

US Patent & Trademark Office

Patent Public Search | Text View

United States Patent Application Publication

20250261937

Kind Code

A1

Publication Date

August 21, 2025

Inventor(s)

Deville; Derek Dee et al.

MULTIPLE-FIRING SUTURE FIXATION DEVICE AND METHODS FOR USING AND MANUFACTURING SAME

Abstract

A multiple-firing clip device includes a hollow shaft defining a lateral opening communicating with an environment and a distal shaft portion between the lateral opening and a distal end opening. A shuttle longitudinally moves on the shaft and comprises a shuttle body defining a lumen surrounding the shaft, a snare, and a snare-extender slide defining a snare track to form a snare travel path in which the snare is disposed from the body and through the track and a portion of the body. The slide moves along a given extent defining a slide distance and a distal end and movement of the slide to the distal end shortens the snare travel path to extend the snare portion through the lateral opening, through the distal shaft portion, and distally out from a distal side of the body longer than the given extent to secure a suture with the snare.

Inventors: Deville; Derek Dee (Coral Gables, FL), Smith; Kevin W. (Coral Gables, FL), Kirk; Michael Walter (Miami, FL), Rivera; Carlos (Cooper City, FL), Nunez; George (Miami, FL), Bales, Jr.; Thomas O. (Miami, FL), Kline; Korey (Miami, FL), Palmer; Matthew A. (Miami, FL), McBrayer; M. Sean (Miami, FL), Cartledge; Richard George (Boca Raton, FL), Mendez; Max Pierre (Miami, FL), Dang; Kevin K. (Huntington Beach, CA), Janish; Bryan A. (Huntington Beach, CA), Miraki; Manouchehr A. (Laguna Hills, CA)

Applicant: Edwards Lifesciences AG (Nyon, CH)

Family ID: 1000008586795

Appl. No.: 19/069961

Filed: March 04, 2025

Related U.S. Application Data

parent US continuation 17455215 20211116 parent-grant-document US 12251097 child US 19069961

parent US continuation 16355373 20190315 parent-grant-document US 11172924 child US

17455215

parent US continuation 14965323 20151210 parent-grant-document US 10624630 child US 16355373

us-provisional-application US 62164016 20150520

us-provisional-application US 62103045 20150113

us-provisional-application US 62096749 20141224

us-provisional-application US 62090097 20141210

Publication Classification

Int. Cl.: **A61B17/04** (20060101); **A61B17/00** (20060101); **A61B90/00** (20160101); **A61B90/30** (20160101)

U.S. Cl.:

CPC **A61B17/0485** (20130101); **A61B17/0467** (20130101); **A61B17/0487** (20130101); **A61B2017/00017** (20130101); **A61B2017/00119** (20130101); **A61B2017/00349** (20130101); **A61B2017/00358** (20130101); **A61B2017/00398** (20130101); **A61B2017/00477** (20130101); **A61B2017/00734** (20130101); **A61B2017/00876** (20130101); **A61B2017/00902** (20130101); **A61B2017/0488** (20130101); **A61B2017/0496** (20130101); **A61B2090/064** (20160201); **A61B2090/0807** (20160201); **A61B2090/309** (20160201); **A61B2090/3937** (20160201)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 17/455,215, filed Nov. 16, 2021, which is a continuation of U.S. patent application Ser. No. 16/355,373, filed Mar. 15, 2019, now U.S. Pat. No. 11,172,924, which is a continuation of U.S. patent application Ser. No. 14/965,323, filed Dec. 10, 2015, now U.S. Pat. No. 10,624,630, which claims the benefit of U.S. Patent Application No. 62/090,097, filed Dec. 10, 2014; U.S. Patent Application No. 62/103,045, filed Jan. 13, 2015; U.S. Patent Application No. 62/164,016, filed May 20, 2015; and U.S. Patent Application No. 62/096,749, filed Dec. 24, 2014, the entire disclosures all of which are incorporated by reference for all purposes. This application is also related to: U.S. patent application Ser. No. 13/715,640, filed Dec. 14, 2012, now U.S. Pat. No. 9,017,347; U.S. patent application Ser. No. 13/938,071, filed Jul. 9, 2013; U.S. patent application Ser. No. 14/307,694, filed Jun. 18, 2014; U.S. patent application Ser. No. 14/329,797, filed Jul. 11, 2014; U.S. patent application Ser. No. 14/543,240, filed Nov. 17, 2014; U.S. patent application Ser. No. 14/658,575, filed Mar. 16, 2015; and U.S. patent application Ser. No. 14/868,741, filed Sep. 29, 2015, the entire disclosures all of which are incorporated by reference for all purposes.

FIELD

[0002] The present invention lies in the field of securing cords, such as surgical sutures. The present disclosure relates to a multiple-firing securing device and methods for using and manufacturing same.

BACKGROUND

[0003] Tying sutures in surgical procedures is as old as the first stitch and knot used to close a wound. When stitching wounds, a cable, cord, or other string-like object is passed through both sides of the wound and is tightened down against the wound to close the two sides together. The most common way to tighten down the cord is to tie a knot. This entails forming a loop and passing

one of the free ends of the cord through the loop at least once. When the free ends of the cord are pulled away from one another, the knot reduces until there is no more room for reduction. If left alone, the knot could come loose. Therefore, techniques for forming different and varying knots have been established. In each case, the surgeon desires the knot to be tied with a sufficient tying force, referred to herein as a locking state, that, if retained after letting go of the ends of the cord, will form a stitch that holds the wound closed. Therefore, in the process for securing the knot, a second knot can be employed directly over or after the first knot to retain the first knot in the locking state with a desired tying force. As long as the first knot does not move or loosen while the second securing knot is placed, then the locking state of the first knot remains. However, there are various counter-forces working against keeping the first knot within the locking state. These counter-forces include the removal of the original tying force, the physical structure of the compressed suture expanding back to its uncompressed steady state, the bends of the knotted suture expanding back to their un-bent state, expansion or swelling of the wound tissue, and others. As such, once the surgeon places the first knot in the locking state and releases the first knot to tie the second locking knot, there is a great chance that that first knot will unravel and leave the locking state, thereby reducing the force from the desired tying force. Accordingly, when surgical stitching is done by hand, the surgeon is required to keep up the pulling force on the opposing ends of the suture knot throughout the time that the second knot is being considered, tied, and fastened. This is a technique practiced repeatedly by surgeons and requires the surgeon to use their relatively large fingertips. Even with the best skill, however, the first knot routinely leaves the desired locking state after the surgeon has moved from keeping the tying force constant on the first knot.

[0004] After much experience with tying surgical knots, a surgeon can tie them with approximately the same tying force, but this approximation is neither consistent nor accurate. For each surgical procedure, it is possible to accurately measure the desired tying force, but there is no way for a surgeon to know with any confidence that his/her hand-tied knot is tied close to or at the desired tying force.

[0005] Surgical instruments, such as the Cor-Knot (manufactured by LSI Solutions and as described in U.S. Pat. No. 7,833,237 to Sauer), are used to replace hand tied knots at remote sites within the body. Such instruments have both benefits and drawbacks.

[0006] Drawbacks of such surgical instruments include being limited to use with a single suture and a single crimp and generate significant waste during the suture tying process, which waste must be accounted for because there exists the possibility that the waste could be lost within the patient during surgery if safeguards are not taken. In this system “the Cor-Knot system”, a single suture crimp is loaded into the end effector and is secured for a single crimp use. To load the crimp and the snare that passes the suture through the crimp, a loading hook is passed through an end effector. The loading hook has the crimp at its distal end and is attached to a snare loop, which is threaded through the crimp. To secure the crimp between the handle and the snare loop, the snare loop is secured and held outwards as a loop by a teardrop shaped plastic handle. After the hook is threaded into the end effector and the crimp is pressed into the distal end of the end effector, the user must remove the large, plastic handle and dispose of it properly. As such, the action of loading a reload crimp into the device generates a teardrop shaped piece of plastic waste for every single crimp. Care must be taken because there is no positive method of securing the crimp into the ready position within the crimping device. If the crimp becomes dislodged, it may not form a proper securing crimp. This may require the suture to be replaced, which may be extremely difficult. Once the snare loop is used to pull the sutures through the crimp, the snare loop must also be discarded. If during the process of passing the sutures through the crimp the sutures do not fully pass through the crimp, it is possible that the very small crimp could be dislodged from the crimping device and potentially lost within the patient. It would be beneficial to provide a cord-loading device that has minimal or no waste generated during a procedure and that provides multiple securing structures that do not need to be individually loaded during the procedure.

[0007] With regard to keeping the locking state of a knot, such instruments are improved over hand-tied knots. First, the distal end of the instrument is much smaller than the tip of the smallest finger of the surgeon, which tip is used to hold down the first knot in the knot-tying process. These instruments allow the surgeon to keep the very small distal end of the instrument pressed against the first knot while they are tying the second knot. In this way, pressure against the first knot is maintained until just before the second knot is clamped down on the first knot. The time while the second knot is not against the first knot leaves a gap that allows the first knot to leave the locking state. It would be beneficial to minimize such a gap and to keep the tying force on the first knot to prevent unwinding or opening of the first knot. As with the surgeon's hands, there is no way for such prior art instruments to know whether the first knot is tied with a force that is close to or at the desired tying force and, especially, is not so much greater to cause harm at the surgical site. Accordingly, it would be beneficial to know, in advance, what is the desired tying force for a particular suture and, during suturing, to know if the suture is being tied and kept at the tying force. [0008] Thus, a need exists to overcome the problems with the known systems, designs, and processes as discussed above.

SUMMARY

[0009] A multiple-firing securing device and methods for using and manufacturing same are described herein. In some embodiments, the described devices and methods can overcome the disadvantages of known devices and methods of this general type are described and shown herein.

[0010] The multiple-firing securing device does not generate waste during a procedure and allows enough securing structures (e.g., disks, crimps) for a complete procedure to be loaded before the procedure and, therefore, do not need to be individually loaded during the procedure. The multiple-firing securing device holds a number of securing structures within the device prior to performing a procedure. During the procedure, the multiple-firing securing device automatically loads a single securing structure in a delivery position that is ready to be secured and is in a position allowing cords to pass therethrough for securing after the cords are tightened. The multiple-firing securing device provides a mechanism that passes the cords through one securing structure, placing the securing structure in a ready-to-fire position. The multiple-firing securing device provides a reliable, reusable way of passing the cords through one securing structure at a time for each of the multiple loaded securing structures. There is no waste or separate parts to account for during or after a surgical procedure.

[0011] As used herein, the multiple-firing securing device is able to be used on cords. As defined herein, the term cords is not limited to a plurality of cords, cords can be a single cord as well and, therefore, cords and cord are used interchangeably. For example, four lengths of cord can be threaded through a securing structure for securing one or more of the cords therein after the securing step occurs. Cords also are not limited to a particular type of material. The material can be made of natural fibers, man-made or synthetic fibers, plastics, and/or metals, to name a few. Cords also are not limited to a particular structure. The material can be made of twisted strands, twisted strands with a central core, or a single strand or wire, to name a few. One exemplary embodiment described herein relates to securing a surgical suture with a crimp of the multiple-firing crimp device and another exemplary embodiment described herein relates to securing a surgical suture with a disk of the multiple-firing disk device. The embodiments described herein, however, are not limited to surgical sutures, even though the example of surgical sutures is referred to or is used herein.

[0012] Traditionally, surgical sutures are cut by advancing a movable knife. One exemplary embodiment of the multiple-firing securing device uses a movable knife. Another exemplary embodiment of the multiple-firing securing device uses a fixed knife and a blunt pusher that contacts the suture and moves it to and against the fixed knife for cutting. This configuration prevents cutting from happening prematurely and allows precise control of the distance that the suture is cut from the securing device. A further exemplary embodiment of a multiple-firing

securing device uses a movable inner cylinder movably housed within an outer cylinder having a window through which the cord is passed, the adjoining edges of the window and an edge of the inner cylinder forming scissors that cut the cord when the inner cylinder is moved distally past a given extent. This configuration prevents cutting from happening prematurely and allows precise control of the distance that the suture is cut from the disk.

[0013] In general, the systems and methods herein provide ways to pull cords such as surgical sutures through a set of cord securing structures, such as crimps, clips, and/or disks, all of which are used interchangeably herein. In any multi-fire applier device for fixing cords, a user must be able to pull the cords through a single securing structure where many of the securing structures are loaded in the device. In other words, the device must be a structure-threading device that can be reused during a single surgical procedure. The mechanism that pulls through the securing structure must be easy to use, have a low profile, should not produce waste during use, and significantly, should not be able to leave behind any separate parts. The challenges associated with such a device arise because the device must have a low profile in general and must be able to thread cords through a very small diameter securing structure (e.g., crimp, clip).

[0014] Many steps are undertaken in order to secure a structure onto cords with a multi-fire securing applier. First, the structure must be loaded from a magazine of multiple similar structures. Then, the cords must be threaded through that one structure that will secure the cords but not be threaded within or interfere with the other structures in the magazine. Then, the securing structure must be secured (e.g., crimped, crushed, released) onto the cords at a location that is, typically, very close to a cord-tying location (e.g., a surgical site). Finally, the device must be able to cut the cords extending out of the securing structure, dispose of the cut ends, and present a new securing structure for use next with as little user manipulation as possible.

[0015] It is beneficial to provide an automated device. In such a device, there are different moving assemblies, such as a carriage, a snare-extender, a cord lifter, a crimper or releaser, and a cutter. A handle contains automated motors, servos, and/or transmissions to carry out the functions of each of these movement assemblies. The handle is provided with a single mechanical control device for each of these assemblies or combination control devices that effect two or more functions. Alternatively, some or all of the automated actions can be replaced with mechanical systems. In any embodiment, simplicity in the entire process of installing a new structure, securing the structure at the cords, and loading another structure for repetitive cycles is important. One exemplary embodiment provides a shuttle that translates on the shaft of the device and, when positioned distally, presents a loop into which the cords to be secured are passed. This loop is referred to as a snare herein. The loop is, then, pulled back into the shuttle before the shuttle begins to move proximally. The proximal motion of the shuttle utilizes the loop to draw the cords through the securing structure and expose them to the outside of the shaft. The shuttle has a formed wire guide or channel that resides outside of the outer diameter of the device's shaft and that wire guide is able to move from outside the shaft to inside the shaft, through a window in a side of the shaft (e.g., at an upper side), and then into or through a proximal end of the securing structure. When the tails of the cords are pulled through the securing structure with the shuttle, the tails are dropped off external to the shaft so that they can be grabbed by the user's hands for tensioning and subsequent securement.

[0016] In exemplary embodiments described, the snare is housed in the shuttle, which moves along the shaft attached to the handle of the securing device. If the snare is damaged during a procedure, the entirety of the shuttle containing the snare can be removed from the handle and the shaft and an entirely new shuttle from a separate, sterilized package can be used in place of the damaged shuttle.

[0017] In the exemplary embodiments, the shuttle contains various interlocks. One interlock prevents the formed wire snare from being presented until the shuttle is in a distal-most position. Another interlock prevents the shuttle from moving proximally if the snare is extended in any way. Another interlock holds the shuttle at a distal-most position for (1) extending the snare and (2)

retracting the cords with movement of a shuttle saddle to position the cords in a radiused tip of the snare. Another interlock prevents the snare from moving when the cords reside in the tip and the shuttle is moving proximally to pass the cords through the crimp and thereafter present the cords outside the shaft for handling by the user.

[0018] An exemplary embodiment of the snare is formed and created from Nitinol and has a tight-radiused tip section that prevents the snare from pinching on the cords it snares while it pulls the cords through the securing device and then moves the cords to the outside of the shaft. This tight-radiused tip also ensures entry into a snare guide tube. The reservoir tip of the snare is stopped short of coming into the shuttle to form an open loop that allows the free tails of the cords to be exposed after passing through the securing device and falling free outside the shaft. The snare may be formed of any number of materials such as stainless steel, titanium, or a polymer.

[0019] Ideally, when the handle is in the middle of any of the crimping, cutting, or loading processes, the handle prevents the shuttle from moving away from the nose of the handle. In contrast, when the shuttle is advanced away from the handle, handle functions may be enabled or disabled as appropriate when the shuttle is either moving or is away from the nose.

[0020] Additional interlocks are present to enable/lock out functions in the handle based on a position of the shuttle when in its most proximal position, e.g., resting against the handle. After the shuttle is at the nose of the handle, the user can pull on the cords that run through the securing device and hang loose through a window of the shaft. When in the snaring position, the shuttle can be held by friction and/or with one or more detents or interlocks.

[0021] With the foregoing and other objects in view, there is provided, a multiple-fire securing device including a hollow outer shaft, a reloader, a rail, a reloader movement assembly, and a plurality of securing structures each defining an inner securing orifice. The reloader is longitudinally movable within the outer shaft and has a distal end shaped to temporarily contact one of the securing structures. The rail is disposed within the reloader and the plurality of securing structures are disposed on the rail. The rail has an installing location. The reloader movement assembly moves the reloader longitudinally in a distal direction to deliver a first securing structure to the installing location from a first proximal position and moves the reloader proximally away from the installing location without the first securing structure to a position in which the distal end of the reloader temporarily contacts a second one of the securing structures.

[0022] In accordance with another feature, the inner clipping orifice is an H-shaped orifice.

[0023] In accordance with a further feature, the rail has an H-shape cross-section.

[0024] In accordance with an added feature, the rail has a rectangular cross-section.

[0025] In accordance with an additional feature, the reloader movement assembly moves the reloader longitudinally further in the distal direction to remove the first securing structure from the installing location and off of the rail before moving the reloader proximally away from the installing location to the second securing structure.

[0026] In accordance with yet another feature, when at least one cord to be secured is disposed through the inner securing orifice of the first securing structure, removal of the first securing structure from the rail causes the first securing structure to secure the at least one cord within the inner securing orifice of the first securing structure.

[0027] In accordance with yet a further feature, after the reloader contacts the second securing structure, the reloader movement assembly moves the reloader longitudinally in the distal direction to deliver the second securing structure distally along the rail to the installing location.

[0028] In accordance with yet an added feature, when at least one cord to be secured is disposed through the inner securing orifice of the second securing structure, removal of the second securing structure from the rail causes the second securing structure to secure the cord within the inner securing orifice of the second securing structure.

[0029] In accordance with another feature, there is also provided a multiple-fire securing device comprising a plurality of securing structures each defining an H-shaped orifice, a hollow outer

shaft having an exterior surface, an interior, and a distal end, and defining a lateral opening proximal to the distal end and communicating between the interior and the environment outside the exterior surface, a hollow inner shaft longitudinally movable within the outer shaft and having fingers extending from an intermediate point distally to define opposing structure-grasping slots shaped to temporarily grasp one of the securing structures, an H-shaped rail longitudinally disposed within the inner shaft and shaped to slidably receive thereon the plurality of securing structures, the H-shaped rail having an installing location, an inner shaft movement assembly automatically moving the inner shaft longitudinally in both distal and proximal directions and delivering one securing structure to the installing location by sliding a first securing structure longitudinally along the H-shaped rail from a first proximal position to the installing location and returning to a second proximal position without the first securing structure, and a snare movement assembly. The snare movement assembly has a snare with a snare opening and is shaped to pass through the H-shaped orifice of the first securing structure, to pass out of the interior of the outer shaft distally past the installing location, and to secure the at least one cord temporarily. The snare movement assembly moves the snare through the first securing structure past the installing location and out the distal end of the outer shaft to a snare position in which the at least one cord can be threaded through the snare opening and proximally to pull a portion of the at least one cord secured in the snare opening proximally through the first securing structure and out a side of the outer shaft through the lateral opening and present at least some of the portion of the at least one cord out through the lateral opening for access by a user.

