeled d**2**, and the inner diameter of the lip **504** is labeled d**1**. In some examples, the inner diameter d**3** of the cavity **505** is larger than the outer diameter d**2** of the collet **508** at a proximal inner wall region **503** of the cavity **505** to allow the collet **508** to expand radially outward and allow the ball-shaped end **520** to be inserted and removed from the collet **508**. In some examples, the outer diameter d**2** of the collet **508** is larger than the diameter d**1** of the opening of the cavity **505** as defined by the lip **504**. The ball and socket joint assembly **500** can also include a cap **599** to cover a proximal end of the housing **501**, and the cap **599** can be, for example, pressed, threaded, or otherwise connected to the proximal end of the housing **599**, for example to cover a proximal opening of the housing **501** that is used to insert the compression member **530** into the housing **501**. In operation, the cap **599** also allows the actuator shaft **518** to pass into the housing **501** to be coupled with the compression member **530**, and the actuator shaft can include a circular section **519** arranged to constrain rotation of the actuator shaft **518** in the cap **599** to a longitudinal axis of the assembly **500**. In some examples, the cap **599** is sealed to the housing **501**, and the circular section **519** of the actuator shaft **518** can be coupled to the cap **599** while still allowing both rotation and translation of the actuator shaft **518** with respect to the housing **501**.

(37) In some examples, and as illustrated, the collet **508** extends beyond and around a midpoint (i.e., a maximum diameter location) of the ball-shaped end **520**, such that the collet **508** passively retains the ball-shaped end **520**. Additionally, in some examples, the distal outer surface **507** of the collet **508** is sloped such that, when the collet **508** is advanced distally against the lip **504**, the lip **504** imparts both a radially inward and proximal force on the collet **508** to retain the ball-shaped end **520** in the collet **508**. This diameter d**1** of the lip **504** can be smaller than the outer diameter d**2** of the collet **508** at a location distal to the midpoint (i.e., a maximum diameter location) of the ball-shaped end **520**. In some examples, and as illustrated, the lip **504** can include a conical or sloped region **506** to increase the surface area over which the distal outer surface **507** of the collet **508** engages the lip **504**.

(38) FIGS. **7**A and **7**B are partially-transparent detail views of the ball and socket joint assembly **500** of FIGS. **5**A and **5**B showing a locking operation. In FIG. **7**A, with the ball-shaped end **520** (shown in phantom by dotted line) disposed in the collet **508**, the actuator shaft **518** is rotated (arrow **592**) to advance the cam pin **550** out of the axial channel **538** and into the angled channel **539**. This rotation **592** of the actuator shaft **518** drives the collet **508** distally with significant mechanical advantage against the lip **504**, until the collet **508** cannot be driven further distally, at which point a significant friction fit exists between the collet **508** and the lip **504**, which securely holds the ball-shaped end **520** in the collet **508**.
(39) In FIG. **7**B the ball and socket joint assembly **500** is shown in a locked configuration, near the end of the travel of the cam pin **550** in the angled channel **539**. Interference shown between the collet **508** and the lip **504** of the housing **501** indicates that the collet **508** has been deflected upon interference with the interior cone **506** of the lip **504** to secure the ball-shaped end **520** in the collet **508**. This collapse, forced by the mechanical advantage of the threaded connection, creates a friction lock on the ball-shaped end **520** (shown in phantom by dotted line) and can prevent rotation or other movement between the housing **501** and the connector **502**. Additionally, when the cam pin is disposed in the angled channel **539** to a position that advances the collet **508** against the lip **504**, the collet **508** is prevented from expanding radially outward, which prevents the ball-shaped end **520** from being removed from the collet **508** because removal of the ball-shaped end **520** would require the collet **508** to expand radially outward to a larger diameter than allowed by the lip **504**. From this position, counter rotation of the actuator shaft **518** moves the compression member **530** proximally and disengages the collet **508** from the lip **504**, which returns the ball and socket joint assembly **500** to the loading/unloading position of FIG. **5**B, where the ball-shaped end **520** can be removed from the collet **508** and passed out of the opening **509** of the housing **501**.
(40) In some instances, the degree of torque applied to the actuator shaft **518** determines the strength of the friction fit between the collet **508** and the lip **504**, which in turn defines the strength of the hold that the collet **508** has on the ball-shaped end **520**. Accordingly, a user can tighten the actuator shaft **518** to completely lock the ball-shaped end **520** in place in the collet **508**, or to a degree which still allows for some resisted polyaxial movement of the ball-shaped end **520** in the collet **508**. In some instances, and as shown in FIG. **7**C, the angled channel **539** may have a straight section **737** or, as shown in FIG. **7**D, the angled channel **539** can include one or more divots **738** at one or more circumferential locations, each of these being able to define predetermined friction levels as the user rotates the actuator shaft **518**, where the straight sections **737** or divots **738** can also prevent any axial movement of the compression member **530** due to the force applied by the lip **504** against the collet in the proximal direction, thereby creating a passively locked retention position.
(41) While a cam pin and track are used in the illustrated embodiments, a threaded connection can be used as well, provided the collet has an axial groove allowing the thread segment in the housing to travel freely. For example, the compression member **530** can be threaded into the housing **501** such that rotation of the compression member **530** translates the compression member **530** distally towards the lip **504** or proximally away from the lip **504**. In operation, the actuator shaft **581** can be rotated to rotate the compression member **530** such that it is translated proximally to allow the ball-shaped end **520** to be received by the collet **508** and, afterwards, the actuator shaft **518** can be rotated in an opposite direction to rotate the compression member **530** such that the collet **508** is moved distally into contact with the lip **504** until the ball-shaped end **520** is locked and/or frictionally constrained by the collet **508**. Alternatively, the compression member **530** can include an angled channel **538** without the axial channel **538** such that the rotation of the compression member **530** about the cam pin **550** translates the compression member **530** in the housing **501** between a proximal location where the collet **508** can accept the ball-shaped end **520** (e.g., as shown in FIG. **5**B) and a distal location where the collet **508** locks the ball-shaped end **520** into the collet **508** (e.g., as shown in FIG. **7**B). In some examples, the axial channel **538** functions to enable

