United States Patent	12390203
Kind Code	B2
Date of Patent	August 19, 2025
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Rotational drive apparatus with ratcheting mechanism

Abstract

A hand held, hand operated apparatus for rotating, or spinning, rotatably oscillating and/or inducing back and forth longitudinal movement in a device, such as an elongated medical device. A drive shaft of the hand held, hand operated rotational drive apparatus includes a ratcheting mechanism capable of enabling oscillating (repeated forward and reverse) rotation of a device that has been coupled thereto when there is little or no resistance on the rotated device, and of enabling an actuator to return to a position that will enable further forward, or driving, rotation of the drive shaft and the rotated device when resistance on the rotated device prevents the rotated device and the drive shaft from rotating in a reverse direction.

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Appl. No.:	**17/317838**
Filed:	**May 11, 2021**

Prior Publication Data

Document Identifier	**Publication Date**
US 20210332872 A1	Oct. 28, 2021

Related U.S. Application Data

continuation parent-doc US 16513581 20190716 US 11002346 20210511 child-doc US 17317838
continuation parent-doc US 15890223 20180206 US 10352411 20190716 child-doc US 16513581
us-provisional-application US 62455534 20170206

Publication Classification

Int. Cl.: **A61B17/00** (20060101)

U.S. Cl.:

CPC **A61B17/00234** (20130101); A61B2017/00367 (20130101); A61B2017/00407 (20130101)

Field of Classification Search

CPC: F16H (19/02); A61B (10/02); A61B (2017/00407); A61B (2010/0208)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 16/513,581, filed on Jul. 16, 2019 and titled ROTATIONAL DRIVE APPARATUS WITH RATCHETING MECHANISM (“the '581 Application”), now U.S. Pat. No. 11,002,346, issued May 11, 2021, which is a continuation of U.S. patent application Ser. No. 15/890,223, filed on Feb. 6, 2018 and titled ROTATIONAL DRIVE APPARATUS WITH RATCHETING MECHANISM (“the '223 Application”), now U.S. Pat. No. 10,352,411, issued Jul. 16, 2019. The '223 Application includes a claim for the benefit of priority made pursuant to 35 U.S.C. § 119(e) to the Feb. 6, 2017 filing date of U.S. Provisional Patent Application No. 62/455,534, titled ROTATIONAL DRIVE APPARATUS WITH RATCHETING MECHANISM (“the '534 Provisional Application”).

TECHNICAL FIELD
(1) This disclosure relates generally to hand-held, hand-operated apparatuses and methods for rotating, or spinning, rotatably oscillating and/or inducing back and forth longitudinal movement in various devices, including, but not limited to, elongated medical instruments. More specifically, this disclosure relates to a hand-held, hand-operated rotational drive apparatus with a drive shaft that includes a ratcheting mechanism capable of enabling oscillating (repeated forward and reverse) rotation of a device that has been coupled thereto when there is little or no resistance on the rotated device, and of enabling an actuator to return to a position that will enable further forward, or driving, rotation of the drive shaft and the rotated device when resistance on the rotated device prevents the rotated device and the drive shaft from rotating in a reverse direction.
SUMMARY
(2) In one aspect, the present disclosure includes various embodiments of an apparatus for causing an elongated medical instrument to rotate, or spin, about its longitudinal axis. Such an apparatus may be referred to herein as a “rooter.” In a specific embodiment, a rooter includes a housing, a rotatable element within the housing, retention elements for securing the rotatable element in place relative to the housing, and an actuator capable of causing the rotatable element to rotate within the housing. The rotatable element may also be referred to as a “drive shaft.” An apparatus according to this disclosure may also include a coupling element at (e.g., coupled to, etc.) a distal end of the rotatable element.
(3) The actuator includes a ratcheting mechanism, which may enable rotation of the rotatable element in both directions (i.e., forward and reverse or clockwise and counterclockwise) about its longitudinal axis when less than a threshold rotational resistance is present on a rotated device, such as an elongated medical instrument, that has been coupled to the coupling element at the distal end of the rotatable element, and, thus, less than a threshold rotational resistance is present on the

rotatable element. The ratcheting mechanism may also enable the actuator to return to a starting position from which the actuator can drive rotation of the rotatable element, even when the rotational resistance on the rotated device and/or the rotatable element equals or exceeds the threshold rotational resistance and, thus, prevents the rotated device and the rotatable element from oscillating, or from rotating in a direction (e.g., reverse, etc.) that would otherwise enable the actuator to return to its starting position.

(4) The coupling element may be capable of engaging a specific type of device or any of a variety of different types of devices. Without limitation, the coupling element may be capable of engaging one or more different types of elongated medical instruments, such as a drill bit, a biopsy needle, a needle, a trocar, a cannula and/or stylet, a catheter, a wire, a macerator, or another elongated instrument that may be used to enable or effect a medical procedure within the body of a subject. In various embodiments, at least one end of the coupling element, which is accessible at or from a distal end of the housing of the apparatus, may be configured to receive and retain the device that is to be rotated.

(5) The rotatable element may be disposed within an interior of the housing in a manner that enables the rotatable element to spin about its longitudinal axis. As the rotatable element rotates within the housing, which may remain substantially stationary (e.g., within a user's grasp, etc.), a device, such as an elongated medical instrument engaged by the coupling element may rotate. In some embodiments, the rotatable element may comprise an elongated member with a longitudinal axis, about which the rotatable element may rotate, or spin. In a more specific embodiment, the rotatable element may include a helical ridge that may enable the rotatable element to be rotationally driven.