[0030] An exemplary embodiment of the cord-securing devices and methods described herein includes a sensor associated with the device to detect and measure the amount of tying force that is being imparted by the user to the cords when tying a first knot at a location. This sensor supplies information to a display (e.g., on the handle) that shows either the amount of tying force or whether or not the amount of tying force is equal to or greater to a pre-set limit, or both. The display can take any form, such as an LCD display with graphics, an LED with yellow, green, and red display colors, or just a simple yes/no mechanical and/or electrical indicator that sufficient tying force is being applied. In this way, the user can maintain pressure against the first knot until the second knot secures the first knot. There is, accordingly, no time for loosening the first knot before the second knot secures the first knot in place with the tying force intact and leaving the first knot at the locking state. A surgeon can determine, with actual measurements or with pre-supplied data, the desired tying force for a particular cord to be tied (e.g., a surgical suture) and, during tying, to know dynamically if the cord is being tied and kept at the tying force after the cord is released.

[0031] Although the devices and methods are illustrated and described herein as embodied in a multiple-firing securing device and methods for using and manufacturing same, it is, nevertheless, not intended to be limited to the details shown because various modifications and structural changes may be made therein without departing from the spirit thereof and within the scope and range of equivalents of the claims. Additionally, well-known elements of exemplary embodiments will not be described in detail or will be omitted so as not to obscure the relevant details.

[0032] Additional advantages and other features characteristic of the present devices and methods will be set forth in the detailed description that follows and may be apparent from the detailed description or may be learned by practice of exemplary embodiments. Still other advantages may be realized by any of the instrumentalities, methods, or combinations particularly pointed out in the claims.

[0033] Other features that are considered as characteristic for the devices and methods are set forth in the appended claims. As required, detailed embodiments are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one of ordinary skill in the art to variously employ the present devices and methods in

virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description thereof. While the specification concludes with claims defining the features that are regarded as novel, it is believed that the devices and methods will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, which are not true to scale, and which, together with the detailed description below, are incorporated in and form part of the specification, serve to illustrate further various embodiments and to explain various principles and advantages all in accordance with the present devices and methods. Advantages of embodiments will be apparent from the following detailed description of the exemplary embodiments thereof, which description should be considered in conjunction with the accompanying drawings in which:

[0035] FIG. 1 is a fragmentary, longitudinal, cross-sectional view of an exemplary embodiment of an end effector for a multiple-firing crimp device with a crimp sub-assembly in a position ready to load a first crimp;

[0036] FIG. 2 is a fragmentary, longitudinal, cross-sectional view of the end effector of the multiple-firing crimp device of FIG. 1 with the crimp sub-assembly removed;

[0037] FIG. 3 is a fragmentary, side elevational and partially longitudinal cross-sectional view of an exemplary embodiment of a portion of a handle for operating the end effector of FIG. 2 with the crimp sub-assembly fully retracted;

[0038] FIG. 4 is a fragmentary, longitudinal, cross-sectional view of the end effector of FIG. 1 with the crimp sub-assembly in an extended position prior to seating of a crimp;

[0039] FIG. 5 is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle portion of FIG. 3 with the crimp sub-assembly actuators in a carriage-extended position corresponding to FIG. 4;

[0040] FIG. 6 is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. 1 with the crimp sub-assembly in a crimp-seated position ready for use;

[0041] FIG. 6A is a fragmentary, longitudinally cross-sectional view of an enlarged distal portion of the end effector of FIG. 6;

[0042] FIG. 7 is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle portion of FIG. 3 with the crimp sub-assembly actuators in a suture-use position corresponding to FIG. 6;

[0043] FIG. 8 is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. 6 with a snare in an extended snare position ready for capturing one or more cords;

[0044] FIG. 9 is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle portion of FIG. 3 with the snare sub-assembly actuator in a snare-use position corresponding to FIG. 8;

[0045] FIG. 10 is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. 8 with a snare in an extended snare position ready for or capturing a suture and with the suture screw carriage disengaged from the distal-most clip and fully retracted;

[0046] FIG. 11 is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle portion of FIG. 3 with the snare sub-assembly actuator in a snare-use position corresponding to FIG. 10 and with the suture screw carriage disengaged from the distal-most crimp and fully retracted;

[0047] FIG. **12** is a fragmentary, perspective view of the end effector of FIGS. **8** and/or **10** with cords to be captured extended within the loop of the snare;

[0048] FIG. **13** is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. **10** enlarged with respect to FIG. **10**, with the snare in a partially retracted snare position after capturing cords and with the cords having passed partially through the crimp;

[0049] FIG. **14** is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. **13** reduced with respect to FIG. **13** and with the snare in a further partially retracted snare position after capturing the cords;

[0050] FIG. **15** is a fragmentary, side elevational view of the end effector of FIG. **14**;

[0051] FIG. **16** is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle of FIG. **11** with the snare sub-assembly actuator further retracted than the position of the snare corresponding to FIG. **12**;

[0052] FIG. **17** is a fragmentary, longitudinally cross-sectional view of the end effector of FIGS. **14** and **15** with a cord-lifting device in a lowered position;

[0053] FIG. **18** is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. **17** with the cord-lifting device in a lifted position positioning the cords for grasping by a user;

[0054] FIG. **19** is a fragmentary, perspective view of the end effector of FIG. **18**;

[0055] FIG. **20** is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle of FIG. **16** with the cord-lifting device actuated to position the cord lifter to the position corresponding to FIGS. **18** and **19**;

[0056] FIG. **21** is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. **19** with the cord-lifting device in a lifted position, with the suture grasped by a user, and with the snare in the partially retracted position;

[0057] FIG. **22** is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. **21** with the cord-lifting device in a lowered position, with the cords grasped by a user at an acute angle with the longitudinal axis of the end effector, and with the snare in a retracted position;

[0058] FIG. **23** is a fragmentary, perspective view of the end effector of FIG. **22**;

[0059] FIG. **24** is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle of FIG. **20** with the cord-lifting device returned to the unactuated position that places the cord-lifting device in the lowered position corresponding to FIGS. **22** and **23** and with the snare actuator in the retracted position;

[0060] FIG. **25** is a fragmentary, longitudinally cross-sectional view of the end effector of FIG. **23** enlarged with respect to FIG. **23** and with the outer tube partially extended to move the hammer radially inwards and thereby crimp the crimp to the cords therewithin;

[0061] FIG. **26** is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle of FIG. **24** with the outer tube extended distally into the position corresponding to FIG. **25**;

[0062] FIG. **27** is fragmentary, longitudinally cross-sectional view of the end effector of FIG. **25** with the crimp and cords removed;

[0063] FIG. **28** is fragmentary, longitudinally cross-sectional view of the end effector of FIG. **25** with the cutter actuator fully extended to move the cutting blade and thereby cut the cords;

[0064] FIG. **29** is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle of FIG. **26** with the cutter actuator fully extended distally into the position corresponding to FIG. **28** to thereby cut the captured cords;

[0065] FIG. **30** is a fragmentary, perspective view of the end effector of FIG. **25**;

[0066] FIG. **31** is a fragmentary, side elevational and partially longitudinal cross-sectional view of the handle of FIG. **29** with the cutter and crimping actuators retracted proximally to release the crimped crimp and with the crimp sub-assembly ready to reload a new crimp into the end effector;

[0067] FIG. **32** is an enlarged perspective view of the crimp of FIG. **1**;

[0068] FIG. **33** is a longitudinal cross-sectional view of the crimp of FIG. **1**;

[0069] FIG. **34** is an enlarged perspective view of the crimp of FIGS. **33** and **34** after being crimped;

[0070] FIG. **35** is an enlarged perspective and longitudinal cross-sectional view of the crimp of FIGS. **32** and **33** after being crimped;

[0071] FIG. **36** is a photograph of an exemplary embodiment of a distal end of a snare with a loop and its tip expanded;

[0072] FIG. **37** is a photograph of an exemplary embodiment of a snare with a loop and its tip expanded;

[0073] FIG. **38** is a photograph of another exemplary embodiment of a distal end of a snare with a loop and its tip expanded;

[0074] FIG. **39** is a fragmentary, longitudinally cross-sectional view of an exemplary embodiment of an alternative end effector to the device shown in FIGS. **1** to **31** and similar to FIG. **8**, wherein the snare is replaced with a distal hook that hooks the cords and draws them into the assembly for securing with a loaded crimp, this embodiment allowing the user to thread the crimp with a single hand that is holding the device's handle;

[0075] FIG. **40** is a fragmentary, enlarged perspective view of the end effector of FIG. **39**;

[0076] FIG. **41** is a fragmentary, enlarged perspective view of the end effector of FIG. **40** with the hook holding two leads of a suture;

[0077] FIG. **42** is a fragmentary, longitudinally cross-sectional view of an exemplary embodiment of a multiple-firing crimp device having an end effector with a manually actuated crimp sub-assembly in a position with a first crimp loaded for use;

[0078] FIG. **43** is a fragmentary, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42** with the manually actuated crimp sub-assembly in a partial snare-movement position toward the first crimp;

[0079] FIG. **44** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42**;

[0080] FIG. **45** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **43**;

[0081] FIG. **46** is a fragmentary, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42** with the manually actuated crimp sub-assembly lowering the snare guide tube into the snare guide tube loading track and axially aligning with the center of the first crimp;

[0082] FIG. **47** is a fragmentary, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42** with the manually actuated crimp sub-assembly inserting the snare guide tube up to the center of the first crimp for receiving therein the snare, the lowering of the snare guide tube unlocking the snare assembly for distal movement;

[0083] FIG. **48** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **46**;

[0084] FIG. **49** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **47**;

[0085] FIG. **50** is a fragmentary, enlarged, partially longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **47**;

[0086] FIG. **51** is a fragmentary, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42** with the manually actuated crimp sub-assembly extending the snare through the snare guide tube and through and out from the first crimp for receiving therein the cords to be snared, movement of the outer body being locked and only permitting movement of the snare assembly for snare movement;

[0087] FIG. **52** is a fragmentary, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **51** with cords in the snare;

[0088] FIG. **53** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **51**;

[0089] FIG. **54** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **52**;

[0090] FIG. **55** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42** with the manually actuated crimp sub-assembly having retracted the snare and the cords along with the snare guide tube out from the distal end of the shaft assembly and having pulled the cords through the first crimp, movement of the outer body being free in the proximal direction and movement of the snare assembly being free to retract the snared cords;

[0091] FIG. **56** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **42** with the manually actuated crimp sub-assembly having completely retracted the snare from the cords to allow a user to manually pull the free ends of the previously snared suture tight and to place the crimp adjacent to the loop of the cords where crimping is to take place after the user pulls tightly on the cords to place the distal end of the device at the cord-tying location;

[0092] FIG. **57** is a photograph of a fragmentary, perspective view of an exemplary embodiment of a shuttle for the multiple-firing crimp device of FIG. **42**

[0093] FIG. **58** is a fragmentary, perspective view of an exemplary embodiment of a multiple-firing crimp device having an end effector with a manually actuated crimp sub-assembly in a position with a first crimp loaded for use, with a shuttle in a ready to use state, and with a handle removed;

[0094] FIG. **59** is a fragmentary, perspective view of the multiple-firing crimp device of FIG. **58** with the manually actuated crimp sub-assembly with the shuttle in a snare-movement position;

[0095] FIG. **60** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **58** with the shuttle in an intermediate position between the handle and the crimp and with a snare scroll removed;

[0096] FIG. **61** is a fragmentary, enlarged, partially transparent, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **58** with the shuttle in an intermediate position between the handle and the crimp and with the snare scroll removed;

[0097] FIG. **62** is a fragmentary, enlarged, transparent, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **58** with the shuttle in an intermediate position between the handle and the crimp and with the snare scroll removed;

[0098] FIG. **63** is a fragmentary, enlarged, partially transparent, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **59** with the shuttle in a snare-movement position;

[0099] FIG. **64** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **59** with the shuttle in the snare-movement position;

[0100] FIG. **65** is a fragmentary, enlarged, transparent, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **59** with the shuttle in the snare-movement position;

[0101] FIG. **66** is a fragmentary, perspective view of the multiple-firing crimp device of FIG. **58** with the manually actuated crimp sub-assembly with the shuttle in a snare-extended position;

[0102] FIG. **67** is a fragmentary, enlarged, partially transparent, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **66** with the shuttle in the snare-extended position;

[0103] FIG. **68** is a fragmentary, enlarged, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **66** with the shuttle in the snare-extended position;

[0104] FIG. **69** is a fragmentary, enlarged, transparent, longitudinally cross-sectional view of the multiple-firing crimp device of FIG. **66** with the shuttle in the snare-extended position;

[0105] FIG. **70** is a fragmentary, perspective view of an exemplary embodiment of a distal end of a multiple-firing crimp device having a distal headlight assembly in an off state and an end effector with a manually actuated crimp sub-assembly in a position with a first crimp loaded for use and with a shuttle in a ready to use state;

[0106] FIG. **71** is a fragmentary, partially transparent, perspective view of the multiple-firing crimp device of FIG. **70**;

[0107] FIG. **72** is a fragmentary, perspective view of the multiple-firing crimp device of FIG. **70**

with a headlight cover removed;

[0108] FIG. **73** is a fragmentary, transparent, perspective view of the multiple-firing crimp device of FIG. **70**;

[0109] FIG. **74** is a fragmentary, partially transparent, perspective view of the multiple-firing crimp device of FIG. **70** with the shuttle in the snare-extended position;

[0110] FIG. **75** is a perspective view of a left side of an alternative exemplary embodiment of a shuttle body;

[0111] FIG. **75A** is a transparent, perspective view of the shuttle body of FIG. **75**;

[0112] FIG. **75B** is a perspective view of a right side of the shuttle body of FIG. **75**;

[0113] FIG. **76** is a perspective view of a left side of an alternative exemplary embodiment of a shuttle body with snare-extender slide removed;

[0114] FIG. **76A** is a transparent, perspective view of the shuttle body of FIG. **76**;

[0115] FIG. **76B** is a perspective view of a right side of the shuttle body of FIG. **76**;

[0116] FIG. **77** is a perspective view of a left side of a left half of an alternative exemplary embodiment of a shuttle body with snare-extender slide removed;

[0117] FIG. **77A** is a transparent, perspective view of the shuttle body half of FIG. **77**;

[0118] FIG. **77B** is a perspective view of a right side of the shuttle body half of FIG. **77**;

[0119] FIG. **78** is a perspective view of a left side of an alternative exemplary embodiment of a shuttle body with snare-extender slide removed;

[0120] FIG. **78A** is a transparent, perspective view of the shuttle body of FIG. **78**;

[0121] FIG. **78B** is a perspective view of a right side of the shuttle body of FIG. **78**;

[0122] FIG. **79** is a fragmentary, perspective view of a right side of an exemplary embodiment of a handle for a multiple-firing crimp device with the right half of the handle body removed;

[0123] FIG. **80** is a fragmentary, perspective view of the handle of FIG. **79** with a cover of a carriage movement assembly transparent;

[0124] FIG. **81** is a fragmentary, side elevational view of a right side of the handle of FIG. **79** in a crimp-retracted state;

[0125] FIG. **82** is a fragmentary, side elevational view of the right side of the handle of FIG. **79** in a crimp-holding state;

[0126] FIG. **83** is a fragmentary, side elevational view of the right side of the handle of FIG. **79** in a clutched state;

[0127] FIG. **84** is a fragmentary, side elevational view of the right side of the handle of FIG. **79** in a crimp-extended state;

[0128] FIG. **85** is a fragmentary, perspective view of an exemplary embodiment of an end effector of a multiple-firing crimp device with a fixed blade and a blade pushrod in a fully retracted position and a crimping assembly in a non-crimping state;

[0129] FIG. **86** is a fragmentary, perspective view of the end effector of FIG. **85** with the outer tube transparent;

[0130] FIG. **87** is a fragmentary, perspective view of the end effector of FIG. **86** with the crimping assembly in a crimped state;

[0131] FIG. **88** is a fragmentary, perspective view of the end effector of FIG. **87** with the blade pushrod in a partially actuated state before cutting;

[0132] FIG. **89** is a fragmentary, perspective view of the end effector of FIG. **88** with the blade pushrod in a fully actuated state after cutting;

[0133] FIG. **90** is a fragmentary, longitudinally cross-sectional, perspective view of a distal end of the end effector of FIG. **85**;

[0134] FIG. **91** is a fragmentary, longitudinally cross-sectional, perspective view of a distal end of the end effector of FIG. **89**;

[0135] FIG. **92** is a flow chart of a process for completing a crimping procedure with a multiple-firing crimping assembly;

[0136] FIG. **93** is a photograph of a fragmentary, perspective view of an exemplary embodiment of the distal end of the multiple-crimp firing device with a suture wrapped around but not cinched at an illustration of a surgical site;

[0137] FIG. **94** is a photograph of a fragmentary, perspective view of the distal end of the multiple-crimp firing device of FIG. **93** with the suture closed at the surgical site;

[0138] FIG. **95** is a photograph of a fragmentary, perspective view of the distal end of the multiple-crimp firing device of FIG. **93** with the suture and the distal end lifted from the surgical site;

[0139] FIG. **96** is a photograph of a fragmentary, perspective view of the distal end of the multiple-crimp firing device of FIG. **93** with the suture cinched at the surgical site before a tying force is reached;

[0140] FIG. **97** is a photograph of a fragmentary, perspective view of the distal end of the multiple-crimp firing device of FIG. **93** with the suture cinched at the surgical site when the tying force is reached;

[0141] FIG. **97A** is a fragmentary, enlarged, perspective view of the right side of the handle of FIG. **79** with a load sensor for detecting and measuring an amount of force being imparted on the cords at the surgical site before being secured;

[0142] FIG. **98** is a right side elevational view of an exemplary embodiment of a multiple-clip securing device in a ready-to-use state, a snare contained within a retracted snare assembly;

[0143] FIG. **99** is a right side elevational view of the multiple-clip securing device of FIG. **98** in a shuttle-extended state with the snare still contained within the snare assembly;

[0144] FIG. **100** is a right side elevational view of the multiple-clip securing device of FIG. **98** in a snare-extended state with the snare, indicated by dashed lines, extended out from the snare assembly and the snare assembly locked in the shuttle-extended position while the snare is extended;

[0145] FIG. **101** is a right side elevational view of the multiple-clip securing device of FIG. **100** in the shuttle-extended state with the snare retracted back into the snare assembly and the snare assembly unlocked to permit retraction of the snare assembly;

[0146] FIG. **102** is a right side elevational view of the multiple-clip securing device of FIG. **101** in a ready-to-fire-clip state with the snare contained within the snare assembly and the snare assembly locked in position to permit placement of a cord-retaining clip;

[0147] FIG. **103** is a flow chart of a process for performing and completing a securing procedure with a multiple-clip securing device;