assembly of the compression member **530** into the housing **501** such that the cam pin first passes through an axial channel **538** during assembly and then moves into the angled channel **539** to be placed into an operational arrangement.

(42) FIG. **8** is a perspective view of ball and socket joint assembly **500** of FIGS. **5**A and **5**B, with the proximal end cap **599** of the housing **501** removed. In FIG. **8**, the cam pin **550** is shown extending into the axial channel **538**. The actuator shaft **518** has a hexagonal profile along proximal and distal portions **818**, **819** thereof. The proximal hexagonal section **818** can be used to connect to a handle or driver to enable a user to apply torque to the actuator shaft **518**. This could be shaped like any driver feature or simply be a bent shaft (similar to an Allen key) to provide leverage. The distal hexagonal section **819** can be used to transfer torque from the actuator shaft **518** to the compression member **530**, which can also be of any shape capable of applying torque. FIG. **8** shows the circular section **519** of the actuator shaft **518** is between the proximal and distal portion **818**, **819** that is arranged to constrain rotation of the actuator shaft **518** in the cap **599**.

(43) FIG. **9**A is an illustration of a retractor body **202** and tissue retractor implement arms **208**, **210** of a surgical instrument assembly **900** being connected via a ball and socket joint assembly **500**, with the body **202** having the housing **501** of the ball and socket assembly **500**. In operation, each ball and socket joint **500** can be arranged to couple the body **202** to an arm **208**, **210** that is itself coupled to, for example, a tissue manipulating implement **204**, **206**. The ball-shaped end **520** each connector **502** can be urged into the housing **501** attached to the body **202**, and a compression member **530** in the housing **501** of the ball and socket joint assembly **500** can accept the ball-shaped end **520**, as discussed with respect to FIGS. **5**A-**8**. With the ball-shaped end **520** disposed in the collet **508** of the compression member **530**, the arms **208**, **210** can be polyaxially rotated about the housing **501**. Additionally, with the ball-shaped end **520** disposed in the collet **508**, the actuator shaft **518** can be rotated to translate the compression member **530** and lock the ball-shaped end **520** in the assembly **500** and frictionally restrain the polyaxial position of the arm **208**, **210** with respect to the body **202** to a degree that can depend on the degree of rotation of the actuator shaft **518**. Similarly, with the ball-shaped end **520** disposed into the collet **508**, the actuator shaft **518** can be rotated in a direction opposite that used to lock the ball-shaped end **520** to unlock the assembly **500** such that the ball-shaped end **520** can be urged out of the compression member **530** to disconnect the arm **208**, **210** from the body **202**. In the configuration of FIG. **9**A, rotation and actuation occurs on the retractor body **202** rather than the arms **208**, **210** of the retractor blades, as shown in FIG. **9**B, where the housing **501** is coupled to the arms **208**, **210**.