(6) An actuator may be associated with the rotatable element in such a way as to cause the rotatable element to rotate. In a specific embodiment, the actuator may include an external element configured for manual operation, as well as an internal element that interacts with the rotatable element. The actuator may be disposed around at least a portion of the rotatable element. In embodiments where the rotatable element has a helical ridge, the internal element of the actuator may be positioned between longitudinally adjacent locations of the helical ridge. In other embodiments, an actuator may include one or more grooves that are configured complementarily to and cooperate with the helical ridge. The actuator may move longitudinally relative to the rotatable element (e.g., in directions substantially parallel to the rotational axis of the rotatable element, etc.), while the internal element of the actuator and the helical ridge of the rotatable element interact with one another to cause the rotatable element, as well as any medical element engaged thereby, to rotate, or spin.

(7) Longitudinal movement of the actuator relative to the housing may be enabled by one or more elongated slots that extend through the housing, along at least a portion of its length, and by one or more external elements and one or more intermediate elements of the actuator. Each intermediate element of the actuator may extend through a corresponding elongated slot. The corresponding external element of the actuator may be moved (e.g., manually, by way of an associated handle, with a motor, etc.) along at least a portion of the length of the elongated slot to drive movement of the actuator along a length of the rotatable element. In embodiments where the external element and/or the intermediate element pivot relative to the actuator, the axis about which such pivoting occurs may be oriented perpendicular to and extend through an axis about which the rotatable element rotates (e.g., a longitudinal axis of the rotatable element, etc.). This configuration may impart the rooter with stability and prevent binding as the actuator moves back and forth along the length of the rotatable element. The elongated slot may receive an intermediate element of the actuator, holding the actuator in place as it is moved along the length of the rotatable element.

(8) The ratcheting mechanism of the actuator may enable the actuator to return to a starting position along the rotational element and, thus, enable further driving rotation of the rotational element, even when rotational resistance on a device that has been coupled to the coupling element prevents

the rotated device and the rotational element from oscillating, or from rotating in reverse direction. In some embodiments, the ratcheting mechanism includes a distal member of the actuator, a proximal member of the actuator, and a biasing member (e.g., a spring, etc.). The distal member may be coupled to a movable element of a handle. The distal member may be capable of sliding along a length of the rotatable element without directly causing the rotatable element to rotate. The distal member may also include engagement features capable of engaging the proximal member and holding the proximal member rotationally stationary when the movable element of the handle forces the distal member in a proximal direction along the length of the rotatable element. As the proximal member is held rotationally stationary over the rotational element while it is forced in the proximal direction along the length of the rotatable element by the distal member, it may engage the rotational element in a manner that drives rotation of the rotational element (e.g., by receiving or engaging a helical ridge of a rotatable element, etc.). Upon releasing the movable element of the handle, the biasing member may force the proximal member and the distal member in a distal direction along the length of the rotatable element. If the force the biasing element exerts on the proximal member exceeds a rotational resistance on a rotated device that has been coupled to the coupling element (and, thus, to the rotational element), the proximal member may remain rotationally stationary over the rotatable element, distal movement of the proximal member of the ratcheting mechanism may drive the rotational element and the rotated device in a reverse direction, thus enabling oscillation of the rotatable element and of the rotated device. If the rotational resistance on the rotated device exceeds the biasing force the biasing member exerts on the proximal member, the engagement features of the proximal member may disengage corresponding engagement features on the distal member of the ratcheting mechanism, enabling the proximal member to rotate over the rotational element and, thus, enabling the biasing member to force the proximal member distally without limited rotation or no rotation of the rotatable element (i.e., the proximal member, rather than the rotatable element, may spin when the rotatable element moves distally), and forcing the distal member of the ratcheting mechanism and the moveable member of the handle distally as well.

(9) This disclosure also includes systems for effecting rotational processes. A system of this disclosure includes a rooter, as well as a rotated device (e.g., an elongated medical instrument, etc.) capable of being coupled with the coupling element of the rooter. The rooter may be manually operable. As the rooter operates, it causes the rotated device to rotate or spin in a drive direction and, depending upon an amount of rotational resistance on the rotated device, it may cause the rotated device to spin in a reverse direction (which may enable oscillation of the rotated device). If at least a threshold amount of rotational resistance is present on the rotated device, the ratcheting mechanism may enable the rotational element and the rotated device to remain stationary, while enabling the proximal and distal members of the actuator and any moveable element of a handle associated therewith to return to a starting position.

(10) In another aspect, methods for rotating, or spinning, devices (e.g., elongated medical instruments, etc.) are disclosed, as are methods for inducing oscillatory (i.e., alternating between clockwise and counterclockwise rotation) or vibration-like movement, longitudinal movement (e.g., a back-and-forth hammering action, etc.) and other types of movement in rotated devices. In such a method, an elongated medical instrument is associated with (e.g., engaged by, etc.) a coupling element of a rooter. Operation of an actuator of the rooter (e.g., manually, with a user's thumb or finger on a moveable element of a handle; with a motor; etc.) causes the rotatable element, along with the rotated device that has been secured in place relative to the rotatable element, to rotate or spin in a forward direction. The rotatable element may be rotated continuously in a single direction (e.g., clockwise or counterclockwise), or it may be rotated in an alternating or oscillating fashion (i.e., one direction, then another).

(11) In embodiments where rotational resistance on the rotated device prevents it from rotating in a reverse direction (e.g., is equal to or greater than a threshold rotational resistance, etc.), the