[0148] FIG. **104** is a fragmentary, partially transparent, side elevational view of a distal end of an exemplary embodiment of a distal end of the multiple-clip securing device of FIG. **98** with a clip loaded at the distal end in a ready-to-clip state;

[0149] FIG. **105** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **104** with a clip extended off a clip-holding rail and clipped to one or more cords but the cords not yet cut;

[0150] FIG. **106** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **104** with a clip extended off a clip-holding rail and clipped to one or more cords after the cords are cut;

[0151] FIG. **107** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **104** after a clip has been clipped to one or more cords and is ready to cut again or to reload another clip into a clip-ready location;

[0152] FIG. **108** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **104** with a clip pusher moved proximally towards a clip-reloading position and with one of the clip-holding fingers removed for clarity;

[0153] FIG. **109** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **108** with the clip pusher moved distally taking with it a subsequent clip and placing the subsequent clip into a clip-ready position and with one of the clip-

holding fingers removed for clarity;

[0154] FIG. **110** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **109** with a subsequent clip extended off a clip-holding rail and clipped to one or more cords after the cords are cut;

[0155] FIG. **111** is a fragmentary, partially transparent, side elevational view of the distal end of the multiple-clip securing device of FIG. **98** with a last clip on the clip-holding rail, a clip pusher proximal of the last clip, and with one of the clip-holding fingers removed for clarity;

[0156] FIG. **112** is a fragmentary, perspective and partially transparent view of an exemplary embodiment a distal end effector of a multiple-clip securing device with a cutting/reloading assembly in a ready-to-clip position;

[0157] FIG. **113** is a fragmentary, perspective, vertically cross-sectional view of the end effector of FIG. **112**;

[0158] FIG. **114** is a fragmentary, perspective, vertically cross-sectional view of the end effector of FIG. **112** with the cutting/reloading assembly in a clip-delivered position before the first clip is ejected;

[0159] FIG. **115** is a fragmentary, perspective, vertically cross-sectional view of the end effector of FIG. **112** with the cutting/reloading assembly in a clip-delivered position after the first clip is ejected;

[0160] FIG. **116** is a fragmentary, perspective, vertically cross-sectional view of the end effector of FIG. **115** with the cutting/reloading assembly in a subsequent clip-retrieval position;

[0161] FIG. **117** is a fragmentary, perspective, vertically cross-sectional view of the end effector of FIG. **116** with the cutting/reloading assembly in a subsequent clip-retrieval position after the previous 11 clips have been ejected;

[0162] FIG. **118** is a fragmentary, perspective, vertically cross-sectional view of the end effector of FIG. **117** with the cutting/reloading assembly in a ready-to-clip position;

[0163] FIG. **119** is a fragmentary, perspective and vertically cross-sectional view of the distal end of the cutting/reloading assembly of FIG. **112**;

[0164] FIG. **120** is a fragmentary, perspective and horizontally cross-sectional view of the distal end of the cutting/reloading assembly of FIG. **112**;

[0165] FIG. **121** is a fragmentary, enlarged, perspective view from distal of a distal end of an exemplary embodiment of a shaft of the multiple-clip securing device of FIG. **98** with a clip in a snare-ready position and with one of the clip-holding fingers removed for clarity;

[0166] FIG. **122** is a fragmentary, enlarged, partially transparent, perspective view from proximal of the distal end of the shaft of FIG. **121** with a pair of cords, indicated in dashed lines, threaded through the clip before being clipped together to the clip and with both of the clip-holding fingers;

[0167] FIG. **123** is a fragmentary, enlarged, cross-sectional view of the distal end of the shaft of the multiple-clip securing device of FIG. **112** with the clip in a snare-ready position, a path for a cord to be clipped by the clip being indicated with a dashed line;

[0168] FIG. **124** is a fragmentary, enlarged, cross-sectional view of an intermediate portion of the shaft of the multiple-clip securing device of FIG. **112** with a set-screw holding the clip support beam within the shaft;

[0169] FIG. **125** is a fragmentary, perspective and vertically cross-sectional view of the distal end of the cutting/reloading assembly of FIG. **112** with the cutting/reloading assembly in a clip delivery position;

[0170] FIG. **126** is a fragmentary, perspective and horizontally cross-sectional view of the distal end of the cutting/reloading assembly of FIG. **125**;

[0171] FIG. **127** is a fragmentary, enlarged, perspective view from distal of the distal end of the shaft of the multiple-clip securing device of FIG. **112** with the clip ejected from the clip guide beam, disposed within the distal end of the shaft, and clipping a pair of cords before the cords are cut and with one of the clip-holding fingers removed for clarity;

[0172] FIG. **128** is a fragmentary, enlarged, perspective view from distal of the distal end of the shaft of FIG. **127** with the clip clipped on the pair of cords after the cords are cut and before the clip exits the distal end of the shaft and with one of the clip-holding fingers removed for clarity;

[0173] FIG. **129** is a fragmentary, enlarged, cross-sectional view of the distal portion of the shaft of the multiple-clip securing device of FIG. **112** with the clip pushing arm in a first retracted reloading position for reloading a distal-most clip on the clip-guiding rail before the distal-most clip contacts a clip-pushing face of the clip-holding finger, the clip-holding finger being cammed outwards due to an interior cam surface, and with one of the clip-holding fingers being removed for clarity;

[0174] FIG. **130** is a fragmentary, enlarged, cross-sectional view of the distal portion of the shaft of the multiple-clip securing device of FIG. **112** with the clip pushing arm in a second retracted reloading position for reloading the distal-most clip with the clip-pushing face of the clip-holding finger proximal of the distal-most clip, with the cam surface resting on a second distal-most clip and being cammed outwards due to the interior cam surface to retain the finger tip outside the outer diameter of the distal-most clip, and with one of the clip-holding fingers being removed for clarity;

[0175] FIG. **131** is a fragmentary, enlarged, cross-sectional view of the distal portion of the shaft of the multiple-clip securing device of FIG. **112** with the clip pushing arm in a third extended reloading position for reloading the distal-most clip by contacting the clip-pushing face of the clip-holding finger with the proximal side of the distal-most clip and the interior surface of the finger tip of the clip-holding finger with the exterior surface of the distal-most clip, and with one of the clip-holding fingers being removed for clarity;

[0176] FIG. **132** is a fragmentary, enlarged, cross-sectional view of the distal portion of the shaft of the multiple-clip securing device of FIG. **112** with the clip pushing arm in a fourth extended reloading position where the distal-most clip is in an intermediate reloading position on the clip-guiding rail, and with one of the clip-holding fingers being removed for clarity;

[0177] FIG. **133** is a fragmentary, enlarged, cross-sectional view of the distal portion of the shaft of the multiple-clip securing device of FIG. **112** with the clip pushing arm in the clip-loaded, ready-to-clip position, and with one of the clip-holding fingers being removed for clarity;

[0178] FIG. **134** is a fragmentary, enlarged, cross-sectional view of the distal portion of the shaft of the multiple-clip securing device of FIG. **112** with the clip pushing arm in a clipped position, the clip pushed off of the clip-guiding rail, before the clip exits the shaft, and with one of the clip-holding fingers being removed for clarity;

[0179] FIG. **135** is a fragmentary, enlarged, top plan view of a clip pushing arm of FIGS. **129** to **134**;

[0180] FIG. **136** is a fragmentary, enlarged, perspective view of a distal portion of the clip-holding rail of the multiple-clip securing device of FIG. **112** showing an offset of an intermediate floor between two lateral walls;

[0181] FIG. **137** is an enlarged, perspective view of from proximal of a proximal end of the clip-holding rail of the multiple-clip securing device of FIG. **112** showing the chamfers at the proximal end that enable loading the clips thereon with an initially reduced stress;

[0182] FIG. **138** is a photograph of a fragmentary side view of a handle portion of an exemplary embodiment of a multiple-clip securing device with a right cover removed to reveal a power supply, a drop-in single circuit board with side-mounted switches to minimize a footprint of the electrically powered components, a multi-colored LED display, a clip-fire switch, a reload switch, and a motor and gearbox connected to a rack and pinion;

[0183] FIG. **139** is a fragmentary, side perspective view of a portion of the handle of FIG. **138**;

[0184] FIG. **140** is a horizontal cross-sectional view of the handle of FIGS. **138** and **139** viewed from below to reveal an outer shaft sleeve, an inner clip movement tube, and the pinion and rack connected to a proximal portion of the clip movement tube;

[0185] FIG. **141** is a fragmentary, partially vertical cross-sectional, perspective view of an exemplary embodiment of a snare assembly having a movement body in a proximal retracted

position with respect to an interior body to place a snare in its most-retracted position yet still extending slightly out from a snare-guiding tube and a trombone-shaped snare guide path that, in the embodiment shown, provides an extension of the snare out from the snare-guiding tube to distance that is three times the length that the movement body traverse with respect to the interior body;

[0186] FIG. **142** is a fragmentary, partially vertical cross-sectional, perspective view of the snare assembly of FIG. **141** with the movement body in a distal position with respect to the interior body to place the snare in its distal-most extended position;

[0187] FIG. **143** is a fragmentary, vertical cross-sectional view of the snare assembly of FIG. **141** with the lockout in a first lockout state in which: the assembly can translate along the shaft from the handle to the distal end of the shaft while the canopy of the lockout rides in a groove of the shaft to key the interior body of the snare assembly in a fixed circumferential position about the shaft; and one or more side pontoons of the lockout prevent the movement body from moving with respect to the interior body to retain the snare within the snare assembly, and with the components internal to the outer shaft tube removed for clarity;

[0188] FIG. **144** is a fragmentary, vertical cross-sectional view of the snare assembly of FIG. **141** with the lockout in the first lockout state and just before a second lockout state in which the lockout pivots and a wider tail of the lockout enters a lower window of the shaft and the canopy remains within the groove of the shaft or can exit the groove, and with the components internal to the outer shaft tube removed for clarity;

[0189] FIG. **145** is a fragmentary, vertical cross-sectional view of the snare assembly of FIG. **141** with the lockout in a second lockout state in which the lockout pivots and: keeps the interior body circumferentially fixed, either the canopy remains within the groove or the canopy exits the groove while the tail enters the lower window of the shaft distal of the groove or both; and the side pontoons pivot down to no longer prevent the movement body from moving distally with respect to the interior body, thereby allowing the snare to exit, and with the components internal to the outer shaft tube removed for clarity;

[0190] FIG. **146** is a fragmentary, vertical cross-sectional view of the snare assembly of FIG. **141** with the lockout in the second lockout state in which the movement body has moved distally with respect to the interior body and a snare exits for snaring cords to be clipped, and with the components internal to the outer shaft tube removed for clarity;

[0191] FIG. **147** is a fragmentary, partially vertical cross-sectional, perspective view of the snare assembly of FIG. **143** about the shaft with the lockout in the first lockout state, and with the components internal to the outer shaft tube removed for clarity;

[0192] FIG. **148** is a fragmentary, partially vertical cross-sectional, perspective view of the snare assembly of FIG. **144** about the shaft with the lockout in the first lockout state, and with the components internal to the outer shaft tube removed for clarity;

[0193] FIG. **149** is a fragmentary, partially vertical cross-sectional, perspective view of the snare assembly of FIG. **145** about the shaft with the lockout in the second lockout state in which the movement body is free to move distally and, when moved distally, secures the interior body to this distal-most position on the shaft, and with the components internal to the outer shaft tube removed for clarity;

[0194] FIG. **150** is a fragmentary, partially vertical cross-sectional, perspective view of the snare assembly of FIG. **146** about the shaft with the lockout in the second lockout state, and with the components internal to the outer shaft tube removed for clarity;

[0195] FIG. **151** is a fragmentary, enlarged, perspective view of a distal portion of the snare assembly of FIG. **141** illustrating the relative sizes of the groove and lower window of the outer shaft tube and the canopy and tail of the lockout;

[0196] FIG. **152** is a fragmentary, enlarged, partially vertical cross-sectional, perspective view of a distal portion of the snare assembly of FIG. **146** with the lockout in the second lockout state and

with the movement body in a distal position with respect to the interior body and the snare extended for snaring cords to be secured;

[0197] FIG. **153** is a fragmentary, partially vertical cross-sectional, perspective view of a distal portion of the snare assembly of FIG. **143** with the lockout in the first lockout state and with the movement body in a proximal retracted position with respect to the interior body and with the snare in its most-retracted position extending slightly out from the guiding tube;

[0198] FIG. **154** is a horizontal cross-sectional view of a top portion of the handle of FIG. **98** viewed from the bottom to reveal a portion of the handle with magnet holding orifices for receiving magnets that retain the snare assembly at the handle and the snare assembly with a movable outer sleeve, magnet holding orifices for receiving magnets that retain the snare assembly at the distal end of the handle, and a lock-out subassembly including a pivoting lockout;

[0199] FIG. **155** is a vertical cross-sectional view of an exemplary embodiment of a multiple-clip securing device with a drop-in single circuit board with side-mounted switches to minimize a footprint of the electrically powered components, a multi-colored LED display, a clip-fire switch, a reload switch, a distal shaft, a motor and gearbox connected to a rack and pinion disposed in the shaft, and a snare assembly in a proximal-most position on the shaft;

[0200] FIG. **156** is a fragmentary, enlarged, vertical cross-sectional, perspective view of the snare assembly of FIG. **155** in an intermediate position on the shaft;

[0201] FIG. **157** is a vertical cross-sectional view of the multiple-clip securing device of FIG. **155** with the snare assembly at a distal position on the shaft before a snare is extended;

[0202] FIG. **158** is a fragmentary, enlarged, vertical cross-sectional, perspective view of the snare assembly of FIG. **157**;

[0203] FIG. **159** is a fragmentary, enlarged, vertical cross-sectional, perspective view of the snare assembly of FIG. **158** with a snare extension handle removed;

[0204] FIG. **160** is a vertical cross-sectional view of the multiple-clip securing device of FIG. **155** with the snare assembly at the distal position on the shaft in a snare extended configuration, the snare not illustrated;

[0205] FIG. **161** is a fragmentary, enlarged, vertical cross-sectional, perspective view of the snare assembly of FIG. **160**;

[0206] FIG. **162** is a vertical cross-sectional view of the multiple-clip securing device of FIG. **155** with the snare assembly returned to the distal-most position on the shaft in a cord-snared configuration with a snared cord draped below the shaft;

[0207] FIG. **163** is a vertical cross-sectional view of the multiple-clip securing device of FIG. **162** with the cord-securing trigger depressed to secure the cord and the cut cords falling away from below the shaft;

[0208] FIG. **164** is a fragmentary, enlarged, partially vertical cross-sectional and perspective view of the snare assembly of FIG. **156** in an intermediate position on the shaft and with the snare and snare guide tube secured to the shuttle body with a Z-bend;

[0209] FIG. **165** is a fragmentary, enlarged, vertical cross-sectional view of the snare assembly of FIG. **164** in a distal position on the shaft with the snare guiding tube extended into the shaft;

[0210] FIG. **166** is an enlarged perspective view of an exemplary embodiment of a clip-sliding rail of the multiple-clip securing device of FIG. **155** and a set of clips thereon, one in a clip-securing position;

[0211] FIG. **167** is a fragmentary, side elevational and partially transparent view of a proximal securement-movement assembly of an exemplary embodiment of a multiple-fire securing device with a securement moving inner tube shaft in a retracted position and with a proximal handle not illustrated;

[0212] FIG. **168** is a fragmentary, side elevational and partially transparent view of the securement-movement assembly of FIG. **167** with the securement moving inner tube in an extended position;

[0213] FIG. **169** is a fragmentary, perspective and partially transparent view of the securement-

movement assembly of FIG. 168;

[0214] FIG. 170 is a diagrammatic, longitudinally vertical cross-sectional view of an exemplary embodiment of a multiple-firing securement device having a motor-controlled mechanism that moves the inner tube shaft to grasp various securements installed on the guide rail at successively further distances on the guide rail from the securement-installing location and a mechanical lever that moves the entire inner tube shaft assembly distal to perform cutting; and

[0215] FIG. 171 is an enlarged, perspective view of an exemplary embodiment of a cord-securing clip in a steady state;

[0216] FIG. 172 is an enlarged, perspective view of the cord-securing clip of FIG. 171 in an expanded, ready-to-clip state;

[0217] FIG. 173 is an enlarged, front elevational view of another exemplary embodiment of a cord-securing clip in a steady state;

[0218] FIG. 174 is an enlarged, front elevational view of a further exemplary embodiment of a cord-securing clip in a steady state; and

[0219] FIG. 175 is an enlarged, front elevational view of still another exemplary embodiment of a cord-securing clip in a steady state.

DETAILED DESCRIPTION

[0220] As required, detailed embodiments of the systems and methods are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the systems and methods, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the systems and methods in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the systems and methods. While the specification concludes with claims defining the features of the systems and methods that are regarded as novel, it is believed that the systems and methods will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward.

[0221] In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which are shown by way of illustration embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of embodiments is defined by the appended claims and their equivalents.

[0222] Alternate embodiments may be devised without departing from the spirit or the scope of the invention. Additionally, well-known elements of exemplary embodiments of the systems and methods will not be described in detail or will be omitted so as not to obscure the relevant details of the systems and methods.

[0223] Before the systems and methods are disclosed and described, it is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. The terms “comprises,” “comprising,” or any other variation thereof are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by “comprises . . . a” does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element. The terms “including” and/or “having,” as used herein, are defined as comprising (i.e., open language). The terms “a” or “an”, as used herein, are defined as one or more than one. The term “plurality,” as used herein, is defined as two or more than two. The term “another,” as used herein, is defined as at least a second or more. The description may use the terms “embodiment” or

“embodiments,” which may each refer to one or more of the same or different embodiments.

[0224] The terms “coupled” and “connected,” along with their derivatives, may be used. It should be understood that these terms are not intended as synonyms for each other. Rather, in particular embodiments, “connected” may be used to indicate that two or more elements are in direct physical or electrical contact with each other. “Coupled” may mean that two or more elements are in direct physical or electrical contact (e.g., directly coupled). However, “coupled” may also mean that two or more elements are not in direct contact with each other, but yet still cooperate or interact with each other (e.g., indirectly coupled).

[0225] For the purposes of the description, a phrase in the form “A/B” or in the form “A and/or B” or in the form “at least one of A and B” means (A), (B), or (A and B), where A and B are variables indicating a particular object or attribute. When used, this phrase is intended to and is hereby defined as a choice of A or B or both A and B, which is similar to the phrase “and/or”. Where more than two variables are present in such a phrase, this phrase is hereby defined as including only one of the variables, any one of the variables, any combination of any of the variables, and all of the variables, for example, a phrase in the form “at least one of A, B, and C” means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0226] Relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The description may use perspective-based descriptions such as up/down, back/front, and top/bottom. Such descriptions are merely used to facilitate the discussion and are not intended to restrict the application of disclosed embodiments. Various operations may be described as multiple discrete operations in turn, in a manner that may be helpful in understanding embodiments; however, the order of description should not be construed to imply that these operations are order dependent.

[0227] As used herein, the term “about” or “approximately” applies to all numeric values, whether or not explicitly indicated. These terms generally refer to a range of numbers that one of skill in the art would consider equivalent to the recited values (i.e., having the same function or result). In many instances these terms may include numbers that are rounded to the nearest significant figure.