(44) FIG. **9**B is an illustration of a retractor body **202** and tissue retractor implement arms **208**, **210** of a surgical instrument assembly **900** being connected via a ball and socket joint assembly **500**, with the body **202** having the connectors **502** (as opposed to the arms **208**, **210** having the connectors **502**, as shown in FIG. **9**A). In operation, each ball and socket joint **500** can be arranged to couple the body **202** to an arm **208**, **210** that is itself coupled to, for example, a tissue manipulating implement **204**, **206**. The ball and socket joint assembly **500** can be urged against the ball-shaped end **520** of a connector **502** attached to the body **202**, and a compression member **530** in the housing **501** of the ball and socket joint assembly **500** can accept the ball-shaped end **520**, as discussed with respect to FIGS. **5**A-**8**. With the ball-shaped end **520** disposed in the collet **508** of the compression member **530**, the arms **208**, **210** can be polyaxially rotated about the ball-shaped end **520**. Additionally, with the ball-shaped end **520** disposed in the collet **508**, the actuator shaft **518** can be rotated to translate the compression member **530** and lock the ball-shaped end **520** in the assembly **500** and frictionally restrain the polyaxial position of the arm **208**, **210** with respect to the body **202** to a degree that can depend on the degree of rotation of the actuator shaft **518**. Similarly, with the ball-shaped end **520** disposed into the collet **508**, the actuator shaft **518** can be rotated in a direction opposite that used to lock the ball-shaped end **520** to unlock the assembly **500** such that the ball-shaped end **520** can be urged out of the compression member **530** to disconnect the arm **208**, **210** from the body **202**.

(45) It should be noted that any ordering of method steps expressed or implied in the description above or in the accompanying drawings is not to be construed as limiting the disclosed methods to performing the steps in that order. Rather, the various steps of each of the methods disclosed herein can be performed in any of a variety of sequences. In addition, as the described methods are merely exemplary embodiments, various other methods that include additional steps or include fewer steps are also within the scope of the present disclosure.
(46) The instruments disclosed herein can be constructed from any of a variety of known materials. Exemplary materials include those which are suitable for use in surgical applications, including metals such as stainless steel, titanium, nickel, cobalt-chromium, or alloys and combinations thereof, polymers such as PEEK, ceramics, carbon fiber, and so forth. The various components of the instruments disclosed herein can have varying degrees of rigidity or flexibility, as appropriate for their use. Device sizes can also vary greatly, depending on the intended use and surgical site anatomy. Furthermore, particular components can be formed from a different material than other components. One or more components or portions of the instrument can be formed from a radiopaque material to facilitate visualization under fluoroscopy and other imaging techniques, or from a radiolucent material so as not to interfere with visualization of other structures. Exemplary radiolucent materials include carbon fiber and high-strength polymers.
(47) The devices and methods disclosed herein can be used in minimally-invasive surgery and/or open surgery. While the devices and methods disclosed herein are generally described in the context of spinal surgery on a human patient, it will be appreciated that the methods and devices disclosed herein can be used in any of a variety of surgical procedures with any human or animal subject, or in non-surgical procedures.
(48) The devices disclosed herein can be designed to be disposed of after a single use, or they can be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.
(49) The devices described herein can be processed before use in a surgical procedure. First, a new or used instrument can be obtained and, if necessary, cleaned. The instrument can then be sterilized. In one sterilization technique, the instrument can be placed in a closed and sealed container, such as a plastic or TYVEK bag. The container and its contents can then be placed in a field of radiation that can penetrate the container, such as gamma radiation, x-rays, or high-energy electrons. The radiation can kill bacteria on the instrument and in the container. The sterilized instrument can then be stored in the sterile container. The sealed container can keep the instrument sterile until it is opened in the medical facility. Other forms of sterilization known in the art are also possible. This can include beta or other forms of radiation, ethylene oxide, steam, or a liquid bath (e.g., cold soak). Certain forms of sterilization may be better suited to use with different portions of the device due to the materials utilized, the presence of electrical components, etc.
(50) One skilled in the art will appreciate further features and advantages based on the above-described embodiments. Accordingly, the disclosure is not to be limited by what has been particularly shown and described. All publications and references cited herein are expressly incorporated herein by reference in their entirety.