ratcheting mechanism of the rooter may enable the actuator (i.e., its proximal and distal members) to disengage and to return to their starting positions.
(12) In some embodiments, movement of the rotatable element of a rooter and any elongated medical instrument coupled thereto may be accompanied by longitudinal movement of the rotatable element and any elongated medical instrument in one or more directions. When the rotatable element is oscillated, this longitudinal movement may include a repeated back-and-forth movement, inducing a hammering action in the rotatable element and any elongated medical instrument that has been coupled thereto. This hammering action may be used alone or in conjunction with oscillation of an elongated medical instrument to facilitate its introduction into or through a structure (e.g., a blockage, such as arterial plaque; a calcification; bone; etc.).
(13) Other aspects, as well as features and advantages of various aspects, of the disclosed subject matter will become apparent to those of skill in the art from consideration of the ensuing description, the accompanying drawings, and the appended claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) In the drawings:
(2) FIG. **1** depicts an embodiment of rooter of this disclosure;
(3) FIG. **2** is an exploded view of the embodiment of rooter shown by FIG. **1**;
(4) FIGS. **3**A, **3**B, and **3**C are, respectively, bottom, distal end, and proximal end views of a housing of the embodiment of rooter depicted by FIGS. **1** and **2**;
(5) FIGS. **4**A, **4**B, and **4**C are, respectively, side, distal end, and proximal end views of a rotatable element of the embodiment of rooter shown in FIGS. **1** and **2**;
(6) FIGS. **5**A, **5**B, and **5**C are side, rear, and front views, respectively, of a cap of the embodiment of rooter illustrated by FIGS. **1** and **2**;
(7) FIGS. **6**A, **6**B, and **6**C are, respectively, side, distal end, and proximal end views of a proximal retention element of the embodiment of rooter shown in FIGS. **1** and **2**;
(8) FIG. **6**D is a cross-section taken through the length of the proximal retention element depicted by FIGS. **6**A-**6**C;
(9) FIGS. **7**A, **7**B, and **7**C are side, distal end, and proximal end views of a distal retention element of the embodiment of rooter illustrated by FIGS. **1** and **2**;
(10) FIG. **8**A is an exploded side view showing an embodiment of an actuator of a rooter according to this disclosure, including a distal member and a proximal member that may engage and disengage one another;
(11) FIG. **8**B is a perspective view of the distal member of the embodiment of actuator shown in FIG. **8**A;
(12) FIG. **8**C is a cross-section through the proximal member of the embodiment of actuator shown in FIG. **8**A;
(13) FIG. **8**D is a perspective view of the proximal member of the embodiment of actuator shown in FIG. **8**A;
(14) FIGS. **8**E and **8**F are end views of the proximal member of the embodiment of actuator shown in FIG. **8**A;
(15) FIG. **8**G shows the distal and proximal members of the embodiment of actuator of FIG. **8**A in abutting, engaged positions;
(16) FIG. **9** shows the embodiment of actuator depicted by FIG. **8**A in its starting position over a distal end of the rotational element of the embodiment of rooter illustrated by FIGS. **1** and **2**;
(17) FIG. **10** shows the manner in which a biasing element is associated with the proximal member of the embodiment of actuator shown in FIG. **8**A; and

(18) FIG. **11** provides a partial perspective cutaway view illustrating the embodiment of actuator shown in FIG. **8**A in its starting position with the housing or a rooter.

DETAILED DESCRIPTION

(19) With reference to FIGS. **1** and **2**, an embodiment of a rooter **10** that incorporates teachings of this disclosure is illustrated. The rooter **10** includes a housing **20**, a rotatable element **40**, a distal retention element **60** and a proximal retention element **70**, and an actuator **90**. Either or both of the distal retention element **60** and the proximal retention element **70** may couple a device that is to be rotated (e.g., an elongated medical instrument, etc), or a "rotated device," to the rotatable element **40**; accordingly, the distal retention element **60** and the proximal retention element **70** may be referred to as a "coupling element."

(20) The housing **20**, which is also shown in FIGS. **3**A-**3**C, is an elongated element with an exterior **22** and a hollow interior **24**. In the depicted embodiment, the housing **20** is cylindrical in shape, with a longitudinal axis **21** extending centrally through the length of the housing **20**. The housing **20** includes a distal end **26** and an opposite, proximal end **30**. A longitudinal slot **34** extends along a portion of the length of the housing **20**.

(21) The distal end **26**, which is the end of the housing **20** that may be located farthest from an individual during use of the rooter **10** (FIGS. **1** and **2**), is partially closed, as depicted by FIG. **3**B. In a specific embodiment, the distal end **26** may include a circumferential lip **27** that defines an opening **28**, which extends through the housing **20**, from its exterior **22** to its interior **24**. The opening **28** may be centered about the longitudinal axis **21** of the housing **20**.

(22) As seen in FIG. **3**C, the proximal end **30** of the housing **20**, which may be located closest to the individual during operation of the rooter **10**, may include an opening **32** that exposes the interior **24** of the housing **20**. In some embodiments, the proximal end **30** of the housing **20** may be configured to receive a cap **56** (FIGS. **5**A-**5**C), which may at least partially close the opening **32** at the proximal end **30**.

(23) The longitudinal slot **34**, illustrated in FIGS. **3**A and **3**C, extends through a wall of the housing **20**, from the exterior **22** of the housing **20** to the interior **24** of the housing **20**. In the embodiment depicted by FIG. **3**A, the longitudinal slot **34** is substantially linear. A distal end **36** of the longitudinal slot **34** may be located adjacent to, but proximally spaced apart from, the distal end **26** of the housing **20**. An opposite, proximal end **38** of the longitudinal slot **34** is located at or near (i.e., distally spaced apart from) the proximal end **30** of the housing **20**.

(24) The rotatable element **40** of the embodiment of the rooter **10** (FIGS. **1** and **2**) illustrated by FIGS. **4**A-**4**C is an elongated element that is configured to be assembled with the housing **20** (FIGS. **3**A-**3**C) of the rooter **10**. In some embodiments, the rotatable element **40** may be tubular and, thus, include a conduit **55** extending through a portion of its length or through its entire length. A longitudinal axis **41** of the rotatable element **40** extends centrally or substantially centrally through a length of the rotatable element **40**. In embodiments where the rotatable element **40** includes a conduit **55**, the conduit **55** and the longitudinal axis **41** of the rotatable element **40** may be aligned (e.g., concentric, etc.).

(25) In embodiments where the rotatable element **40** includes a conduit **55**, the conduit **55** may enable flow communication between the interior of a hollow device (e.g., an elongated medical instrument, such as a needle, catheter, etc.) to be coupled to the rooter **10** and a separate flow facilitating apparatus (e.g., a syringe, an aspiration device, and infusion device, a vacuum line, etc.).