[0228] It will be appreciated that embodiments of the systems and methods described and/or shown herein may be comprised of one or more conventional processors and unique stored program instructions that control the one or more processors to implement, in conjunction with certain non-processor circuits and other elements, some, most, or all of the functions of the powered injector devices described and/or shown herein. The non-processor circuits may include, but are not limited to, signal drivers, clock circuits, power source circuits, and user input and output elements.

Alternatively, some or all functions could be implemented by a state machine that has no stored program instructions, or in one or more application specific integrated circuits (ASICs) or field-programmable gate arrays (FPGA), in which each function or some combinations of certain of the functions are implemented as custom logic. Of course, a combination of these approaches could also be used. Thus, methods and means for these functions have been described herein.

[0229] The terms “program,” “software,” “software application,” and the like as used herein, are defined as a sequence of instructions designed for execution on a computer system. A “program,” “software,” “application,” “computer program,” or “software application” may include a subroutine, a function, a procedure, an object method, an object implementation, an executable application, an applet, a servlet, a source code, an object code, a shared library/dynamic load library and/or other sequence of instructions designed for execution on a computer system.

[0230] Herein various embodiments of the systems and methods are described. In many of the different embodiments, features are similar. Therefore, to avoid redundancy, repetitive description of these similar features may not be made in some circumstances. It shall be understood, however, that description of a first-appearing feature applies to the later described similar feature and each respective description, therefore, is to be incorporated therein without such repetition.

[0231] Described now are exemplary embodiments. Referring now to the figures of the drawings in detail and first, particularly to FIGS. **1** to **35**, there is shown a first exemplary embodiment of a multiple-firing crimp device **1**. FIG. **1** shows an end effector of the multiple-firing crimp device **1** with a crimp assembly in a position ready to load a first crimp. From the center to the exterior of the crimp assembly, the innermost structure is a snare **10**. In an exemplary embodiment, the snare **10** is laser cut out of a sheet of Nitinol or is a Nitinol wire and is heat set in a snare shape.

Exemplary heat-set embodiments are shown in FIGS. **36** to **38**. The snare **10** has a very low profile sufficient to fit, as shown in FIG. **1**, within a hollow tube having an inner diameter of approximately 0.025". A contained area or loop **12** is formed in the snare **10** to provide a large opening in which the user threads the cords to be connected together (e.g., ends of a surgical suture). For example, the loop **12** is approximately ovular with a major axis approximately 1.25" long and a minor axis approximately 1" long. The snare **10** is formed with a distal tip **14** that is described in further detail below. Herein, various snares are described and shown and are equally applicable to temporarily secure a cord or cords. Shapes of the snares described and/or shown herein are not exclusive and are not to be taken as the only shapes and/or configurations possible for snaring a cord/cords. Shapes can include closed or open loops, hooks, curves, or other shapes. [0232] Surrounding the snare **10** is a crimp carriage **20**. The crimp carriage **20** has a central lumen **22** with an inner diameter of approximately 0.025" to house therein the snare **10**. One or more of the inner surface of the central lumen **22** and the snare **10** is lubricious so that the snare **10** can move out from and back into the central lumen **22** with little friction and without catching. As the snare **10** exits the central lumen **22**, the loop **12** expands and forms its heat-set shape after the entirety of the loop **12** exits the distal end of the central lumen **22** (see, e.g., FIGS. **36** to **38**). The outer surface of the crimp carriage **20** has an exterior thread **24**. This exterior thread **24** is described in further detail below with regard to the crimps **30** and has a shape corresponding to an interior thread **32** of each crimp **30**. As such, the length of the exterior thread **24** can be as long as the crimp carriage **20** but it can also be only as long as is needed to thread the desired number of crimps **30** thereon in series. Five of the crimps **30** are illustrated as threaded onto the crimp carriage **20** in FIG. **1** but the threads are only shown diagrammatically in FIG. **1** within one crimp **30** and half of a second crimp **30** (this is done for illustration purposes only). These threads are present on the crimp carriage **20** at least for the length of all of the crimps **30** that are to be loaded on the carriage **20**. Alternatively the carriage can be smooth and have the crimps stacked up on it with a retention feature disposed on the end of the carriage that prevents the crimps from falling off the end of the carriage. In such an embodiment, the crimps are biased toward the retention feature by a slide that is, itself, biased distally by a compression spring. The slide has a mechanism that only allows it to slide distally along the carriage. In this way, the crimps are advanced into position and, once the distal-most crimp is moved into the ready position, the stack of remaining crimps index forward moving the next crimp into position.

[0233] Surrounding the crimp carriage **20** at the distal end of the device is the end effector body **40**, which is best seen in FIGS. **17** to **22**. The end effector body **40** defines a crimp loading orifice **42** in which a crimp **30** is loaded and, when loaded, is ready for firing. FIG. **1** does not show a crimp **30** in a loaded crimping position. A crimping device **50** is disposed at the orifice **42** and, in the exemplary embodiment shown, is positioned on opposing sides of the orifice **42**. More particularly, an anvil **52** is present on one side of the orifice **42** and a hammer **54** is present on the other side of the orifice **42** opposite the anvil **52**. The anvil **52** can be of a different material than the end effector body **40** or it can be integral with the end effector body **40**. A cutting assembly **60** is also present at the end effector body **40**. The cutting assembly **60**, in the exemplary embodiment shown, includes a cutter **62** that is biased in a non-cutting position (shown) by a non-illustrated spring, for example. The cutter **62** is moved (e.g., rotated) by a cutter push-rod **64**, **66** that extends back to the handle **100** of the multiple-firing crimp device **1**; the handle **100** is diagrammatically shown in FIG. **3**, for example, and is actuated by any number of actuation mechanisms, such as a motor, a relay, a lever,

and/or a rack-and-pinion. To bias at least one of the movement assemblies in a proximal direction, a bias device **3** is provided and is diagrammatically shown in the handle **100** adjacent the movement assemblies. In this example, the bias device **3** is a spring.

[0234] An outer tube **70** surrounds the end effector body **40** and surrounds at least part of the cutting assembly **60** as it moves distal and proximal with respect to the end effector body **40**. Also disposed within the outer tube **70** is a suture lifter **80**, which is explained in further detail below.

[0235] To explain how the multiple-firing crimp device **1** operates, reference is made to the progression of FIGS. **2** through **31**. The multiple-firing crimp device **1** comes pre-loaded to the user with a number of crimps **30** on the crimp carriage **20**. This number is sufficient to accomplish a particular procedure. For example, if a heart valve replacement is the procedure and there are nine, twelve, or fifteen sutures needed to fix the replacement heart valve within the native valve orifice (this assumes an even spacing on a tri-leaflet valve), then the crimp carriage **20** will be fitted with nine, twelve, or fifteen crimps **30** (e.g., six crimps **30** are shown on the crimp carriage **20** in FIG. **4**).

[0236] When the multiple-firing crimp device **1** is loaded with crimps **30** and is ready to use, the movement devices of the various loading/retracting, crimping, and cutting sub-assemblies within the handle **100** will be at a first rest or start position. These assemblies are shown diagrammatically within FIGS. **3**, **5**, **7**, **9**, **11**, **12**, **16**, **20**, **24**, **26**, **29**, and **31**. Ways that each of the movement sub-assemblies can actuate the various tasks of the multiple-firing crimp device **1** include any combination of levers, motors, relays, and other mechanical structures, such as a rack-and-pinion. Thus, they are not described in further detail. Here, each of the movement sub-assemblies includes a movement spool as an exemplary structure for actuating the assembly, each of which will be identified when the particular movement assembly is referenced herein. Spools are used to allow for longitudinal translation with free rotation.

[0237] When the multiple-firing crimp device **1** is loaded with crimps **30** prior to use, as shown in FIGS. **2** and **3**, the crimp carriage **20** is retracted proximally out of the end effector body **40**. Thus, the carriage spool **29** is in the furthest retracted position (i.e., proximal or closest to the user). In this state, the cutter **62** is retracted and the hammer **54** is in its steady or resting state away from the anvil **52**. Significantly, no crimp **30** is loaded within the crimp orifice **42**. In this state, the snare **10** is also retracted with the crimp carriage **20** and, therefore, the snare spool **19** is in the furthest retracted position as well.

[0238] To load the multiple-firing crimp device **1** with a crimp **30** and make it ready for use, the crimp carriage **20** is extended distally. This is done by placing the carriage spool **29**, along with the snare spool **19**, in the position shown in FIG. **5**. In this step, the snare spool **19** can be free-floating because the carriage spool **29** (having a shaft within a shaft attached to the snare spool **19**) forces the snare spool **19** distally as far as the carriage spool **29** is moved. To secure the distal-most crimp **30'** within the crimp orifice **42**, the head **34** of the soon-to-be-loaded crimp **30'** must pass the distal ends of the hammer **54** and the anvil **52**, a state that is shown in FIG. **4**. To describe how the crimp **30'** is loaded into the crimp orifice **42** and held there, it is beneficial to first describe an exemplary embodiment of a crimp **30**, which is shown in FIGS. **32** and **33**. To thread the crimp **30** onto the externally threaded crimp carriage **20**, the crimp **30** defines a bore having internal threads **32** corresponding to the external threads **24** of the crimp carriage **20**. In this way, each crimp **30** can simply be placed in loading position at the distal end of the crimp carriage **20** and rotation of the crimp carriage **20** in a particular direction serially loads each crimp **30** thereon one after the other, as shown, for example, in FIG. **1**. To prevent the crimps **30** from rotating while the crimp carriage **20** is rotating, each crimp **30** has a head **34** formed with at least one polygonal surface **36**. The end effector body **40** has a corresponding shape to the polygonal surface that acts as a structure to keep each crimp **30** aligned therewithin and prevent rotation of the crimp **30**. The crimp **30** has various advantageous characteristics. First, its shape delivers the highest clamp force density. Next, it presents a closed profile that houses the cord(s) therein. Finally, it is easily deformed to restrain the

cord(s) therein in a reliable and secure manner.

[0239] Once the crimp carriage **20** is retracted from the crimp **30'**, it would, without more, rest within the crimp orifice **42** and, potentially, could fall out with movement of the multiple-firing crimp device **1**. Accordingly, to positively lock the crimp **30'** within the crimp orifice **42**, each crimp **30** is provided with a catch **38**, which can take any shape and, in the exemplary embodiment shown, is a transverse groove or cut adjacent a proximal side of the head **34** (the top side of the head **34** in the view of FIG. **33**). The catch **38** can be any shape or structure and need not be the shape depicted in the figures. The catch **38** can be a hole or other depression but it can even be an extension such as a protruding boss. To effect a catch-and-securement of the crimp **30'** within the crimp orifice **42**, the hammer **54** is provided with a distal feature **56** having a shape that, when aligned with the catch **38**, mates therewith. See, e.g., FIG. **6A**. In the exemplary embodiment, the distal feature **56** is a protruding nose having a longitudinal length shorter than the longitudinal length of the catch **38**. In this way, when the head **34** of the crimp **30'** passes the distal feature **56** and is then retracted just slightly proximal, the distal surface of the distal feature **56** abuts the proximal surface of the head **34** and extension of the distal feature **56** into the catch prevents both proximal and distal movement. Thus, along with the polygonal surface **36**, the crimp **30'** is held in place in all dimensions as shown in FIGS. **6** and **6A**. The distal end in FIG. **6A** shows the interaction of the catch **38** and the distal feature **56** and the contact with both the distal faces of the hammer **54** and the anvil **52** to provide a proximal stop for the crimp **30'**.

[0240] It is desirable to provide additional holding force on the crimp **30'** to retain the crimp **30'** therein. Accordingly, the hammer **54**, which is shaped as a flex beam secured distally to the end effector body **40** at one or more contact points **58**, has an interiorly extending section **53** that acts as a cam along the edge of the crimp **30'**. As such, with the distal end **72** of the outer tube **70** preventing the intermediate portion of the hammer **54** from flexing outward, the remaining exposed portion **74** of the distal end of the hammer **54** flexes radially outward and, thereby, imparts a strong radially inward bias against the crimp **30'**. The position of the crimp carriage **20** and the snare **10** in this state defines the corresponding positions of the carriage spool **20** and the snare spool **19** that are shown in FIG. **7**.

[0241] Now that the crimp **30'** is in position for use, in order to thread the cords into and through the hollow center of the crimp **30'**, the snare **10** is extended distally through the crimp **30'** with the tip **14** of the snare **10** moving distally away from the distal end of the end effector body **40**. As the tip **14** moves further distally, the loop **12** is permitted to open to its pre-set shape (e.g., heat-set), an example of which is shown in FIG. **8**. Extension of the snare **10** occurs by moving the snare spool **19** distally away from the carriage spool **29**, as shown in FIG. **9**. At this point, the cords can be inserted through the loop **12** for entry into and through the crimp **30'**. However, the crimp **30'** is still attached to the crimp carriage **20**. Accordingly, the crimp carriage **20** is rotated (by a non-illustrated device that spins the carriage spool **29**, for example) to disengage the crimp **30'** from the distal end of the crimp carriage **20**. At the same time or either before or after, the crimp carriage **20** is moved distally out of the end effector body and is rotated further to cause the distal end thereof to move and place the previously second crimp **30''** in line into the distal-most crimp position, thereby converting the second crimp **30''** into the next crimp **30'** to be used for the next crimping procedure. The depiction in FIG. **10** illustrates the end effector with the crimp carriage **20** entirely disengaged from the distal-most crimp **30'** and retracted out of at least a portion of the end effector body **40** to not interfere with subsequent steps (even though it is shown completely out of the view of FIG. **10**, this does not mean that such a distant retraction is required. It is sufficient if the carriage **20** is retracted sufficiently far enough to not interfere with subsequent steps prior to loading the next crimp **30'**. The orientation of the snare and carriage movement sub-assemblies for this state is depicted with the positions of the snare spool **19** and the carriage spool **29** in FIG. **11**.

[0242] In the example of FIG. **12**, the free ends **2'** of a looped cord **2** are passed through the loop **12** (from the left to the right in the drawing). At this point, the cords **2** are ready to be threaded through

the crimp **30'**. The snare **10** is drawn proximally to catch the cords **2** within the loop **12** and then in the tip **14**, which, in an exemplary embodiment, forms a small extension area of the interior of the loop **12** in which the cords **2** are moved as the loop closes and moves proximally. As the proximal end of the loop **12** is drawn proximally into the crimp **30'**, the loop **12** compresses flat, as in the orientation of FIG. **6**, and the cords **2** are, then, folded in half and reside within the interior of the tip **14**. Further proximal movement draws the cords **2** through the crimp **30'** as depicted in FIG. **13**. The looped ends of the cords **2** in the tip **14** are drawn in further proximally into the device as shown in FIG. **14** until the free ends **2'** of the cords **2** enter the end effector body **40**, as shown in FIGS. **15** and **17**. The orientation of the snare and carriage movement sub-assemblies for this state is depicted with the positions of the snare spool **19** and the carriage spool **29** in FIG. **16**.

[0243] Now that the cords **2** are through the crimp **30'** and the ends **2'** are pulled sufficiently far enough into the shaft of the device, the process for presenting these ends **2'** to the user begins.

[0244] FIGS. **17** to **24** illustrate this process with an exemplary embodiment of a cord-lifting device **170**, which is one possible way to present the ends **2'** to a user. The cord-lifting device **170** is fastened to the end effector body **40** at a pivot **172** so that the cord-lifting device **170** is able to pivot away from the central axis of the outer tube **70**. With this pivot **172**, when the cord-lifting device **170** is actuated, the cord-lifting plate **174** pivots to lift the cords **2** out of the outer tube **70** through a window or lateral opening **171**, as shown in FIG. **18**. The lifting can be effected with any mechanism, for example, a push rod extending from the handle **100** and attached in an intermediate position of the cord-lifting plate **174** or extending adjacent the pivot **172** to connect to a lever that lifts the cord-lifting plate **174** when either pushed or pulled. This actuation device is not depicted for drawing clarity. At this point, the snare **10** still grasps the cords **2**. Accordingly, either the snare **10** can move distally to keep retention of the cords **2**, as shown in FIG. **18**, or the snare **10** can remain in place and, as the cord-lifting device **170** lifts the cords **2** outwards, either the length of the cords **2** distal of the crimp **30'** are pulled into the crimp **30'** or the ends **2'** of the cords **2** are caused to shorten their distance from the tip **14** of the snare **10**. FIG. **19** illustrates the lifted cords **2** still attached to the snare **10** and the cord-lifting device **170** lifted. FIG. **20** illustrates the positions of the various movement sub-assemblies for this state.

[0245] As the snare **10** is pulled further distally, the ends **2'** of the cords **2** become freed therefrom and now rest outside the outer tube **70** of the device. The user can, therefore, grasp these ends **2'** and, after the cord-lifting device **170** is lowered, can pull them taut as shown in FIGS. **22** and **23**. At this point, the snare **10** can be retracted in the device as shown in FIG. **24** by the position of the snare spool **19**. Now, the crimp **30'** can be installed/crimped/deformed on the cords **2**.

[0246] Movement of the distal end of the device with respect to the opposite ends of the cords **2** held by the user (not illustrated but to the lower left of FIG. **23**) will depend on the location that the user desires to fix the crimp **30'**. If the current location is sufficient, then crimping will occur with the length of the cords shown to the lower left of FIG. **23** remaining as is. However, if the distance from the opposite ends of the cords **2** is desired to be short, then the user will move the device distally along the cords **2** while holding onto the free ends **2'** and keeping them taut. If, for example, the cords **2** are surgical sutures and the opposite ends of the cords **2** are fixed at a surgical location, and if the surgeon wishes to have the crimp **30'** be applied as close to the surgical location as possible, then the top of the head **34** of the crimp **30'** will be moved along the sutures distally and up against the surgical site. When there, with tension on the sutures, the surgeon can fix the crimp **30'** at a location closest to the surgical site.

[0247] Crimping occurs by moving the outer tube **70** distally, which is indicated in FIG. **26** by the distal movement of the crimp spool **79**. As the distance for crimping the crimp **30'** is very short, the crimp spool **79** needs to only move a short distance distally. This movement can be caused manually by a lever, a toggle, or a button, for example, or by an electrical motor, such as a stepper motor. Crimping occurs by the outer surface **55** of the hammer **54** acting as a cam profile with the distal end of the outer tube **70**. As the outer tube **70** moves distally parallel to the longitudinal axis

of the device, the rising cam surface with respect to the outer tube **70** causes the hammer **54** to press inwards against the crimp **30'** with a force sufficient to deform the crimp **30'** and fix it to the cords **2**, as shown in FIGS. **25**, **34**, and **35**. In this state, the crimp **30'** is crimped and, thereby, fixed to the cords **2** therewithin (shown diagrammatically with the dashed line in FIG. **35**). For ease of visualization, FIG. **27** illustrates the hammer **54** in the crimping position without the crimp **30'** present.

[0248] It is noted that the internal threads **32** of the crimp **30'** provide additional friction and holding power when crimped onto the cords **2**. The internal threads of the crimp can be adjusted to not be full depth threads. The threads also can be adjusted to optimize the ID of the crimp for clearance to pass the cords and snare as well as to present a less damaging but still gripping surface to the cords upon crimping. The catch **38** also provides crimp relief and length reduction for when the crimp **30'** is squeezed. The distal-most section of the crimp **30'** remains undistorted to provide a smooth transitional surface that the cords **2** can follow to prevent high stress that might damage the cords **2**.