Claims

1. A ball and socket joint assembly comprising: a housing defining a cavity and a distal opening to the cavity, the distal opening having a diameter larger than a diameter of a spherical portion of a connector and less than a diameter of an inner wall of the cavity proximal to the distal opening, the housing comprising an engagement feature extending into the cavity; a compression member disposed in the cavity, a distal end of the compression member comprising a collet configured to accept the spherical portion of the connector, the collet defining an outer diameter that is configured to be larger than the diameter of the distal opening in the housing when the spherical portion is disposed in the collet, and the compression member comprising an outer surface defining a corresponding engagement feature around at least a portion of the outer surface for receiving the engagement feature of the housing; and wherein the engagement feature of the housing and the corresponding engagement feature of the compression member are configured to define a first configuration in which the compression member is free to translate along a longitudinal axis of the housing and a second configuration in which rotation of the compression member causes translation of the compression member to compress the collet against the distal opening of the cavity.
2. The assembly of claim 1, wherein, after inserting the spherical portion of the connector into the collet, rotation of the compression member in a first direction and engagement between the engagement feature of the housing and the corresponding engagement feature of the compression member advances the compression member distally, and, when advanced distally, the collet engages the distal opening of the cavity and locks the collet about the spherical portion.
3. The assembly of claim 1, wherein the cavity defines an outwardly tapered inner wall region extending proximally from the distal opening.
4. The assembly of claim 1, wherein a distal end of the compression member defines a plurality of resilient fingers each having a tapered exterior surface configured to interface with the outwardly tapered inner wall region of the cavity when the compression member is advanced distally, the outwardly tapered inner wall region constricting the plurality of resilient fingers.
5. The assembly of claim 1, wherein the engagement feature is a cam pin and the corresponding engagement feature comprises an angled locking channel sized and shaped to receive the cam pin.
6. The assembly of claim 5, wherein the angled locking channel defines a variable pitch to provide a variable mechanical advantage during rotation of the compression member with respect to the cam pin, when the cam pin is disposed in the angled locking channel.
7. The assembly of claim 5, wherein the angled locking channel comprises one or more divots or straight sections at one or more circumferential locations, each divot or straight section defining a predetermined level of friction between the collet and the distal opening of the housing.
8. The assembly of claim 1, wherein the outer surface of the compression member further comprises an axial channel for receiving the engagement feature of the housing and allowing the compression member to translate freely along the longitudinal axis in the cavity, and the corresponding engagement feature of the compression member extends from the axial channel and is angled proximally from the axial channel.
9. The assembly of claim 8, comprising a spring disposed in the housing, the spring being coupled to the housing and the compression member for biasing the compression member towards the distal opening.
10. The assembly of claim 8, wherein the spring is configured to urge the collet against the distal opening and impart a drag force on the spherical portion for resisting polyaxial movement of the spherical portion about the collet.
11. The assembly of claim 8, wherein the spring is configured to urge the collet against the distal opening and impart a retaining force on the spherical portion.

12. The assembly of claim 1, wherein the engagement feature of the housing comprises a threaded portion of the inner wall of the cavity, and the corresponding engagement feature of the compression member comprises a corresponding threaded portion of the outer wall of the compression member, wherein the compression member is in threaded engagement with the housing.
13. The assembly of claim 1, wherein the collet is configured to passively secure the spherical portion of the connector without engaging the distal opening of the housing.
14. The assembly of claim 1, wherein the collet is configured to extend distally beyond a maximum diameter location of the spherical portion of the connector.
15. The assembly of claim 1, wherein the collet defines a distal opening having an inner diameter less than a maximum inner diameter of the collet.
16. The assembly of claim 1, further comprising an actuator shaft coupled to the compression member and configured to rotate the compression member in the cavity.
17. A surgical instrument, comprising: a retractor body configured to couple to an implantable anchor; the retractor body comprising a first coupling feature and a second coupling feature; a first tissue manipulating implement comprising a first connector having a spherical portion coupled to the first coupling feature of the retractor body and capable of polyaxial movement relative thereto; and a second tissue manipulating implement comprising a second connector having a spherical portion coupled to the second coupling feature of the retractor body and capable of polyaxial movement relative thereto; wherein each of the first and second tissue manipulating implements couples to the corresponding coupling feature via the ball and socket joint assembly of claim 1, wherein each of the first and second coupling features comprises the housing of the ball and socket joint assembly.
18. The instrument of claim 17, wherein each of the first and second connectors comprises an extension post coupled to the first or second tissue manipulating implements.
19. A method of assembling a surgical instrument, the method comprising: inserting a spherical portion of a connector into a collet of a compression member disposed within a cavity of a body, the connector being attached to a body of a surgical retractor, the spherical portion passing through a distal opening to the cavity that has a diameter larger than a diameter of the spherical portion of a connector and less than a diameter of an inner wall of the cavity proximal to the opening; rotating the compression member with respect to an engagement feature of the body that extends into the cavity, the engagement feature interfacing with the compression member such that the rotation of the compression member urges the compression member distally in the cavity; and continuing to rotate the compression member until an outer surface of the collet is compressed against the opening of the cavity and an inner surface of the collet is compressed around the spherical portion to retain the spherical portion in the collet.
20. The method of claim 19, wherein inserting the spherical portion into the collet includes urging the compression member proximally against a spring force, wherein the spring force urges the compression member distally towards the opening after the inserting.