(26) In some embodiments, the conduit **55** through the rotatable element **40** may be configured to receive the device. The conduit **55** may be configured in such a way that a portion of the device may extend partially or completely through a length of the rotatable element **40**. In other embodiments, the conduit **55** may serve as an intermediate channel between the device and the flow facilitating apparatus.

(27) In the depicted embodiment, the rotatable element **40** includes an intermediate portion **45**, as

well as a distal portion **42** and a proximal portion **50** at opposite ends of the intermediate portion **45**.

(28) The intermediate portion **45**, which may be generally cylindrical in shape, includes a rotation facilitator. In the illustrated embodiment, the rotation facilitator comprises a helical ridge **47**, which protrudes from an outer surface **46** of the intermediate portion **45**. In particular, the helical ridge **47** may wrap circumferentially around the intermediate portion **45**. The helical ridge **47** may be continuous, as illustrated, or it may comprise a discontinuous structure. The helical ridge **47** extends along at least a portion of the length of the intermediate portion **45**. In some embodiments, the helical ridge **47** may extend along only a part of the intermediate portion **45**, as in the depicted embodiment, where the ends of the helical ridge **47** are spaced apart from corresponding ends of the intermediate portion **45**.

(29) The pitch of the helical ridge **47** may be configured to impart the rooter **10** with a desired number of rotations per stroke (i.e., full movement of the actuator **90** along the length of the rotatable element **40**). For example, a helical ridge **47** with a relatively large pitch may cause the rotatable element **40** to rotate more slowly, with greater torque, and with fewer revolutions per stroke (e.g., about 1½ revolutions per stroke, about 1 revolution per stroke, etc.) than a helical ridge **47** with a smaller pitch. When faster rotation or an increase in revolutions per stroke (e.g., five revolutions per stroke or more, etc.) is desired, the pitch of the helical ridge **47** may be decreased.

(30) The helical ridge **47** may be configured in a manner that facilitates the use of certain processes in the manufacture of the rotatable element **40**. For example, one or more surfaces of the helical ridge **47** may be flattened to facilitate the use of injection molding processes to manufacture the rotatable element **40**.

(31) The distal portion **42** of the rotatable element **40** may also be cylindrical in shape. In the embodiment shown in FIGS. **4**A-**4**C, the distal portion **42** of the rotatable element **40** has a smaller diameter than the intermediate portion **45** of the rotatable element **40**. Thus, a circumferential ledge **44** is present at the boundary between the distal portion **42** and the intermediate portion **45**. The distal portion **42** may also be configured to pass through the opening **28** in the distal end **26** of the housing **20** (FIGS. **3**A and **3**C), and to protrude from the distal end **26**. The distal portion **42** may be configured to engage or be engaged by the distal retention element **60** (FIGS. **7**A-**7**C). In this regard, a distal portion **42** of some embodiments of a rotatable element **40** of a rooter **10** may include one or more retention features **43**, such as the helical thread shown in FIG. **4**A.

(32) The proximal portion **50** of the rotatable element **40** may likewise have a cylindrical shape. In some embodiments, the proximal portion **50** may be configured to protrude beyond the proximal end **30** of the housing **20** of a rooter **10**. The proximal portion **50** may be configured to engage or be engaged by the proximal retention element **70** (FIGS. **6**A-**6**D). Such engagement may, in some embodiments, be at least partially enabled by at least one retention feature **52**, such as the helical thread illustrated by FIG. **4**A.

(33) A circumferential rim **54**, which extends around and protrudes from the outer portion **46** of the rotatable element **40**, may delimit, or define a boundary between, the intermediate portion **45** of the rotatable element **40** and its proximal portion **50**. The circumferential rim **54** may provide a stop for a proximal member **120** of an actuator **190** (FIGS. **8**A-**8**D) that cooperates with the rotatable element **40** and is configured to cause the rotatable element **40** to rotate about its longitudinal axis **41**.

(34) In some embodiments, a rooter **10** (FIGS. **1** and **2**) may include a cap **56** configured to cooperate with the circumferential rim **54** to retain the rotatable element **40** within the interior of the housing **20**. An embodiment of the cap **56** that may be used as part of the rooter **10** (FIGS. **1** and **2**) is shown in FIGS. **5**A-**5**C. The cap **56** may be configured to be disposed over the opening **32** (FIGS. **3**A and **3**C) in the proximal end **30** of the housing **20**. In a specific embodiment, the cap **56** may include a receptacle **57** that receives the proximal end **30** of the housing **20**. An interior surface of an end **58** of the cap **56** may be configured to abut the circumferential rim **54** (FIGS. **4**A and **4**C)

of the rotatable element **40** and an edge of the proximal end **30** of the housing **20**, while an aperture **59** through the end **58** of the cap **56** may be configured to receive the proximal portion **50** of the rotatable element **40**.

(35) The cap **56** may, in some embodiments, be held in place on the proximal end **30** of the housing **20** by way of the proximal retention element **70**, an embodiment of which is depicted in FIGS. **6**A-**6**D. The proximal retention element **70** is configured to be coupled with the proximal portion **50** (FIGS. **4**A and **4**C) of the rotatable element **40**. More specifically, the proximal retention element **70** may have the appearance of a cap, with an open distal end **72** and a receptacle **74** that are configured to receive the proximal portion **50** of the rotatable element **40**. In addition, at an opposite end of the receptacle **74** from the open distal end **72**, the proximal retention element **70** may have a substantially closed proximal end **78**.

(36) The receptacle **74** may be configured to engage or to be engaged by the proximal portion **50** (FIGS. **4**A and **4**C) of the rotatable element **40**. In a specific embodiment, the receptacle **74** may include at least one retention feature (not shown), such as a helical thread on an interior surface of the receptacle **74**, configured to mutually engage a corresponding retention feature **52** of the proximal portion **50** of the rotatable element **40**.