[0249] After crimping occurs, the lengths of the cords **2** on the proximal side of the fixed crimp **30'** are to be trimmed off. The cutting assembly **60** described above is able to cut the cords **2** with a cutter pushrod having a relatively stiff proximal portion **64** and a relatively flexible distal portion **66** that is able to bend as the pivoting blade **62** moves (see, for example, FIG. **28**). As such, cutting of the cords **2** occurs when an actuator at the handle **100** causes the proximal portion **64** to move distally. This, in turn, causes the distal portion **66** to move distally and, because it is fixed to the proximal side of the blade **62**, causes the blade **62** to move about its pivot point and allow the cutting edge **68** to sever the cords **2**. As the blade **62** is only required to move a very short distance, the distance that the cutting rod **64**, **66** needs to move is also very short and is illustrated by the relative positions of the cutting spool **69** in FIGS. **26** and **29**. It is noted that the outer tube **70** and tube spool **79** also move along with the cutting spool **69**, but this movement is optional. In order to assure cutting is complete and the device is unobstructed for use of the next crimp **30**, the cutting movement assembly is biased proximally (e.g., with a spring) to automatically retract the knife **62** after a cut is complete.

[0250] This cutting configuration of the cutter assembly **60** is merely one exemplary embodiment. Another embodiment can include a pusher that cuts the cords **2** by pressing the cords **2** against a fixed blade as described in further detail below. A further embodiment can have the knife cut against a cut block or stop. Yet another embodiment can apply electric current to the knife and allow it to cut as a hot wire. In any case, it is desirable to have the knife cut close to location of the crimped crimp **30'** to reduce the remaining length of the cords **2** extending from the end of the crimp **30** opposite the head **34**.

[0251] Like the cutting movement assembly, the movement assembly for the outer tube **70** is biased proximally (e.g., with a spring, even the same spring as the cutting movement assembly) to automatically retract the outer tube **70** after a crimp **30'** fixation is complete. In this way, the hammer **54** is allowed to spring back to its ready-to-crimp position when the outer tube **70** is disengaged.

[0252] An alternative to the loop **12** of the snare **10** is a hook needle configuration shown in FIGS. **39** to **41**. Instead of the loop **12**, the snare **10** has a hook **13** that is able to catch and hold the cords **2** as shown in FIG. **41**. Like the loop **12**, the hook **13** is pulled proximally until the ends **2'** of the cords **2** release from the hook **13** and become loose for presentation to a user. The presentation can include the cord-lifting device **170**, for example.

[0253] Another exemplary embodiment of a multiple-firing crimp device **200** is illustrated in FIGS. **42** to **56**. In this multiple-firing crimp device **200**, the crimp carriage **20** and the crimps **30** along with their respective movement sub-assemblies can be similar or identical to the previous embodiments described and shown. Thus, where identical structures are present, the same reference numerals may be used herein. Different structures, in contrast, have numbers with a prefix of two

hundred. In the embodiment of FIGS. 42 to 56, the movement devices for placing and operating the snare **10** are included within a shuttle **280** that is movably displaced along the outer tube **270**. In order to keep the shuttle **280** rotationally aligned in one orientation about the outer tube **270**, the shuttle **280** and the outer tube **270** contain an alignment structure that can take many forms. One possible form is a tongue-and-groove in which one of the shuttle **280** and the outer tube **270** has the groove and the other has the tongue. A further alignment device can attach a secondary tube or rod **570** to the bottom of the outer tube **270** and form a rail upon which a corresponding longitudinal orifice in the shuttle **280** slidably resides. In such a configuration, the cross-section of the outer tube **270** and rail can take the shape of an “8” (as shown in FIG. 57). The rail can have a different diameter than the diameter of the outer tube **270**, for example, it can be smaller. Alternatively the outer tube **270** can have a non-round profile such as an oval or a hexagon. It is noted that all of the features of the handle **100** need not be illustrated and, therefore, only a diagrammatic portion of the handle **100** is shown.

[0254] The process for completing a crimp installation is described and/or shown in the transition from FIGS. 42 through 56, in which the various parts are introduced. The steps of loading the crimp **30'** into the end effector body **240** and then withdrawing the crimp carriage **20** proximally for crimping is not repeated or shown here for the sake of brevity. In these figures, the crimp **30'** has already been set into the end effector body **240** and is ready to be used and crimped on cords **2**.

[0255] In FIG. 42, the manually actuated shuttle **280** is in a fully retracted position, in which position the steps of loading the crimp **30'** into the end effector body **240** and then withdrawing the crimp carriage **20** proximally occurs. Accordingly, the first crimp **30'** is in a position for use. FIG. 43 illustrates the shuttle **280** moving distally towards the end effector body **240**. In both the fully retracted and intermediate positions almost to the distal end of the outer tube **270** (see FIGS. 44 to 48), a snare-extension tube **212** resides outside the outer tube **270**.

[0256] The shuttle **280** includes a snare-aligning assembly **282** and a snare-movement assembly **290**, both of which are illustrated, for example, in FIG. 44. The snare-aligning assembly **282** pivots the snare-extension tube **212** into and out of alignment with the central axis of the outer tube **270** so that the distal end of the snare-extension tube **212** can be placed adjacent or even enter the longitudinal cavity of the crimp **30'** from the proximal side and, thereby, allow extension of the snare **210** directly through the crimp **30'**. The pivot of the snare-aligning assembly **282** is disposed approximately at the midpoint of a vertical height of the shuttle body **281** and, because the outer tube **270** is present in these figures, the pivot is obscured from view. The pivoting action can be seen in the transition from FIG. 48 to 49. The snare-aligning assembly **282** is biased with a force from a bias device **283** that presses the snare-extension tube **212** downwards against the outer surface of the outer tube **270**. In this manner, the outer surface of the outer tube **270** acts as a cam surface to the snare-extension tube **212**.

[0257] Additionally, the snare-aligning assembly **282** also has a lock-out arm **284** extending proximally from the bias device **283** and residing in a pocket **291** of the snare-movement assembly **290**. The lock-out arm **284** has a proximal surface that opposes the distal-facing interior surface of the pocket **291** and, when the proximal end of the lock-out arm **284** is disposed in the pocket **291**, the proximal surface prevents distal longitudinal movement of a snare-extender slide **292** until the lock-out arm **284** exits the pocket **291**. In this manner, until the snare-aligning assembly **282** is able to pivot the snare-extension tube **212** into alignment with the crimp **30'**, the snare-extender slide **292** is longitudinally fixed from moving distally.

[0258] FIGS. 46 and 47 illustrate the longitudinal positions of the shuttle **280** on the outer tube **270** at which the pivoting movement of the snare-aligning assembly **282** is made possible, which movement unlocks the snare-extender slide **292**. FIGS. 48 and 49 are close-up views of the shuttle **280** in its respective positions in FIGS. 46 and 47. Movement of the snare-extension tube **212** is dependent upon the exterior surface of the outer tube **270**. Accordingly, to allow the distal end of the snare-extension tube **212** to align with the lumen in which the crimp carriage **20** travels, the

outer tube **270** has a longitudinal slot **272**. The shape of the slot **272** acts as a track to guide and insert the distal end of the snare-extension tube **212** up to or into the proximal end of the crimp **30'**. As such, when the shuttle **280** passes the position on the outer tube **270** shown in FIG. **48**, the snare-extension tube **212** enters the slot **272** and drops against and into the inner carriage lumen **271** of the outer tube **270**, as shown in FIGS. **49** and **50**. When this dropping movement occurs, the pivot of the snare-aligning assembly **282** is complete and the lock-out arm **284** no longer impedes distal movement of the snare-extender slide **292**. In this state, the distal opening of the snare-extension tube **212** is axially aligned with the center of the crimp **30'**.

[0259] Also revealed in detail in FIGS. **48** and **49** is the crimp carriage **20** carrying a set of crimps **30**. In these views, eighteen crimps **30** are illustrated. This number, however, is only exemplary and the number can be as little or as great as desired dependent upon the procedure being carried out. In these figures, the carriage lumen **271** has the polygonal shape to keep the crimps **30** aligned but this keying feature is not illustrated.

[0260] With the snare-extender slide **292** unlocked for distal movement, extension of the snare is now made possible. The snare **210** is different from the above embodiments in that the distal end is no longer connected to the handle **100**. Here, in contrast, the snare **210** is connected, at its proximal end, to a tab **293** that is fixed to or integral with the snare-extender slide **292**. As such, the longitudinal length of the snare **210** (or its movement shaft) is significantly shorter than those in the previous embodiments. In this manner, when the snare-extender slide **292** moves distally, the snare **210** also moves distally. In these figures, the distal portion of the snare with the loop **12** and the tip **14** are within the snare-extension tube **212** but are hidden for clarity. As the snare **210** is relatively flexible and could possibly buckle when pushed distally out of the snare-extension tube **212**, a non-illustrated support tube (typically polymer based) surrounds the proximal portion of the snare **210** within the shuttle body **281**. This support tube can be attached to or be integral with the snare-extender slide **292**. The length of the support tube should be such that the distal end of the support tube is not able to be freed from the proximal end of the snare-extension tube **212**, thus keeping the two always aligned and preventing exit of the snare **210** from either.

[0261] The snare **210** can now be extended, as shown in FIGS. **51** and **53**. As the snare-extender slide **292** moves distally, the distal end of the snare **210** emerges from inside the crimp **30'** and finally exits to the environment distal of the shuttle **280** so that the loop **12** opens to define an area into which the cords **2** are inserted, as shown in FIGS. **52** and **54**. In FIGS. **51** to **54**, the tip **14** of the snare **210** is not illustrated for clarity.

[0262] It is undesirable for the shuttle **280** to move longitudinally in any way while the snare **210** is moving distally from the position shown in FIGS. **49** and **50**. Accordingly, movement of the shuttle body **281** is locked when the snare-extender slide **292** moves. Such a movement prevention device is not illustrated in FIGS. **42** to **56**, but there is one shown in FIG. **60**, in which a spring clip **590** engages an opening in the shaft **270** (or **570**) when the shuttle is in its distal-most, snare-extending position. The motion of the spring clip **590** into the opening frees the snare-extender slide **292**, allowing it to now move distally while simultaneously locking the shuttle **280** in the snare-extending position.

[0263] Once the cords **2** are inserted into the exposed and expanded loop **12** of the snare **10**, retraction of the cords **2** through the center of the crimp **30'** is now possible. To effect this retraction, the user moves the snare-extender slide **292** proximally, in which position all but the tip **14** of the snare **210** is retracted back into the shuttle body **281**, as shown in FIGS. **57** and **153**. The orientation of the tip **14** while the snare-extender slide **292** is in its proximal-most position is illustrated in FIGS. **57** and **153**. At this point, a portion or all of the free ends of the cords **2** are still within the end effector body **240** or are distal of the crimp **30'** while the cords **2** are threaded through the tip **14**. Now that the snare-extender slide **292** is proximal, proximal movement of the shuttle body **281** becomes possible given the fact that the spring clip **590** is free to flex back to its home position outside the opening in the shaft **270**, **570** (because the interlock holding the shuttle

body **281** has disengaged). The user continues retraction of the shuttle **280** with the snare and the coupled cords **2** proximally until the free ends **2'** pass entirely through the crimp **30'**, exit the shaft through slot **272**, completely shorten, and finally exit the tip **14**, as is shown in the transition from FIG. **55** to FIG. **56**.

[0264] At this point, the user is presented with the free ends **2'** outside the outer tube **270** and is now able to manually pull the free ends **2'** of the previously snared cords **2** tight and place the crimp **30'** adjacent to the distal loop of the cords **2** (not illustrated but to the left of FIG. **56**) where crimping is to take place. While pulling tightly on the free ends **2'** of the cords **2**, the user can place the distal end of the device where the crimp **30'** is being held at a cord-fixing location. Actuation devices of the handle **100** (as described above) cause the crimp **30'** to compress on and fix the cords **2** together and, thereafter or simultaneously, also cut the cords **2** just proximal of the crimped crimp **30'**. The shuttle **280** is moved to its start position shown in FIGS. **42** and **44**, thereby placing the device in a position to load the next crimp **30''** into the crimp orifice **42**.

[0265] The snare **10** is secured at its proximal end to the snare-extender slide **292** (e.g., at tab **293**) positioned adjacent the proximal end of the shuttle **280**. Because the travel distance of the snare-extender slide **292** is greater than or equal to the length of the snare that is to extend outward from the shuttle **280** in the distal direction, the shuttle **280** must have a longitudinal length that is dependent upon and is at least as long as the length of that snare. In other words, the extension of the snare **10** by the snare-extender slide **292** is 1:1. If the length of the shuttle **280** requires it to have significant weight or to have a length that is greater than is needed, it would be desirable to provide an assembly that permits a greater than 1:1 ratio and reduces the longitudinal length and/or weight.

[0266] In the embodiments of FIGS. **58** to **74**, the movement devices for placing and operating the snare **10** are included within a shuttle **580** that is movably displaced along the outer tube **270**. This shuttle **580** is able to be shorter and lighter than the shuttle **280**. To keep the shuttle **580** rotationally aligned in one orientation about the outer tube **270**, the shuttle **580** and the outer tube **270** contain an alignment structure that can take many forms. One possible form is a tongue-and-groove in which one of the shuttle **580** and the outer tube **270** has the groove and the other has a tongue. A further alignment device can attach a secondary tube or rod **570** to the bottom of the outer tube **270** and form a rail upon which a corresponding longitudinal orifice in the shuttle **580** slidably resides. In such a configuration, as shown in FIG. **58**, the cross-section of the outer tube **270** and the rail **570** takes the shape of an "8". As above, the rail **570** can have a different diameter than the diameter of the outer tube **270**, for example, it can be smaller. It is noted here that all of the features of the handle **100** need not be illustrated here and, therefore, the handle **100** is omitted.

[0267] The shuttle **580** depicted in FIGS. **58** to **74** provides a snare extension to slide movement length in a ratio that is greater than 1:1 and, at the same time, reduces the longitudinal length and weight of the shuttle **580**. These features are provided by removing the longitudinal tube fixed to the snare-movement slide and replacing it with a rack-and-pinion snare-movement assembly having the snare wrapped around a snare discharge spool. In this shuttle **580** for the multiple-firing crimp devices herein, the crimp carriage **20** and the crimps **30** along with their respective movement sub-assemblies can be similar or identical to the previous embodiments described and shown. Thus, where identical structures are present, the same reference numerals will be used herein. Different structures, in contrast, will have numbers with a prefix of five hundred.

[0268] FIGS. **58** and **59**, respectively, depict the shuttle translating from a retracted position against the handle **100** to an extended position where the snare-extension tube **512** drops into the slot **272** of the outer tube **270**. FIGS. **60** to **62** illustrate the shuttle **580** in a state where the snare-extension tube **512** has not reached the slot **272** and, therefore, still remains against the outer surface of the outer tube **270**. In comparison, FIGS. **63** to **65** illustrate the shuttle **580** in a state where the snare-extension tube **512** has dropped into the slot **272** and is ready to extend the snare within the outer tube **270** through the crimp **30'** (which is not illustrated here). All of the steps for aligning the

snare-extension tube **512** are the same as above and, therefore, the details of which are not repeated here.

[0269] The body **581** defines an interior snare spool cavity **582** in which a snare spool **583** and a pinion **584** rotatably reside. The snare spool **583** is rotationally fixed to the pinion **584** so that rotation of the pinion **584** results in a corresponding rotation of the snare spool **583**. The snare spool **583** is illustrated in cross-section in FIG. **63**. The body **581** also defines an interior rack cavity **585** in which a rack **586** resides for longitudinal movement within the rack cavity **585**. A distal end of the rack **586** is fixed to the snare-extender slide **292**, for example, it is pinned thereto at point **587**. The snare **10**, which is not illustrated in FIGS. **59** to **68** for purposes of clarity, has a proximal end that is pinned to the snare spool **583**. In an exemplary embodiment of the snare spool **583** in FIG. **63**, the snare spool **583** has a radial bore extending radially inwards from a spool outer contact surface. The distal end of the snare **10** is positioned inside the bore and is fixed there, for example, with a set screw or pin. The snare **10** is then wound around the snare spool **583** (e.g., counterclockwise with respect to FIG. **63**) on the spool contact surface and is threaded into the snare-extension tube **512**. The spool sides are raised to have a diameter greater than a diameter of the spool contact surface to keep the snare **10** from sliding off the snare spool **583** laterally.

[0270] With such a configuration, as the snare-extender slide **292** is moved distally by the user, the rack **586** moves distally as well, thereby rotating the pinion **584** and the snare spool **583**. Because the diameter of the pinion **584** is smaller than the diameter of the snare spool **583**, the pinion **584** acts as a speed increasing gear to enable a larger movement of the snare spool **583** and, thereby, a length of the snare **10** that is wound about the snare spool **583**. In particular, the overall length of the snare **10** is set to position the tip **14** just outside the distal end of the snare-extension tube **512** when the snare-extender slide **292** and the rack **586** are in their proximal-most, unactuated position (shown in FIG. **63**). This tip **14** position is shown, for example, in FIG. **57**. As the rack **586** moves distally, the snare spool **583** unwinds the snare **10** (e.g., in a counterclockwise direction with regard to FIG. **63**) and extends the snare **10** out from the distal end of the snare-extension tube **512**. FIGS. **66** to **69** show the snare-extender slide **292** (and, therefore, the rack **586**) extended distally to the fullest extent to, thereby, move the non-illustrated snare **10** out from the distal face of the shuttle **580**. With the gearing shown, an approximately one inch (1") movement of the rack **586** causes approximately two and one-half inches (2.5") of snare **10** extension out from the distal end. Thus, the overall length of the shuttle **580** can be reduced significantly.

[0271] As indicated above, it is desirable to prevent the shuttle body **581** from movement when the shuttle **580** is in a position where the snare **10** is to be moved. Various retaining features can be provided. One example of this retaining feature is a body interlock **590**. In this example, the body interlock **590** is a leaf spring with an extension **593** that rides along the bottom surface of the guide rod **570** as the shuttle **580** moves and, when the shuttle **580** is in a position where snare **10** movement is permitted, a port **592** in the guide rod **570** is located to catch the extension **593** of the body interlock **590** therein and substantially prevent longitudinal movement of the shuttle **580** on the outer tube **270**. Once the leaf spring of the body interlock **590** is allowed to move into the port **592**, the free end **591** of the body interlock **590** moves out of the way of the extender slide **292**, allowing the extender slide **292** to move distally. It is noted that the wrap-around extender slide **292** embodiment of FIGS. **58**, **59**, **66**, and **70** to **74** entirely wraps around the shuttle body **581**. In this configuration, the free end **591**, is able to positively engage the extender slide **292** and prevent movement. In contrast, the exemplary embodiment of the short extender slide **292** in FIGS. **60** to **65** and **67** to **69** does not wrap around to the bottom surface of the shuttle body **581**. Thus, the configuration of the body interlock **590** would not engage the short extender slide **292**. For the short extender slide **292** in FIGS. **60** to **65** and **67** to **69**, the body interlock **590** would be positioned behind the shaft **270**, **570** in the figures and, therefore, would not be visible in these figures. Accordingly, the body interlock **590** is left at the lower surface of the shuttle body **581** for purposes of clarity only.