(37) An opening **79** may extend through the proximal end **78** of the proximal retention element **70**. In some embodiments, such as that illustrated by FIGS. **6**A-**6**D, the proximal retention element **70** and, in a particular embodiment, its opening **79** may be configured to receive and engage a device that is to be rotated. In the illustrated embodiment, the opening **79** through the proximal end **78** of the proximal retention element **70** communicates with a conduit **82** of a male member **80**. The male member **80** extends through the receptacle **74** of the proximal retention element **70**. When used with an embodiment of rotatable element **40** (FIGS. **4**A-**4**C) that includes a conduit **55**, the male member **80** of the proximal retention element **70** may be configured for insertion into the conduit **55**.

(38) In some embodiments, the proximal retention element **70** may be configured to engage a device that is to be rotated, such as an elongated medical instrument, in a manner that causes the device to rotate as the proximal retention element **70** rotates. For example, and not to limit the scope of this disclosure, the surfaces that define the opening **79** through the proximal end **78** of the proximal retention element **70** may be configured to lock onto, grasp, or engage a surface of the device. As another non-limiting example, the elongated retention element **70** may include one or more features (e.g., a retention slot, a locking feature, etc.) that communicate or are otherwise associated with the opening **79** through the proximal end **78** to enable selective locking, grasping, or other engagement of the surface of the device that is to be rotated. In yet another non-limiting example, the proximal retention element **70** may be configured to couple with a separate device (not shown) that locks onto, grasps, or otherwise engages the surface of the device that is to be rotated.

(39) The distal retention element **60**, an embodiment of which is illustrated by FIGS. **7**A-**7**C, may also have the general appearance of a cap, with an open proximal end **62**, an interior receptacle **64** that communicates with the proximal end **62**, and a substantially closed distal end **68**. The proximal end **62** and the receptacle **64** are configured to receive the distal portion **42** (FIGS. **4**A and **4**B) of the rotatable element **40**. In some embodiments, the receptacle **64** includes one or more retention features (not shown), which may be configured to mutually engage a corresponding retention feature **43** of the distal portion **42** of the rotatable element **40**, such as a helical thread carried by the surface **65** of the depicted receptacle **64**.

(40) The distal end **68** of the distal retention element **60** may include an opening **69**, which may be configured to receive a device that is to be rotated, such as an elongated medical instrument. When such a distal retention element **60** is configured for assembly with an embodiment of rotatable element **40** (FIGS. **4**A-**4**C) that includes a conduit **55** extending therethrough, the opening **69** through the distal end **68** of the distal retention element **60** may be configured for alignment and/or

communication with the conduit **55**.

(41) In addition to being configured to receive a device that is to be rotated, some embodiments of distal retention elements **60** may be configured to lock onto, grasp, or otherwise engage, or at least partially engage, the device that is to be rotated. Without limiting the scope of this disclosure, a distal retention element **60** may include a locking element (not shown) at its distal end **68**, external or internal (i.e., within the opening **69** in the distal end **68**) threading, internal features (e.g., ribs, etc.) that lock onto, grasp, or otherwise engage an outer surface of the device, other locking features, or the distal retention element **60** may be configured to couple with a separate device (not shown) that locks onto, grasps, or otherwise engages the surface of the device that is to be rotated.

(42) Turning now to FIGS. **8**A and **8**G, an embodiment of an actuator **190** that may be used with the embodiments of the housing **20** and the rotatable element **40** shown in FIGS. **4**A-**4**C is illustrated. In particular, the actuator **190** may include a distal member **90** and a proximal member **120**.

(43) In the depicted embodiment, with added reference to FIG. **8**B, the distal member **90** of the actuator **190** comprises a cylindrical element **92** with an aperture **94** extending through its length. The aperture **94** is configured to receive the rotatable element **40** (FIGS. **4**A-**4**C) and, more specifically, to receive the intermediate portion **45** of the rotatable element **40**, enabling the cylindrical element **92** of the distal member **90** to slide, or move, along the length of the rotatable element **40**, without engaging the rotation facilitator (e.g., the helical ridge **47**, etc.) of the rotatable element **40**.

(44) The distal member **90** of the actuator **190** includes a pair of intermediate elements **98** protruding from opposite sides of the cylindrical element **92** and external elements **97** on the ends of the intermediate elements **98**. The intermediate elements **98** of the distal member **90** are capable of being received by the longitudinal slot **34** through the housing **20** (FIG. **3**A). The external elements **97** are capable of protruding from the housing **20** and being received by and coupling with corresponding features on a moveable element **102** of a handle **100** of the rooter **10** (FIGS. **1** and **2**). Thus, the intermediate elements **98** and the external elements **97** of the distal member **90** of the actuator **190** enable movement of the distal member **90** of the actuator **190** along the length of the rotatable element **40** (FIGS. **4**A-**4**C).

(45) At its proximal end **91**, the distal member **90** of the actuator **190** includes alignment features **99** and engagement features that comprise teeth **96**. The alignment features **99** protrude beyond the proximal end **91** of the distal member **90** and are spaced apart and configured (e.g., tapered, etc.) to receive and align a proximal member **120** of the actuator **190** with the distal member **90**. The teeth **96**, which are formed in a proximal edge of the distal member **90**, are configured to engage corresponding engagement features of the proximal member **120**.

(46) As illustrated by FIGS. **8**A and **8**G, as well as by FIGS. **8**C-**8**F, those corresponding engagement features of the proximal member **120** of the actuator **190** comprise teeth **126** formed in a distal edge **129** of the proximal member **120**. In addition to the teeth **126**, the proximal member **120** includes a cylindrical element **122**, an aperture **124** extending through the cylindrical element **122**, and one or more drive features **125** formed in the surface of the aperture **124**. In the specific embodiment shown in FIG. **8**B, the drive features **125** may be configured to engage a corresponding rotation facilitator (e.g., the helical ridge **47**, etc.) of the intermediate portion **45** of the rotatable element **40** (FIGS. **4**A-**4**C). More specifically, the drive features **125** may engage the helical ridge **47** of the intermediate portion **45** of a rotatable element **40**.