[0272] Once the extender slide **292** has moved any distance distally, it forcibly holds the leaf spring of the body interlock **590** in the port **592** thereby locking the shuttle **580** into the shuttle's distal-most position. When the extender slide **292** is returned to its proximal position (e.g., FIG. **60**), the body interlock **590** remains engaged in the port **592**. As the body interlock **590** is a leaf spring with ramps on either side of the extension **593**, a sufficient force by the user to move the shuttle **580** proximally, overcomes the interlock and slides the extension **593** out from the port **592**. In action, the body interlock **590** acts as a removable detent that provides sufficient force to retain the shuttle **580** in position when snare functions occur but that is insufficient to prevent retraction movement of the shuttle **580** by a force imposed by the user.

[0273] When the devices described and/or shown herein are used in surgery, the location where the snare **10** is to capture cords **2** (e.g., sutures), is typically within a surgical site. Even though there is light from the surgical environment, many obstacles present shadows where the snare **10** is located during use. The color and size of the snare **10** also can make it difficult for a surgeon to see the snare **10** within the background of the surgical site. To alleviate this issue, the shuttle body **581** is provided with a distal headlight assembly **550**. One or both of the sides of the shuttle body **581** is hollowed out and provided with a cover **551** to contain parts of the headlight assembly **550**, as shown in FIGS. **70** to **74**. The cover **551** is made transparent in FIG. **71** to show thereunder a power supply **552** (in the form of one or more coin cells) and a headlamp switch **553**, which is, in this exemplary embodiment, a micro-switch having the switch on a proximal side thereof with the body of the micro-switch positioned flush with an end-of-travel surface **710** of the shuttle body **581** for the snare-extender slide **292** and with the switch plunger projecting distally from the end-of-travel surface **710**. In such a configuration, when the snare-extender slide **292** reaches a point where the snare **10** is extended for snaring one or more cords (as shown in FIG. **74**), the switch automatically depresses, thereby turning on the headlamp **554**, which can take the form of one or more LEDs, for example. In this configuration, the headlamp **554** remains on until the snare-extender slide **292** is retracted proximally, in which case the snare **10** is within the shuttle **580** and has captured the one or more cords **2**.

[0274] The shuttle body **581** is not limited to the shapes shown hereinabove. There are other configurations in which various characteristics are maximized or minimized. FIGS. **75**, **75A**, and **75B** illustrate an exemplary embodiment of a shuttle body that allows the snare-extender tube to be relatively straight and positions the snare's exit from the snare spool from above the snare spool instead of below. FIGS. **76**, **76A**, and **76B** illustrate an exemplary embodiment of a shuttle body configuration that removes some of the body material to lighten the shuttle and places the snare-extender slide only on the bottom half of the shuttle. A headlight assembly is also provided. The exemplary configuration in FIGS. **77**, **77A**, and **77B** removes even more material from the shuttle body to further lighten the shuttle. The exemplary configuration of the left half of the shuttle body in FIGS. **78**, **78A**, and **78B** is similar to the shuttle body embodiment of FIGS. **58** to **74** and shows differences in configuration, size, and material from the other shuttle bodies.

[0275] An exemplary embodiment of a handle **100** for the multiple-firing crimp device is illustrated in FIGS. **79** and **80**, in FIG. **80**, the carriage movement assembly is transparent to illustrate the structures therein. Within the handle **100** are various movement assemblies. Some of the movement assemblies are manual and some are automatic. As set forth herein, any of the automatic movement assemblies shown and described can be manual and any of the manual movement assemblies shown and described can be automatic. In this handle embodiment, the movement assemblies include a system control assembly **800**, a carriage movement assembly **810**, a carriage rotation assembly **820**, a crimping assembly **840**, a cutting assembly **860**, a display assembly **880**, and a force-measuring and indicating assembly **900**.

[0276] The system control assembly **800** includes all circuitry sufficient to power and control all electronics on the multiple-firing crimp device. The system control assembly **800** is electrically connected to a power supply **802**, which can be, for example, a pack of batteries, such as one or

more CR2 or CR123 batteries. The power supply **802** can be powered by any electricity delivery measures including a supply mains.

[0277] The carriage movement assembly **810** includes a carriage conveyor **812** with a transparent cover that is best shown in FIG. **80**. Also included in the carriage movement assembly **810** is a carriage motor **814** fixed to the handle **100** and rotating a conveyor spindle **816** that, when rotated, either moves the carriage conveyor **812** proximally or distally with respect to the handle body **102**. The carriage conveyor **812** has a rotation sub-assembly **820** that, at its distal end, includes a coupler **824** that is rotationally and longitudinally fixed to the crimp carriage **20**. As such, when the carriage conveyor spindle **816** rotates and causes the conveyor **812** to move proximally or distally, the crimp carriage **20** moves correspondingly with the coupler **824**. In this regard, the carriage motor **814** is the device that positions the crimp(s) **30** towards and away from the crimp orifice **42** as well as positions the crimp **30'** within the crimp orifice **42**. Two non-illustrated limit switches are present in the carriage movement assembly **810** to define the extension and retraction limits of carriage conveyor **812** and, thereby, the crimp carriage **20**.

[0278] The carriage rotation assembly **820** is part of the carriage movement assembly **810** and resides inside the carriage conveyor **812**. The carriage rotation assembly **820** comprises a carriage rotation motor **822** and the coupler **824**, which is rotationally fixed to the output of the carriage rotation motor **822**. As such, when the carriage rotation motor **822** rotates, the crimp carriage **20** rotates to shuttle the crimps **30** and to withdraw from the crimp **30'** within the crimp orifice **42**. Electrical signals/power are supplied to the carriage rotation assembly **820** through a movable wiring harness **818** that is electrically connected to the main circuit board of the system control assembly **800**.

[0279] The crimping assembly **840** includes a crimping motor **842** fixed to the handle body **102** and rotationally connected a crimping pinion **844**. The teeth of the crimping pinion **844** mesh with teeth of a flying gear **846**. The flying gear **846** has a central bore with an interior thread corresponding to an exterior thread of a crimping clutch **848**. Movement and functionality of the crimping clutch **848** is described with regard to FIGS. **81** to **84**. In particular, there are two states in which the outer tube **70**, **270**, **570** is to be moved. The first is slightly forward so that the hammer **54** is gently pressed against the crimp **30'** to hold it within the crimp orifice **42** and to not deform the crimp **30'**, and the second is forward to have the hammer **54** actively deform and fully crush the crimp **30'**. To provide the first function of gently pressing the crimp **30'**, a clutch bias **850** (in the exemplary form of a spring) is disposed between a distal end of the crimping clutch **848** and a point on the outer tube **70**, **270** a distance away from the distal end of the crimping clutch **848**. This point is defined by a clutch stop **852** that has a proximal vertical surface **854** intended to contact the distal vertical surface of the crimping clutch **848** and prevent it, after such contact, from moving independent of the outer tube **70**, **270**. The clutch stop **852** can be simply a radial extension from the outer surface of the outer tube **70**, **270**, such as an integral collar, which is not adjustable, or it can be an adjustable clutch stop **852**, **854**, **856** that is formed on or is integral with the outer tube **70**, **270** and has, for example, exterior threads **852** and a nut **856** threaded thereon as shown in FIGS. **81** to **84**. With the clutch bias **850** disposed between the distal vertical surface of the crimping clutch **848** and the proximal vertical surface of the nut **856**, the crimping clutch **848** is able to move asymmetrically with respect to the outer tube **70**, **270** as it compresses the clutch bias **850**. In this regard, with the clutch stop **852** disposed just distal of the distal end of the crimping clutch **848** to define a clutch distance therebetween and the clutch bias **850** therearound this intermediate portion, as the crimping clutch **848** starts to move distally (as shown in the transition from FIG. **81** to FIG. **82**), the clutch bias **850** starts to compress and only moves the outer tube **70**, **270** with a force that is proportional to the clutch bias **850**. This force is set to be lower than the point at which the hammer **54** actually compresses the crimp **30'**. In FIG. **82**, for example, the crimping clutch **848** moves distally slightly (as compared to FIG. **81**), compresses the clutch bias **850** and, thereby, moves the outer tube **70**, **270**, **570** distally but only with the force that

compressed the spring. In the transition from FIG. 82 to FIG. 83, the crimping clutch **848** closed the distance and contacted the proximal vertical surface of the clutch stop **852**. Because the spring of the clutch bias **850** has a coefficient less than a force able to compress the crimp **30'**, the spring is compressed without further movement of the outer tube **70, 270, 570** in this transition. However, after the crimping clutch **848** contacts the proximal vertical surface of the clutch stop **852**, any further movement of the crimping clutch **848** corresponds to a 1:1 movement of the outer tube **70, 270, 570** and, thereby, causes movement of the outer tube **70, 270, 570** and crimping of the crimp **30'**

[0280] A limit switch **858** is present adjacent the crimping clutch **848** to determine when the crimping clutch **848** has reached its furthest distance from the flying gear **846** and indicates to the system control assembly **800** that the crimping motor **842** should be stopped and prevent further turning of the flying gear **846**. Also, to prevent the crimping clutch **848** from rotating with respect to the handle body **102**, a keying assembly **859** is provided. This keying assembly can take the form of a pin and slotted block, a tongue-and-groove, or any similar rotation-preventing device.

[0281] As is indicated, the crimping assembly **840** is automated with the various motors and gears. The crimping process is started by depressing a non-illustrated trigger button disposed in a button orifice **857** of the handle **100**. When this button is pressed, crimping of the crimp **30'** occurs. The crimping assembly **840** holds the crimp **30'** down and waits to reset the next crimp **30''** until there is confirmation that the cords **2** have been cut, at which time a new crimp **30'** is transitioned to the crimp orifice **42**. Associated with the cutting assembly **860** is a non-illustrated limit switch that indicates a position at which the cutting blade is known to be or past a point where the cords **2** could be or the cutting blade pushrod is known to be or past the cutting tip of a fixed blade. When this limit switch is triggered, the crimping assembly **840** retracts to the crimp-ready position. An exemplary embodiment of an end effector portion of the cutting assembly **860** having a moving pushrod and a fixed blade is explained below with regard to FIGS. **85** to **91**.

[0282] Exemplary embodiments of a handle portion of the cutting assembly **860** are shown in FIGS. **81** to **84**. With particular reference to FIG. **84**, the handle portion of the cutting assembly includes a lever **862** with a kidney-shaped slot having, at a distal surface thereof, teeth **864** that are each disposed on a fixed radius from a pivot point **866** of the lever **862**. Centrally fixed but rotatably disposed with respect to handle body **102** is a gear assembly **868** having a smaller gear interfacing with the teeth **864** and a larger gear interfacing with a rack **870**. In this configuration with the smaller and larger gears of the gear assembly **868**, closing the lever **862** onto the handgrip **104** of the handle **100** causes a distance-multiplied linear translation of the rack **870**. The rack **870** is fixedly connected to the cutter push rod **64**, thereby effecting a distal displacement of the cutter push rod **64** when the lever **862** is closed.

[0283] An alternative embodiment to the rotating cutter described above is a linear cutter shown in FIGS. **85** to **91**. FIGS. **85, 86, and 90** illustrate an end effector of a multiple-firing crimp device with a fixed blade **890** and a blade pushrod **892** in a fully retracted position and with the crimping assembly **840** in a non-crimping state, in other words, the outer tube **70, 270** is retracted. FIG. **87** shows the crimping assembly **840** in a crimped state with the outer tube **70, 270** extended to crimp the crimp **30'**. FIG. **88** shows the blade pushrod **892** in a partially actuated state before cutting occurs. It is noted from the right side of FIG. **88** that the blade pushrod **892** is a tube that rides inside the outer tube **70, 270**. To insure that the cords **2** are pressed against the fixed blade **890**, the slot in which the cords **2** extend out the side of the outer tube **70, 270** narrows at a distal end **893** and terminates at the tip of the blade **890**. FIGS. **89 and 91** show the blade pushrod **892** in a fully actuated state after cutting has occurred. (Due to limitations of the graphics software, the inwardly compressed hammer **54** in FIG. **91** is shown within the crimp **30'**.)

[0284] The display assembly **880** is connected to the system control assembly **800** and, in this exemplary embodiment, is shown as an LED, which can be, for example, an RGB LED that can produce light in various colors; each distinct color (or even a flashing pattern) is able to indicate a

particular function or status. The display assembly **880**, in an alternative embodiment, can be an LCD or LED or OLED display panel that can produce any colors, text, video, or pictures indicating status or any other characteristic of the multiple-firing crimp device.

[0285] FIG. **92** shows a flow chart of a process for completing a crimping procedure with a multiple-firing crimp device described herein. In order to initialize the device, the outer tube and the crimp carriage are retracted. It is assumed that the crimps come preloaded on the crimp carriage before it is passed to a user. Of course, there can be a pre-initialization requirement that has the user load the crimp carriages with the crimps. Once initialized, the first crimp (the distal-most one) is advanced to the crimp loading orifice. The first crimp is secured at the crimp loading orifice by advancing the outer tube to gently press the hammer against the first crimp and hold it in the orifice. The crimp carriage is then rotated out from the first crimp (e.g., by a predefined number of turns) and further rotated to put the second crimp into a first crimp position at the distal end of the crimp carriage. The crimp carriage is moved proximally away from the end effector sufficiently far to prevent any interference with the crimping procedure into an idle position. The second crimp alignment can occur before, during, or after movement of the crimp carriage. As one crimp is no longer on the crimp carriage, the system can decrement a counter to keep track of the number of remaining crimps. At this point, the device is ready to use.

[0286] The user then carries out the manual steps of extending the snare, capturing the cord(s) within the snare, retracting the snare back to hold the cord(s), and then lifting the cord lifter or moving the shuttle proximally to present the end of the cord(s) outside the shaft of the device. The user grasps the exposed free end(s) of the cord(s) and pulls it/them taut. The end effector is then moved distally along the cord(s) to the place where the user desires to set the crimp. For example, where the cord is a surgical suture, the crimp is desired at the surgical site with no length of the suture between the crimp and the tissue. In such a case, the user will move the end effector up against the tissue to make the crimp ready to be fixed, such as shown in FIGS. **95** to **97**.

[0287] The automatic crimping can now occur. The user presses the crimp-start button (for example) and the outer tube is advanced to the distal position where the hammer crushes the crimp. The tube is held there in place distally until the cutting assembly is actuated to cut the free ends of the cord/suture at the proximal side of the fixed crimp. When the system indicates that cutting has completed (e.g., when the cutting stroke is sufficient to insure that cords have been cut), the cutting assembly retracts to its idle position and the outer tube also retracts to its idle position, during which the now-crimped first crimp is released from the end effector. Now, the device is in its state for the next crimping process to begin, which starts with advancing the crimp conveyor to load the next crimp.

[0288] The process for crimping a cord in the exemplary embodiment of a heart valve replacement surgery is described with regard to FIGS. **93** to **97**. This process and the devices described and/or shown are not limited to such a surgery. This surgery, in contrast, provides a good example for explaining the methods and systems. A ring **1000** is used as a surrogate for an actual replacement heart valve in this exemplary embodiment. The surgical site, e.g., the aortic valve seat in a heart, is indicated with a surface **1010**, for example, made of neoprene. In this example, three sutures **1020** have been employed to secure the ring **100** at the surgical site **1010** by the multiple-firing crimp device **1** and a fourth suture **1022** is in the process of being secured at a surgical site **1001** (for illustrative purposes, the suture **1022** does not penetrate the surface **1010**). An illustrative example of an installed crimp **30** can be seen on one of the sutures **1020** to the right of FIG. **93**.

[0289] In the view of FIG. **93**, the suture **1022** to be crimped is wrapped around the ring **1000** and has already been threaded: through the crimp **30'** that is loaded in the orifice **42**; through the end effector body **40**, **240**; through a portion of the outer tube **70**; and out the lateral opening **171**, **272** of the outer tube **70**. The ends **2'** of the suture are distal of the end effector body **240** and are being held by the surgeon (see FIG. **97**). To secure the suture **1022** for crimping, the suture ends **2'** are pulled taut and the multiple-firing crimp device **1** is slid down the suture **2** until the end effector

body **40, 240** along with the crimp **30'** (not shown) rests against the position where crimping is to take place, which state is shown in FIG. **94**. At this point, if the suture ends **2'** are held in place with respect to the multiple-firing crimp device **1**, both the suture ends **2'** and the multiple-firing crimp device **1** can be raised or lowered without putting force on the surgical site **1001**. Raising of the suture ends **2'** and the multiple-firing crimp device **1** is shown in FIG. **95**. In this state where the two items are moved together, any force imposed on the surgical site by pulling of the suture ends **2'** in direction **D** is being counteracted by and is equal to the force **D'** in the opposite direction, thereby resulting in a net zero force on both the multiple-firing crimp device **1** and on the surgical site **1001**. What is desired to be known is the force in which the suture **1022** is being knotted at the surgical site **1001**, in other words, the tying force. The tying force can be determined because any force **D** that is imparted on the suture ends **2'** is imparted directly upon the end effector body **40, 240**, which force is transmitted directly to the handle **100** being held by the surgeon. Thus, if the distal end of the multiple-firing crimp device **1** is made to be movable with respect to the handle **100**, then the exact amount of force **D** imposed by the surgeon on the suture ends **2'** can be measured by placing the force-measuring and indicating assembly **900** between the distal end of the multiple-firing crimp device **1** and the handle **100**.

[0290] In the exemplary embodiments described above and/or shown, the end effector body **40, 240** is grounded to the handle **100**. The view of FIGS. **79** and **80** is suitable for understanding how the end effector body **40, 240** is grounded and the enlarged view of FIG. **97A** is especially suitable for this purpose. Initially, it is noted that all of the internal components within the handle **100** are not individually connected to the handle **100**. They are connected to a chassis **801** that actually is transparent in FIGS. **79** to **84** and **97** but is visible at least by its exterior lines. All of the components are connected to the chassis **801** and the chassis **801** is fixed to the interior surface of the handle body **803**. If the handle body **803** is of a clam-shell configuration, the chassis **801** can be secured to one side and the second side can be secured to one or both of the one side and the chassis **801**. To ground the end effector body **40, 240** to the chassis **801** (and thereby the handle **100**), the end effector body **40, 240** is fixed to a grounding shaft **805** that runs proximally back and into the handle **100**. The grounding shaft **805** is, then, fixed to the chassis **801**. In this state, any force acting upon the end effector body **40, 240** is transmitted to the chassis **801** and handle **100**. Grounding can be accomplished in a variety of ways, one exemplary configuration being shown by a wing **807** that is fixed/integral with the grounding shaft **805**. By providing the handle **100** or the chassis **801** with a non-illustrated slot corresponding to the exterior dimensions of the wing **807**, the grounding shaft **805** can be secured to the handle **100** and/or to the chassis **801**. With a transverse throughbore in the wing **807** and a corresponding throughbore in the slot, a screw or other fastener can fix the wing **807** to the handle **100** or the chassis **801**. In such a configuration, any force **D** imposed by the surgeon pulling upon the suture ends **2'** will be counteracted by the grounding supplied by the handle **100**.

[0291] This configuration, therefore, provides an appropriate location for determining how much force is being applied by the surgeon when the tying force is being applied and, thereby, received at the end effector body **40, 240**. To allow such a force to be measured, the wing **807** is decoupled from the chassis **801**/handle **100** and the grounding shaft **805** is connected indirectly to the chassis **801**/handle **100** through the force-measuring and indicating assembly **900**, which permits the grounding shaft **805** to move just enough with respect to the chassis **801**/handle **100** to allow measurement of the tying force imposed on the end effector body **40, 240**. To permit this movement, the proximal-most end of the blade pushrod **892** (in which the grounding shaft **805** resides) is provided with a longitudinal slot through which projects the wing **807**. The force-measuring and indicating assembly **900** is disposed between the chassis **801** (or the handle **100**) and the wing **805** and allows the grounding shaft **805** to move far enough to receive and measure the tying force imposed on end effector body **40, 240**. In particular with regard to FIG. **97A**, a load cell **910** (diagrammatically indicated) is fixed with respect to the chassis **801** (or handle **100**) to

receive any proximally directed force from the grounding shaft **805** (which is longitudinally connected to the end effector body **40, 240**). The load cell **910** detects and measures the amount of tying force that is being imparted by the surgeon to the suture ends **2'** when cinching the suture **1022** at the surgical site **1001**. The load cell **910** supplies information corresponding to the tying force to the system control assembly **800** and/or the display assembly **880**. Communication connectivity between the load cell **910** and the system control assembly **800** and/or the display assembly **880** is not illustrated for reasons of clarity. The amount of the tying force can be indicated in any way, for example, with a level indicator, with a dial, or with simple binary or tertiary indicators (e.g., yes/no or yes/no/too much). If a pre-set limit of the tying force is desired, an input function of the control assembly **800** can be used by the surgeon or the staff to set that force. Then, when in use, an indicator showing whether or not the amount of tying force is equal to or greater to the pre-set limit can be displayed. The display can take any form including those already described, for example, an LCD display with graphics, an LED with yellow, green, and red display colors, or simple yes/no mechanical and/or electrical indicators that show when sufficient tying force is being applied. Both audio and haptic feedback can be employed in addition to or instead of the visual indicators. A sound can be increasing in staccato until the desired tying force is imparted, at which time the sound is constant. Likewise, the handle can be still until the tying force is reached, at which time, the handle **100** vibrates. In this way, the user can maintain an exact and desired pressure (without putting too much force) against the surgical site **1001** by the suture **1022** until the crimp **30'** is secured on the suture **2**. When the indicator tells the surgeon that the tying force is within the desired range or at the desired level, the user can effect the crimping process to secure the crimp **30'** to the suture **2**.

[0292] With such a force-measurement assembly, reference is made to FIG. **96**. Here, the surgeon can secure the suture **1022** as desired. First, the end effector body **40, 240** is pressed against the surgical site **1001** and the surgeon starts pulling on the suture ends **2'** in direction D. During this process, the surgeon is looking at the indicator at the handle **100** and/or waiting for audio/haptic feedback. When the desired or pre-set tying force is reached, for example, as shown in the view FIG. **97**, the surgeon actuates the crimping process and the crimp **30'** is secured at the surgical site **1001**. Alternatively, the device and method can have the crimping occur automatically once the desired/pre-set tying force is met and, thereafter, cutting can also occur, either automatically or manually. As a corollary to this, the crimping can be entirely prevented and locked out unless and until a desired or pre-set tying force is detected/measured by the force-measuring and indicating assembly **900**. With the various forms of feedback that can be communicated to the surgeon, the tying force can be indicated to the user that there is not enough force being imparted upon the suture ends **2'** or too much force is being imparted. The systems and methods are not limited to the various electrical embodiments described for supplying force level feedback. Mechanical systems and processes can also be incorporated. For example, a dial or needle on a scale can be provided to show the tying force being imparted. Regardless of the way that the tying force is measured, the system can record all of the data that is experienced by the various sensors and provide it as output for later read out or analysis.

[0293] In the above text, a load cell **910** is indicated as the device that measures the tying force. Any similar and/or equivalent structure or device can be substituted for the load cell **910** to measure the force imparted onto the distal end of the multiple-firing crimp device **1** by pulling on the suture ends **2'**.

[0294] The multi-securing devices described and/or shown herein are not limited to securing with crimps. Other exemplary embodiments include securing devices that are clips. One exemplary embodiment for a multiple-clip securing device **9800** is shown in FIGS. **98** to **102**. A user handle **9810** includes a shaft **9820** in which resides a plurality of cord-securing clips described in detail below. Slidably disposed on the shaft **9820** is a snare assembly **9830**. As in the other exemplary embodiments herein, the securing process includes moving the snare assembly **9830** to the distal

end of the shaft **9820**, as shown in FIG. **99**. When the cords are ready to be snared, the snare **9832** is extended by moving a snare-extender slide **9834** distally, as shown in FIG. **100**, the snare **9832** being represented diagrammatically with dashed lines. Moving the snare-extender slide **9834** proximally, as shown in FIG. **101**, withdraws the snare **9832** and captures the cords **2** within the snare assembly **9830** for movement through a securing clip and out the side of the shaft **9820** for manipulation by the user. Sliding the snare assembly **9830** proximally, as shown in FIG. **102**, pulls the ends of the cords **2** through the clip and out a snare-access window **9822** of the shaft **9820** to an orientation that allows a user to manipulate the free ends **2'** of the cords **2**. In this exemplary embodiment, the snare-access window **9822** is at the top of the shaft **9820** but it can be at another orientation along the circumference of the shaft **9820**. When the cords **2** are ready to be secured by the clip, a clip-securing trigger **9812** of the handle **9810** is depressed to install the clip and activate a cord-cutting assembly within the handle **9810** and the shaft **9820** as described in further detail below. Finally, a reload trigger **9814** is pressed to automatically reload a clip for a further clip-securing procedure.

[0295] FIG. **103** shows a flow chart of a process for completing a cord-securing procedure with a multiple clip-securing device **9800**. In order to initialize the device **9800**, the snare assembly **9830** is in its retracted home position at the handle **9810**. It is assumed that the clips come preloaded within the shaft **9820** before it is passed to a user, the clips being loaded, for example, at the manufacturer. Of course, there can be a pre-initialization requirement that has the user load the shaft **9820** with the clips. Once initialized, if the first clip (the distal-most one) is not already at a cord-securing location, it is advanced to the cord-securing location, examples of which are shown in FIGS. **104**, **119**, **121**, **122**, and **133**. At this point, the device is ready to use.

[0296] One exemplary embodiment of a distal end of the multiple clip-securing device **9800** is depicted in FIGS. **104** to **111**. As can be seen through a side window **10422** of an exemplary embodiment of the shaft **9820**, a set of clips **10400** are installed on a guide rail **10410** for use in subsequent clip-securing operations. It is desirable to provide the outer surface of the shaft **9820** with the side window **10422** to allow a user to count the number of clips **10400** remaining in the multiple-clip securing device **9800**. As can be seen, for example, in FIGS. **104**, **107**, **109** and, in particular, in FIG. **121**, the inner and outer tubes of the shaft **9820** are flush at the distal end of the multiple-clip securing device **9800**. This is desirable to allow a positioning of the clip **10400** flush to the inner and outer tube ends to aid in tensioning the device on cords **2** to be secured with the clip **10400** and to present the most blunt edge possible to the sewing cuff or tissue that is being affixed.

[0297] The distal-most clip **10400** in the clip-securing position is not visible in the view of FIG. **104** because the clip **10400** is behind clip-movement arms **10442** and the body of a cutting/reloading assembly **10440**. The user then carries out the manual steps for capturing the cords. In summary, first, the user distally extends the snare assembly **9830** from a proximal position at the handle **9810**. During this movement, a snare-guiding tube **14140** will lower from the snare assembly **9830**, enter a snare access window **10424**, **11228** of the shaft **9820**, and extend distally to place a distal exit **14142** of the snare-guiding tube **14140** just proximal of the distal-most clip **10400** to be used in the present clip-securing operation. In such an orientation, the distal exit **14142** is aligned with the opening within the clip **10400**. Therefore, when the user distally extends the snare **9832** after the snare assembly **9830** reaches its distal end stop on the shaft **9820**, the snare **9832** passes through the opening of the clip **10400** and opens up to receive cords **2** therein to be secured. The user manually captures the cord(s) **2** within the snare **9832** by, for example, threading sutures through the central opening of the snare **9832**. Capturing is completed when the user retracts the snare **9832** proximally to hold the cord(s) **2** at the distal end of the snare assembly **9830**. Assuming the user is satisfied with the way that the cords **2** are captured in the snare **9832**, the user will, then, return the snare assembly **9830** proximally back to its proximal position at the handle **9810** to present the free ends **2'** of the cord(s) **2** outside the shaft **9820**. If the snaring is not

acceptable, the snare **9832** is extended again for acceptable recapture. An orientation of the distal end of the shaft **9820** when the snare has moved proximally back to the handle **9810** and has threaded the cords **2** through the clip **10400** in this ready-to-secure state is depicted in FIG. **104**. The cords **2** are depicted as being pulled taut by the user.

[0298] The distal end of the shaft **9820** is then slid distally along the cord(s) **2** to a place where the user desires to set the clip **10400** housed inside the distal end of the shaft **9820**. For example, where the cord **2** is a surgical suture, a securing point of the clip **10400** is as close to the surgical site as possible with no length of the suture between the clip and the tissue. In such a case, the user moves the distal end of the shaft **9820** up against the tissue, diagrammatically depicted with reference numeral **10510**, to place the clip **10400** in a ready to be fixed location, shown for example, in FIG. **105**. Automatic clip securement can now occur. The user presses the clip-securing trigger **9812** and, in doing so, two actions occur. First, the clip **10400** is fixed to the cords **2** and, second, the cord(s) **2** is/are cut. FIG. **105** depicts the cutting/reloading assembly **10440** in an intermediate cutting position where the moving portion **10442** of the two cutting surfaces has moved distally towards the fixed portion **10524** of the two cutting surfaces. With further distal movement of the cutting/reloading assembly **10440**, as shown in FIG. **106**, cutting of the cords **2** is completed by placing the moving portion **10442** of the two cutting surfaces distally past the fixed portion **10524**, thereby creating a scissor effect on the cords **2** with the two surfaces **10524**, **10442** while, at the same time, sliding the clip **10400** off of the guide rail **10410** and entirely unsecuring it from the multiple clip-securing device **9800**. Movement of the multiple clip-securing device **9800** away from the securing site **10510** reveals to the user that the clip **10400** is secured on the cords **2** and the cords **2** are cut on the side of the clip **10400** facing away from the site **10510**. The multiple clip-securing device **9800** indicates (by visual, audible, tactile measures) that a cutting action has completed but a user can actuate the clip-securing trigger **9812** again, if desired, and the cutting action will repeat. FIG. **107** illustrates the device **9800** in state that is ready for recutting or reloading.

[0299] In order to reload the device **9800**, the user presses the reload trigger **9814** and a procedure for placing a now distal-most clip **10800** at a cord-securing location **10802** at the distal end of the shaft **9820** can begin. The clip **10800** is visible because the clip-movement arms **10442** are not shown in this figure. The device **9800** automatically moves the cutting/reloading assembly **10440** rearward to a position where the clip-movement arms **10442** catch the clip **10800**, which position is shown in FIG. **108**. Then, the cutting/reloading assembly **10440** extends distally to place the clip **10800** at the cord-securing location **10802**, which is hidden by the clip-movement arms **10442** in FIG. **109**. The securing and cutting operations are repeated as before to secure the second clip **10800** on new cords **2** and move the clip **10800** off of the guide rail **10410**, which orientation is depicted in FIG. **110**. The clip-securing processes are repeated for as many times as needed in a given procedure. In the exemplary embodiment of FIGS. **108** to **111**, there are fourteen clips illustrated. FIG. **111** illustrates the cutting/reloading assembly **10440** in a reloading position for the last clip **11100** after the other thirteen clips have been used. As can be understood, the cutting/reloading assembly **10440** moves a distance proximally that increases for each new clip that is being reloaded. The movement algorithm is set within the device **9800** as described in further detail below.

[0300] Another exemplary embodiment of a distal end of the multiple clip-securing device **11200** is depicted in FIGS. **112** to **137**. Many of the features in this embodiment are similar or even the same as previous embodiments of the device. Even though such features may be referenced with a different numeral, that designation, alone, does not mean that the feature is different and can be the same. Likewise, where features are referenced with the numeral, that designation, alone, does not mean that the feature is the same and can be different.

[0301] Depicted in FIGS. **112** to **118** is an exemplary embodiment of a distal end of the shaft **11220** in which is disposed a set of clips **11250** loaded on a guide rail **11210** that is fixedly secured within

the shaft **11220** through a rail block **11212**. Also disposed within the shaft **11220** is a distal portion of a cutting/reloading assembly **11240**, which is slidably disposed within the shaft **11220**. FIGS. **112** and **118** show the device **11200** a ready-to-secure state, the former showing an example where the device **11200** is full with clips **11250** and the latter showing the device **11200** having nine clips **11250** in addition to the one in the ready-to-secure state. In this state, the cutting/reloading assembly **11240** has delivered a distal-most clip **11251** to a distal cord-securing location **11222** within the shaft **11220**. At this point, the user then carries out the manual steps for capturing the cords. In summary, first, the user distally extends the snare assembly **9830** from a proximal position at the handle **9810**. During this movement, a snare-guiding tube **14140** will lower from the snare assembly **9830**, enter a snare access window **10424**, **11228** of the shaft **11220**, and extend distally to place a distal exit **14142** of the snare-guiding tube **14140** just proximal of the distal-most clip **11251** to be used in the present clip-securing operation. In such an orientation, the distal exit **14142** is aligned with the opening within the clip **11251**, as can be seen in FIG. **152**, for example. Therefore, when the user distally extends the snare **9832** after the snare assembly **9830** reaches its distal end stop on the shaft **11220**, the snare **9832** passes through the opening of the clip **11251** and opens up to receive cords **2** therein to be secured. The user manually captures the cord(s) **2** within the snare **9832** by, for example, threading sutures through the central opening of the snare **9832**. Capturing is completed when the user retracts the snare **9832** proximally to hold the cord(s) **2** at the distal end of the snare assembly **9830**. Assuming the user is satisfied with the way that the cords **2** are captured in the snare **9832**, the user will, then, return the snare assembly **9830** proximally back to its proximal position at the handle **9810** to present the free ends **2'** of the cord(s) **2** outside the shaft **11220**. If the snaring is not acceptable, the snare **9832** is extended again for acceptable recapture. An orientation of the distal end of the shaft **11220** when the snare has moved proximally back to the handle **9810** and has threaded the cords **2** through the clip **10400** in this ready-to-secure state is depicted in FIGS. **122** and **123**. The cords **2** are depicted as being pulled taut by the user. [0302] The distal end of the shaft **11220** is then slid distally along the cord(s) **2** to a place where the user desires to set the clip **11251** housed inside the distal end of the shaft **11220**. For example, where the cord **2** is a surgical suture, a securing point of the clip **11251** is as close to the surgical site as possible with no length of the suture between the clip and the tissue. In such a case, the user moves the distal end of the shaft **11220** up against the tissue, diagrammatically depicted in FIG. **123** with reference numeral **12310**, to place the clip **11251** in a ready to be fixed location. Automatic clip securement can now occur. The user presses the clip-securing trigger **9812** and, in doing so, two actions occur. First, the clip **11251** is fixed to the cords **2** and, second, the cord(s) **2** is/are cut. With distal movement of the cutting/reloading assembly **11240**, as shown in FIG. **127**, cutting of the cords **2** is completed by placing the moving portion **11242** of the two cutting surfaces distally past the fixed portion **11224**, thereby creating a scissor effect on the cords **2** with the two surfaces **11224**, **11242** while, at the same time, sliding the clip **11251** off of the distal end of the guide rail **11210** and entirely unsecuring it from the multiple clip-securing device **11200**. Movement of the multiple clip-securing device **11200** away from the securing site **12310** reveals to the user that the clip **11251** is secured on the cords **2** and the cords **2** are cut on the side of the clip **11251** facing away from the site **12310**. The multiple clip-securing device **11200** indicates (by visual, audible, tactile measures) that a cutting action has completed but a user can actuate the clip-securing trigger **9812** again, if desired, and the cutting action will repeat. FIG. **116** illustrates the device **11200** in state that is ready for recutting and FIG. **115** illustrates the device **11200** in state that is ready for reloading.

[0303] To reload the device **11200**, the user presses the reload trigger **9814** and a procedure for placing a now distal-most clip **11651** at the cord-securing location **11222** at the distal end of the shaft **11220** can begin. The device **11200** automatically moves the cutting/reloading assembly **11240** rearward to a position where the clip-movement arms **11242** (only one is shown in FIGS. **113** to **116**) catch the clip **11651**. Then, the cutting/reloading assembly **11240** extends distally to

place the clip **11651** at the cord-securing location **11222**. The securing and cutting operations are repeated as before to secure the second clip **11651** on new cords **2** and move the clip **11651** off of the guide rail **11210**. The clip-securing processes are repeated for as many times as needed in a given procedure. In the exemplary embodiment of FIGS. **117** and **118**, the procedure has been carried out until there are only ten clips left on the guide rail **11210**. FIG. **117** illustrates the cutting/reloading assembly **11240** in a reloading position for a tenth-to-last clip **11751** after the preceding clips have been used. Likewise, FIG. **118** illustrates the cutting/reloading assembly **11240** reloading the tenth-to-last clip **11751** into the cord-securing location **11222**. As can be understood, the cutting/reloading assembly **11240** moves a distance proximally that increases for each new clip that is being reloaded. The movement algorithm is set within the device **11200** as described in further detail below.

[0304] FIGS. **119** to **134** are various views of enlarged portions of the distal end of the device **11200** in various stages of the clip-securing process. Each will be described in turn.

[0305] FIGS. **119** to **123** illustrate the ready-to-secure state shown in FIGS. **121** and **122**.

Particularly in FIG. **120**, it can be seen that the clip-movement arms **11242** have characteristic curves and thickenings, which will be described in further detail below. When the body of the cutting/reloading assembly **11240** is in this state, the moving portion **11244** of the cord-cutting surfaces is set away from the fixed portion **11224** of the cord-cutting surfaces. In the exemplary embodiment of FIGS. **119** and **120**, the cord-securing location **11222** for the clip **11251** is set back proximally from the extreme distal end **11226** of the shaft **11220**. Also illustrated in FIGS. **119** and **120** are various features of the guide rail **11210**, which features will be described in further detail below. A diagrammatic illustration of the path **11901** of cords **2** is shown in FIG. **119** after they have been snared and pulled through the clip **11251**, through the snare access window **11228**, and out the side of the shaft **11220** for manipulation by a user. The cords **2**, therefore, pivot or curve around the lower surface of the upper interior bending plate of the clip **11251**. Similar views of the distal end of the shaft **11220** are shown in FIGS. **121** and **122**, but these are not in cross-section. The path **11901** of the cords **2** can be seen well in both of these figures as well as in FIG. **123**, and the fixed portion **11224** of the cutting surfaces can be seen especially well in FIG. **122** to be protected by the outer surface **11246** of the body of the cutting/reloading assembly **11240**.