(47) The teeth **126** of the proximal member **120** and the teeth **96** of the distal member **90** may be configured in such a way that the teeth **96** of the distal member **90** will engage the teeth **126** of the proximal member **120** as the distal member **90** is forced proximally, causing the rotatable element **45** to rotate in a first direction, or in a forward direction (e.g., clockwise), but enable the teeth **96** of the distal member **90** to disengage the teeth **126** of the proximal member **120** as the proximal member **120** is forced distally (e.g., by a return element **101** (FIGS. **1** and **10**) and rotates in an

opposite second direction, or in a reverse direction (e.g., counterclockwise), such as when resistance on a device that has been coupled to the rotatable element **45** resists rotation in the second direction. In the illustrated embodiment, each tooth **96**, **126** may include radially oriented drive surface and a somewhat circumferentially oriented slip surface that tapers outward from the base of one drive surface to the top of the next drive surface.

(48) In some embodiments, such as that depicted by FIG. **1**, a rooter **10** that incorporates teachings may also include a return element **101**, which is also referred to herein as a “biasing element,” (e.g., a spring, etc.) that causes the actuator **190** (FIGS. **8**A, **8**G, **9**, and **10**) and the moveable element **102** of the handle **100** to return to or substantially to an initial position. When the moveable element **102** is moved in a first direction (e.g., proximally, etc.), energy may be stored in the return element **101**. When the moveable element **102** is released, the resilience of the return element **101**, and the energy stored within the return element **101**, may cause the actuator **190** and the moveable element **102** of the handle **100** to move in an opposite, second direction (e.g., distally, etc.) along the lengths of the housing **20** and the rotatable element **40** of the rooter **10**. As illustrated by FIG. **10**, the return element **101** may comprise an internal compression spring, which, in the depicted embodiment, is compressed between a proximal edge **121** of the cylindrical element **122** of the proximal member **120** of the actuator **190** and an interior surface of the end **58** of the cap **56** as the moveable element **102** and, thus, the cylindrical element **122** of the proximal member **120** are force proximally along the rotatable element **40** and the housing **20**. A distal end of the return element **101** abuts the proximal edge **121** of the cylindrical element **122** of the proximal member **120** of the actuator **190**, while a proximal end of the return element **101** is held in place against the interior surface of the end **58** of the cap **56** (FIGS. **5**A-**5**C). The return element **101** concentrically surrounds the rotatable element **40** of the rooter **10**.

(49) Return elements **101** that are centered around the rotatable element **40**, such as the compression spring embodiments of the return element **101** shown in FIGS. **1** and **10**, enable the cylindrical element **122** of the proximal member **120** of the actuator **190** to remain concentric or substantially concentric with the longitudinal axis **41** of the rotatable element **40**. Thus, such a return element **101** prevents cocking of the actuator **190** relative to the rotatable element **40** and facilitates smooth strokes as the actuator **190** moves along the length of the rotatable element **40**. Of course, a rooter **10** may also include other embodiments of return elements **101**, including other types of internal springs, external springs (e.g., a torsion spring, which, in the embodiment depicted by FIG. **1**, may be positioned between the moveable element **102** and the elongated handle **110** or equivalent features, etc.), the flexibility and resiliency of a connector **105** between bottom ends of the elongated handle **110** and the moveable element of the handle **100**, and/or other apparatus that will cause the actuator **190** to automatically reverse its position.

(50) The automatic return of the actuator **190** to its initial position may also cause the rotatable element **40** to rotate in its opposite direction, provided that any rotational resistance on a device that has been coupled to the coupling element **60** is not sufficient to overcome the biasing force of the return element **101**. In the event that rotational resistance on the device is sufficient to overcome the biasing force of the return element **101**, the proximal member **120** of the actuator **190** may disengage the distal member **90** of the actuator **190**, enabling the distal member **90** to slide distally along the rotatable element **40** and the proximal member **120** to rotate freely relative to the rotatable element **40**.

(51) Returning reference to FIG. **2**, assembly of a rooter **10** that includes the above-described elements may be accomplished by assembling the rotatable element **40** and the actuator **190**. The distal portion **42** of the rotatable element **40** may be introduced into and through the apertures **94** and **124** of the cylindrical elements **92** and **122** of the distal member **90** and the proximal member **120** of the actuator **190**. As the rotatable element **40** is pushed distally through the aperture **124** of the cylindrical element **122** of the proximal member **120**, the drive features **125** of the proximal member **120** may engage the helical ridge **47** that protrudes from the outer surface **46** of the

intermediate portion **45** of the rotatable element **40**.

(52) Assembly of the housing **50** and the actuator **190** may include introduction of the cylindrical elements **92** (FIGS. **8**A and **8**G) and **122** (FIGS. **8**A and **8**G) of the distal member **90** and the proximal member **120** of the actuator **190** into the opening **32** at the proximal end **30** of the housing **20**, with the intermediate element(s) **98** of the distal member **90** of the actuator **190** located within the longitudinal slot(s) **34** through the housing **20**. The moveable element **102** of the handle **100** is, of course, located outside of the housing **20**, and protrudes from the housing **20**.

(53) The distal portion **42** of the rotatable element **40** may be introduced into the opening **32** at the proximal end **30** of the housing **20** to assemble the rotatable element **40** with the housing **20**. The distal portion **42** of the rotatable element **40** is then moved distally through the interior **24** of the housing **20**, until the distal portion **42** reaches the distal end **26** of the housing **20**. The distal portion **42** of the rotatable element **40** may then be introduced into and through the opening **28** in the distal end **26** of the housing **20**, until the distal portion **42** of the rotatable element **40** protrudes from the distal end **26** of the housing **20**.

(54) With the distal portion **42** of the rotatable element **40** protruding from the distal end **26** of the housing **20**, the longitudinal position of the rotatable element **40** within the interior **24** of the housing **20** may be fixed or substantially fixed by coupling the distal retention element **60** to the distal portion **42** of the rotatable element **40**.

(55) When the housing **20** and the rotatable element **40** are assembled, the proximal portion **50** of the rotatable element **40** protrudes beyond the proximal end **30** of the housing **20**. To hold the rotatable element **40** and the actuator **190** within the interior **24** of the housing **20**, the cap **56** may then be placed over the proximal end **30** of the housing **20**. More specifically, the receptacle **57** of the cap **56** may be positioned over the proximal end **30** of the housing **20**. Additionally, the proximal portion **50** of the rotatable element **40** may be aligned with the aperture **59** through the end **58** of the cap **56**. As the cap **56** moves distally relative to the housing **20** and the rotatable element **40**, the proximal portion **50** of the rotatable element **40** may be positioned around proximal portion **50** of the rotatable element **40**.

(56) The cap **56** may be held in place relative to the proximal end **30** of the housing **20** by coupling the proximal retention element **70** to the protruding proximal portion **50** of the rotatable element **50**.

(57) Some embodiments of use of a rooter **10** according to this disclosure to rotate devices, such as elongated medical instruments, and to perform various procedures, including medical procedures, are disclosed. Since the rooter **10** may be configured to be used with a plurality of different types of devices, it provides a user (e.g., a healthcare provider, etc.) with a great deal of flexibility in selecting a specific device with which he or she prefers to perform a certain procedure.

(58) In use, a proximal end of device that is to be rotated may be introduced into an opening **69** in the distal end **68** of the distal retention element **60** of the rooter **10**. When the device comprises a relatively short device, insertion of the proximal end of the device into the opening **69** may at least partially couple the device to the rooter **10** without inserting the device further into the rooter **10**. In embodiments where the device comprises a longer device, its proximal end may be inserted only into the opening **69** of the distal end **68** of the distal retention element **60**, or the proximal end of the device may be inserted further into the rooter **10**. Without limiting the scope of this disclosure, the proximal end of the device may also be pushed proximally through the conduit **55** of the rotatable element **40** of the rooter **10**, and through the opening **79** through the proximal end **78** of the proximal retention element **70** of the rooter **10**.

(59) With the device in place, it may be rotationally coupled to the rooter **10**. In embodiments where the distal retention element **60** and/or the proximal retention element **70** of the rooter **10** includes features that lock onto, grasp, or otherwise engage a surface of the device that is to be rotated, rotational coupling of the device to the rooter **10** occurs during assembly of the device with the rooter **10**. In other embodiments, at least one separate locking device may be assembled with

and lock onto, grasp, or otherwise engage the surface of the device that is to be rotated, and each locking device may be coupled to the distal retention element **60** or the proximal retention element **70** of the rooter **10**. Rotational coupling of the device to the distal retention element **60** or the proximal retention element **70** may be effected in a manner that causes the device to rotate as the distal retention element **60** and/or the proximal retention element **70** rotates.

(60) Rotation of the device (e.g., about its longitudinal axis, etc.) may be effected by causing the rotatable element **40**, as well as the distal retention element **60** and/or the proximal retention element **70**, to rotate (e.g., about longitudinal axis **41**, etc.). In the illustrated embodiment, such rotation may be caused by moving the moveable element **102** of the handle **100** of the rooter **10** along the length of the housing **20** of the rooter **10**. As the moveable element **102** is moved along the length of the housing **20**, the intermediate element **98** of the distal member **90** of the actuator **190** moves through the longitudinal slot **34** in the housing **20**, which causes the cylindrical element **92** of the distal member **90** of the actuator **190** within the interior **24** of the housing to move along the length of the rotatable element **40**. As the cylindrical element **92** moves proximally along the length of the rotatable element **40**, it forces the cylindrical element **122** of the proximal member **120** of the actuator **190** to move proximally along the length of the rotatable element **40**. As the cylindrical element **122** moves proximally, drive features **125** (FIG. **8**C) on or in the interior surface of the aperture **124** of the cylindrical element **122** may engage the complementarily configured rotation facilitator **47** of the rotatable element **40** (e.g., the depicted helical ridge, etc.). The configurations of the longitudinal slot **34** and the actuator **190** (specifically, the intermediate element(s) **98** of the distal member **90**) may prevent rotation of the cylindrical element **92** of the distal member **90** within the interior **24** of the housing **20**, or at least enable the rotatable element **40** to rotate relative to the housing **20**. During rotation of the rotatable element **40**, one or both of the distal retention element **60** and the proximal retention element **70** to rotate relative to the housing **20**, which rotation may also cause the device that is to be rotated to spin relative to the housing **20** of the rooter **10**. If the rooter **10** is held stationary, or at least substantially stationary, movement of the moveable element **102** of the handle **100** of the rooter **10** may cause the device to rotate or spin. In other embodiments, the rooter **10** may be used to rotationally oscillate the device, which may enhance the performance of the device. As an example, oscillation of a device may cause some vibration or quivering of the device, which may reduce friction during use of the device.

(61) Rotation or oscillation of the device may be effected during or separately from longitudinal movement (e.g., distal movement, proximal movement, back-and-forth movement, etc.), or hammering movement, of the device. Conversely, hammering movement of a device may be effected with our without rotation or oscillation of the device.

(62) When the proximal end of a tubular device is accessible from or proximally beyond the proximal end of the rooter **10** (e.g., beyond the proximal end **78** of the proximal retention element **70** of the rooter **10**, etc.), other activities (e.g., aspiration, infusion, introduction of other elongated medical instruments, etc.) may be effected through the tubular device while it is assembled with the rooter **10** and, in some embodiments, as the tubular device is rotated, spun, or oscillated.

(63) Although the foregoing description contains many specifics, these should not be construed as limiting the scope of any of the appended claims, but merely as providing information pertinent to some specific embodiments that may fall within the scopes of the disclosed subject matter the appended claims. Other embodiments may also be devised which lie within the scopes of the appended claims. Features from different embodiments may be employed in combination. The scope of each claim is, therefore, indicated and limited only by its plain language and the legal equivalents to the claim elements. All additions, deletions, and modifications to the disclosed subject matter that fall within the meaning and scopes of the claims are to be embraced thereby.

Claims

1. A rooter, comprising: a rotatable element having a longitudinal axis and a length; an actuator, including: a first member movable along the length of the rotatable element and including a first side; and a second member movable along the length of the rotatable element and including a second side positionable against the first side of the first member, the second member having: an engaged arrangement in which the second member engages the first member in a manner that prevents rotation of the first member about the longitudinal axis of the rotatable element and enables the first member to rotate the rotatable element in a first direction and a second direction; and a disengaged arrangement in which the second member prevents the first member from rotating the rotatable element in the second direction by permitting the first member to rotate about the longitudinal axis of the rotatable element.
2. The rooter of claim 1, wherein the engaged arrangement of the second member of the actuator enables the first member to drive rotation of the rotatable element as the first member moves along the length of the rotatable element.
3. The rooter of claim 1, wherein the second member of the actuator can only be in the engaged arrangement when the second member pushes the first member of the actuator along the length of the rotatable element.
4. The rooter of claim 1, wherein the disengaged arrangement of the second member of the actuator enables the first member of the actuator to move along the length of the rotatable element without rotating the rotatable element.
5. The rooter of claim 3, wherein the disengaged arrangement of the second member of the actuator enables the first member of the actuator to move along the length of the rotatable element without rotating the rotatable element.
6. The rooter of claim 1, wherein the rotatable element includes a coupling element.
7. The rooter of claim 6, wherein the coupling element includes a medical device engagement feature.
8. A rooter, comprising: a rotatable element; and an actuator that causes the rotatable element to rotate, the actuator including: a second member that slides over the rotatable element without driving rotation of the rotatable element, the second member including a second side; and a first member that drives rotation of the rotatable element in a first direction and can drive rotation of the rotatable element in a second direction, the first member including a first side that can: engage the second side of the second member upon encountering less than a threshold resistance while rotating the rotatable element in the second direction to hold the second member rotationally stationary as the first member moves along the rotatable element to drive rotation of the rotatable element in the second direction, disengage the second side of the second member upon encountering at least the threshold resistance while rotating the rotatable element in the second direction to prevent the rotatable element from rotating in the second direction as the first member moves along the rotatable element by enabling the first member to rotate about the longitudinal axis of the rotatable element.
9. The rooter of claim 8, wherein the second member engages the first member as the second member is forced against the first member to hold the first member rotationally stationary and to enable the first member to drive rotation of the rotatable element in the first direction.
10. The rooter of claim 8, further comprising: a moveable element of a handle coupled to the second member of the actuator to force the second member over the length of the rotatable element and cause the second member to engage the first member to hold the first member rotationally stationary while forcing the first member over the length of the rotatable element to drive rotation of the rotatable element in the first direction.
11. The rooter of claim 8, further comprising: a biasing member that exerts a longitudinally

oriented force on the first member.

12. The rooter of claim 8, further comprising: a biasing member that forces the first member along the length of the rotatable element.

13. The rooter of claim 12, wherein the biasing member comprises a coiled spring with: a first end abutting a second side of the first member of the actuator, an intermediate portion surrounding a portion of the rotatable element, and a second end held at a fixed location.

14. The rooter of claim 8, wherein the second side of the second member of the actuator and the first side of the first member of the actuator comprise cooperating teeth.

15. The rooter of claim 14, wherein: teeth of the second member of the actuator are arranged in a circle on the second side of the second member; and teeth of the first member of the actuator are arranged in a circle on a first side of the first member.

16. The rooter of claim 15, wherein each tooth of the cooperating teeth includes: a drive surface oriented radially to hold the first member of the actuator rotationally stationary when the second member of the actuator forces the first member along the rotatable element to drive rotation of the rotatable element in the first direction; and a slip surface tapering outward from a base of the drive surface to enable the teeth of the first member to disengage the teeth of the second member to enable rotation of the first member about the rotatable element and movement of the first member along the rotatable element when the rotatable element resists rotation in the second direction.

17. The rooter of claim 8, further comprising: a housing carrying the rotatable element.

18. A method for rotating an elongated medical device, comprising: securing a proximal end of the elongated medical device to a coupling element of a manually operable rooter; forcing a second member of an actuator of the manually operable rooter over a rotatable element of the manually operable rooter in a first direction without the second member rotationally driving the rotatable element; causing the second member of the actuator to engage a first member of the actuator of the manually operable rooter in a manner that prevents the first member from rotating relative to the rotatable element, moves the first member over the rotatable element in the first direction, and enables to the first member to drive rotation of the rotatable element and rotation of the elongated medical device in a first rotational direction; releasing a force on the second member of the actuator; and forcing the first member of the actuator over the rotatable element in a second direction to enable the first member to rotate the rotatable element in a second rotational direction.

19. The method of claim 18, further comprising: upon releasing the force on the second member of the actuator, disengaging the first member of the actuator from the second member of the actuator if the elongated medical device resists rotation in a second rotational direction opposite from the first rotational direction, enabling the first member to rotate about the rotatable element and to move along the rotatable element in the second direction without rotating the rotational element in the second rotational direction.

20. The method of claim 18, further comprising: upon releasing the force on the second member of the actuator, maintaining engagement between the first member of the actuator and the second member of the actuator if the elongated medical device can rotate in the second rotational direction opposite from the first rotational direction, holding the first member rotationally stationary relative to the rotatable element, and causing the first member to move along the rotatable element in the second direction and drive rotation of the rotatable element in the second rotational direction.