[0306] FIG. **124** illustrates an exemplary embodiment of how the guide rail **11210** is secured to the rail block **11212**. In this embodiment, a port **12420** in the shaft **11220** allows a set screw **12422** to fix the proximal end of the guide rail **11210** to the rail block **11212**. In turn, the rail block **11212** is fixed (e.g., by welding, soldering, press-fitting, threading) to an internal shaft **12424** that is fixed to the handle **9810** and, therefore, that does not move with respect to the shaft **11220**. Alternatively, this can be made as a subassembly that is all welded or otherwise fixed together by any measures.

[0307] In comparison to FIGS. **119** to **123**, FIGS. **125** to **128** illustrate the clip **11251** in a cord-secured state, in which the cords **2** are clamped or clipped between the upper and lower surfaces of the respective upper and lower interior bending plates of the clip **11251**. In the view of FIGS. **125**, the body of the cutting/reloading assembly **11240** has moved the clip **11251** distally from the cord-securing location on the guide rail **11210** to a position where the cords **2** are cut and the clip **11251** is free from the guide rail **11210**. The cutting of the cords **2** is accomplished by distally moving the moving portion **11244** of the cord-cutting surfaces past the fixed portion **11224** of the cord-cutting surfaces. In this view, only the clip-movement arms **12560** are holding the clip **11251** and, with any proximal movement of the shaft **11220** by the user, that gripping force will be overcome to release the clip **11251** at the site where it has been clipped. FIG. **126** illustrates how the distal fingers **12563** of the clip-movement arms **12560** hold the clip **11251** in this manner before release. FIGS. **127** and **128** are views approximately of FIGS. **125** and **126** without the cross-section. FIG. **127** depicts the end of the device **11200** after the clipping has occurred but before cutting of the cords **2** have occurred. Here, the body of the cutting/reloading assembly **11240** has moved the clip **11251** distally from the cord-securing location on the guide rail **11210** to a position where the clip **11251**

is free from the guide rail **11210**. However, the moving portion **11244** of the cord-cutting surfaces is still proximal of the fixed portion **11224** of the cord-cutting surfaces before cutting occurs. In contrast, FIG. **128** depicts the end of the device **11200** after both clipping and cutting of the cords **2** have occurred. As in FIG. **127**, the body of the cutting/reloading assembly **11240** has moved the clip **11251** distally from the cord-securing location on the guide rail **11210** to a position where the clip **11251** is free from the guide rail **11210**. Additionally, the moving portion **11244** of the cord-cutting surfaces is distal of the fixed portion **11224** of the cord-cutting surfaces to effect cutting of the cords **2**.

[0308] The snare access window **11228** that allows the cords **2** to be passed from distal of the device through the clip **11250** proximally and outside the shaft **11220** is placed to provide various desirable features. As can be seen in FIGS. **121** to **128**, the two edges **11224**, **11244** forming the scissor for cutting cords **2** are protected when not in use. First, as shown in FIGS. **121** and **123**, the upper cutting edge **11244** of the movable inner tube **11240** is protected by offsetting the proximal edge of the window **11228** distally with respect to the upper cutting edge **11244** when in the ready-to-fire position. Second, the lower cutting edge **11224** of the outer shaft **11220** is covered and, thereby, protected when the inner tube **11240** is in the non-cutting state as shown in FIGS. **122** and **123**. Particularly with respect to FIG. **123**, the portion of the inner tube **11240** that protects the lower cutting edge can be formed from a short-length tubular section **12540** that is very precise in its diameter to lower the drag of the inner tube **11240** within the outer shaft **11220** while providing the best edge for improved cutting. This short-length, precision-diameter section **12540** can be integral with the inner tube **122542** or it can be a separate piece that is attached to the inner tube. See, for example, FIGS. **119** and **125**.

[0309] With regard to the connection between the cutting/reloading assembly **10440**, **11240** and the securing devices, e.g., the clip **10400**, **10800**, **11250**, **11251**, various exemplary embodiments include a tube that slides back and forth within the shaft **9820**, **11220**, a body of that tube having, at its distal end, two clip-movement arms **10442**, **11242**, **12560**. FIGS. **129** to **134** illustrate the details of the clip-movement arms **10442**, **11242**, **12560** and how they interact with the clip **10400**, **10800**, **11250**, **11251** in order to carry out the cord-securing processes of the device **9800**, **11200**. For ease of understanding, only clip-movement arms **12560** will be referred to but this single reference applies to all embodiments of the clip-movement arms, including arms **10442** and **11242**. Likewise, only clip **11251** will be referred to but this single reference applies to all embodiments of the clip, including clips **10400**, **10800**, and **11250**.

[0310] As can be seen in FIGS. **125** and **126**, an exemplary embodiment of the arm-carrying tube of the cutting/reloading assembly **12540** can be made from two parts, a proximal portion **12542** and a distal portion **12544**. The proximal portion **12542**, because of its long length within a narrow shaft **9820**, **11220**, is made of a material having strong torque and flexion features, for example, it is of stainless steel 304 or 316 that can be easily drawn into tubing. The distal portion **12544** carries the two clip-movement arms **12560**. To secure the clip-movement arms **12560** thereto, the distal portion **12544** is made of a material, for example, able to bond through welding such as Stainless 17-7 but is substantially harder to make for an improved cutting edge. The clip-movement arms **12560** can be made of a similarly hard material, such as SS17-7 or 17-4, which can be hardened to a spring temper to allow the arms **12560** to flex and return to their original position.

[0311] In the exemplary embodiment, the clip-movement arms **12560** have three portions, a proximal base **12561**, an intermediate flex spring **12562**, and a distal finger **12563**. The proximal base **12561** is shaped and configured to fixedly attach to the distal portion **12544**. It can be press-fit, bonded, welded, or secured in any way so that, when so secured, it moves with the distal portion **12544** within the shaft **9820**, **11220**. The intermediate flex spring **12562** is, in this exemplary embodiment, in the form of a flexible, rectangular plate spring that is thinner (in the radial direction of the shaft **9820**, **11220**) than the proximal base **12561**. This radial thickness difference from the proximal base **12561** is not a requirement. Finally, the distal finger **12563** has a

number of features that is best described with reference to FIGS. **129** to **134** and, in particular, to FIG. **133**.

[0312] When the clip-movement arms **12560** are in the orientation of FIG. **115**, they flex radially inwards, due to the pre-set form of the flex spring **12562**, and the fingers **12563** are in a radial position further inwards than that shown in FIGS. **112** to **114**, i.e., when a clip **11251** is being held between the opposing fingers **12563**. In such a state, a new, distal-most clip **11251** is desired to be loaded into the cord-securing location **11222**. As described and/or shown herein, the cutting/reloading assembly **10440**, **11240** retracts proximally for this action to occur. For a distance, the arms **12560** are still distal of the clip **11251** and do not touch any of the clips **12560**. At a point illustrated in FIG. **129**, an inside angled cam surface **12564** of each arm **12560** makes contact with the distal-most clip **11251**. This cam surface **12564** is angled to form a guide rail that gradually moves each of the fingers **12563** radially outward, one of which is shown in FIG. **129**. The distal end of the cam surface **12564** terminates at a clip step **12565**, which, along with a distally extending fingernail **12566** at the outer end of the clip step **12565**, forms a pocket or ledge that grasps and is used to move the clip **11251** from its pre-loaded position to the cord-securing location **10802**, **11222** and, then, off of the guide rail **10410**, **11210**. In other words, the fingernail **12566** of each of the arms covers a side of the clip **11251** and the clip step **12565** acts as a pushing face that moves the clip **11251** distally by pressing against a proximal side of the clip **11251**. The fingernail **12566** keeps the clip step **12565** engaged evenly at the edges of the clip **11251** to make sure that the clip **11251** is pushed straight and true. The fingernail **12566** also keeps the flexible arm **12560** straight to apply its forces in straight column loading. To pick up and move the distal-most clip **11251**, the clip step **12565** must be on the proximal side of that clip **11251**. But, if the clip step **12565** is moved too far proximally, there is a danger that the arms **12560** may pass the distal-most clip **11251** and the nose **12567** of the fingernail **12566** will fall proximally behind the distal-most clip **11251** and, thereafter, be unable to pick up that clip **11251**. This situation is to be avoided. To ensure that such an event does not occur, the longitudinal length of the cam surface **12564** and the width of the arm **12560** are selected so that proximal movement of the arms **12560** allows the cam surface **12564** to touch the second distal-most clip **11252** as shown in FIG. **130** and, therefore, if the nose **12567** does happen to move proximal of the rear plane of the clip **11251**, the nose **12567** will, nevertheless, still be positioned to the outside of the clip **11251** and will not be trapped behind the clip **11251**. In other words, the cam surface **12564** has a length such that its radial thickness engages the next (e.g., second distal-most) clip **11252** before the fingernail **12566** disengages from the first clip **11251** to be loaded.

[0313] The clips **11251** are spaced apart from one another at known, pre-set distances **13000**. By having the length of the cam surface **12564** be long enough to contact the second distal-most clip **11252**, longitudinal control of the cutting/reloading assembly is provided with play to insure that the clip step **12565** will be moved proximally behind the distal-most clip **11251** every time a reloading procedure is undertaken and will fall radially inwardly to place the distal surface of the clip step **12565** against the proximal side of the clip **11251** and the inner surface of the fingernail **12566** against the outer side of the clip **11251**—a position shown in FIG. **131**. This position insures positive control of the clip **11251** from its pre-installed position (shown in FIG. **131**), distally along the guide rail **10410**, **11210** to an intermediate position **12200** before the cord-securing location (shown in FIG. **132**), to the cord-securing location **10802**, **11222** (shown in FIG. **133**), and then off the distal end of the guide rail **10410**, **11210** (shown in FIG. **134**). An enlarged separated view of a distal portion of the arms **12560** is shown in FIG. **135**.

[0314] Each of the arms **12560** flexes outwards to provide a positive bias against the clip **11251** that aids in holding the clip **11251** during all relevant steps where forces could act against the clip **11251**. The fingernail features (**12565**, **12566**) aid in stabilizing the arms **12560** so that they can be biased inward to a greater extent than needed. This forces the pushing faces to be held even with the outside edges of the clip **11251** and still have a biasing force against the clip **11251**. For

research and development purposes, a hold-open feature **12800** is provided (as shown in FIG. **128**) to allow a field-reloadable magazine (e.g., with a funnel on its end to hold open the fingers) to reload a set of clips or for reprocessing the multiple-clip securing device. As can be seen in FIG. **129**, a non-illustrated tool can be inserted into the feature **12800** to apply a force that moves the arms **10442**, **11242** radially outward to, thereby, provide room for reloading clips **11251** onto the guide rail **10410**, **11210**.

[0315] The guide rail **10410**, **11210** also possesses features that enhance the clip-securing processes of the exemplary systems **9800**, **11200**, exemplary embodiments of which are illustrated in FIGS. **136** and **137**. For ease of understanding, only guide rail **11210** will be referred to but this single reference applies to all embodiments of the guide rail, including guide rail **10410**. In the exemplary embodiment of FIG. **136**, the clip-holding guide rail **11210** is H-shaped (in cross-section) with an intermediate bridge **11214** between opposing walls **11216**. Here, the bridge **11214** is offset from center, but it can be centered in an alternative embodiment. The H-shape allows the clips **11251** to be held open with a minimal amount of contact area between the clip **11251** and the upper and lower edges of the walls **11216**. This configuration can prevent damage to the clip **11251** as it is being slid over the length of the guide rail **11210**. Polishing and surface treatments can further reduce any friction and/or wear that occurs during the sliding movement of the clips **11251**. Other advantages of having an H-shape cross-section is that it provides an open space through which the cord-capturing snare **9832** can be passed to slide along the upper surface of the bridge **11214** and pass through the proximal face of the open clip **11251**. To aid in guiding the snare through the internal opening of the clip **11251**, the distal end of the intermediate bridge **11214** has a tapered slope **11218**. This configuration allows for more precise and accurate movement of the snare **9832** out from its guiding tube, through the clip **11251**, and out to a user. The angle of the slope **11218** can be set at any value, however, one beneficial angle is a value that is approximately equal to the angle that the lower internal flexing wall **13300** of the clip **11251** makes with respect to the bridge **11214**. In this way, if the snare **9832** slides against the upper surface of the bridge **11214** and then down the slope **11218**, having the lower surface of the wall **13300** match the slope **11218** permits travel of the snare **9832** substantially without friction or snagging. This is especially true if the central edge of the wall **13300** is just below the distal end of the slope **11218**.

[0316] During manufacture of the multiple-clip securing device **9800**, **11200**, it is desirable to preload all of the clips **11251** onto the guide rail **11210** before the guide rail **11210** is installed in the handle **9810**. To assist with this preloading, the proximal ends **11217** of the walls **11216** are ramped or chamfered. The ramp can start from a point or from almost a point and can taper outwards (up/down) until reaching a wall height that is desirable for extending the snare **9832** through the opening within the clip **11251**. This means that the walls **11216** can have a variable height over a length of the guide rail **11210** that starts small to place a lower load on the internal features of the clip **11251**, for example, for storage purposes, and only place the higher load on the internal features when the clip **11251** is at the distal end of the guide rail **11210** ready to be used. The walls **11216** at the distal end of the guide rail **11210** extend past the slope **11218** to create a fork that provides a larger opening in the available space through which the snare **9832** and cords **2** can be maneuvered. For manufacturing ease, one or more retainer holes **11219** can be made in the intermediate bridge **11214**, as shown in FIG. **137**, which holes **11219** do not interfere with the clean polished surfaces on which the clips **11251** slide. These holes **11219** can also be used to support the guide rail **11210** as the clips **11251** are loaded thereon. Shapes other than an H-shaped cross-section of the guide rail **11210** can be used to hold the clips **11251** open and ready for use. For example, a square bar that transitions to an H-shape, two independent square/round rods, a W-rail, a double U-shaped rail, a C-channel, or a rectangular cross-section bar.

[0317] The guide rail **11210** can be fabricated using various production methods including grinding, milling, wire EDM, stamping, laser cut and welding, extrusion with hardcoat, roll-formed, wire spool and welding, from ceramic, MIM, and/or DMLS. Some of the materials that can

be used to form the guide rail **11210** include, but are not limited to, stainless steel, nickel and nickel alloys (e.g., MP5N), titanium, CoCr, aluminum with hardcoat, carbide, tool steel, and sapphire. Exemplary surface finish processes for the guide rail **11210** include, but are not limited to, materials that make the surface smooth, polishing (e.g., abrasive/mirror/electro), and grain orientation.

[0318] The handle of the multiple-clip securing devices contains various novel features. An exemplary embodiment of circuitry and proximal portions of the cutting/reloading assembly are contained in and attached to a single, drop-in, circuit board **13820**, all of which is housed within a handle **13810** shown in FIG. **138**.

[0319] All of the switches, including the clip-securing trigger **13830**, the clip-reload button **13840**, and the parking switch **13900** are side-mounted onto the circuit board **13820** to decrease the footprint within the handle **13810**. The clip-securing trigger **13830** is, in this exemplary embodiment, pivoted about a pivot pin **13832**. Actuation of the clip-securing **13830** is carried out by depressing a micro-switch or tact-switch **13834** that is surface-mounted on the circuit board **13820**. In an alternative embodiment shown, for example in FIG. **155**, the pivoting trigger **13830** is replaced by a sliding trigger **15512**. A trigger that slides provides a longer stroke than the pivoting trigger **13830** and, by including a relatively heavier spring, the sliding trigger **15512** gives the user time to decide if firing should be cancelled, which makes the device less sensitive to inadvertent clip firing.

[0320] An exemplary embodiment of proximal portions of the cutting/reloading assembly is depicted in FIGS. **138** to **140**. Included in the cutting/reloading assembly is a motor **13850** having a pinion **13852** that is operably connected to a proximal portion of a rack **13854**. The exemplary embodiment of the motor **13850** shown has an internal gear box that terminates with the external pinion **13852**. The distal portion of the rack **13854** is fixed longitudinally to the tube **12540** carrying the clip-movement arms **11242**, **12560**. Because it is desirable for the outer tube of the shaft **9820**, **11220** to have an outer diameter that is no greater than 5 mm, to improve control of the device, a torque stiffening tube **14000** (which is free from interruptions and/or slots) is connected between the rack **13854** and the tube **12540**. This functions to prevent torsional bending or twisting of the shaft **9820**, **11220** in use. Another exemplary configuration for stiffening the two nested tubes **9820**, **11220**, **12540** in torque includes non-illustrated cross-pins at either end.

[0321] A power supply **13860**, such as a battery, can be electrically connected to the circuit board **13820** by a wired connector as shown in FIG. **138** or by board-mounting. For various reasons, easy battery disposal is desirable. To provide such a feature, the handle **13810** in FIG. **138** shows the left-side clamshell **13812** but the right side clam-shell is removed. This right-side clamshell can be in two parts, which are delimited by the dashed breakaway line **13801**. One part will be fixed to the left-side clamshell **13812** and will cover the circuit board and all of the components in the upper section above line **13801** and the second part will be a non-illustrated breakaway section that is the structure on the right side below the line **13801** in FIG. **138**. This breakaway section, when pried away by a hemostat or other object inserted within a seam or a pocket below the line **13801** will expose the battery **13860** and allow it to be removed with ease. The battery **13860** is shown as being clipped into a standard 9V press-fit connection. In an alternative non-illustrated exemplary embodiment, the battery **13860** is pressed upwards, e.g., by a lower spring, to merely physically connect to two contacts that are on the top surface of the battery compartment **13862** adjacent the circuit board **13820**. The ability to remove the battery **13860** can be accomplished in many other ways, such as a structure similar to a gun magazine, which can be released and slid out of the bottom of the grip portion or the entire grip portion containing the battery can be separated from the device to remove the battery and render the device unusable. This is of concern for a circumstance where separation is necessary for disposal of the battery for recycling purposes.

[0322] FIGS. **98** to **102** illustrates one exemplary embodiment of a movable snare assembly **9830**. Another exemplary embodiment of a snare assembly **14100** is depicted in FIGS. **141** to **153** The

snare assembly **14100** provides various complex functions. First, it is disposed on the shaft **11220** so that it can move longitudinally thereon from a retracted proximal position at the handle **13810** to an extended distal position in which the snare is extended through the snare access window **9822**, **10424**, **11228** and through the clip **10400**, **11250** to a position distal of the shaft **11220** for capture of the cords **2**. Second, the snare assembly **14100** provides various lockouts during this movement along the shaft **11220**, for example, to prevent extension of the snare at all times except when the snare delivery tube is correctly positioned just proximal of the clip **10400**, **11250**. Third, the snare assembly **14100** extends the snare to a distal position that is maximized for easy cord snaring by a user but, at the same time, is to be as physically compact as possible for good human ergonomics. [0323] FIGS. **141** and **142** illustrate the third feature, how the snare assembly **14100** extends the snare to a distance while the actual snare assembly **14100** is relatively small. To start, the snare assembly **14100** comprises three main parts, including an outer snare-extending sleeve **14110** that freely rotates about an interior body **14120** that is connected to a snare-movement body **14130**. The ability of the snare-extending sleeve **14110** to rotate freely about the interior body **14120** allows the user to not be concerned about how his/her hand is placed on the sleeve **14110** as the device is being rotated constantly during a surgical procedure. Free rotation also prevents torque from being imparted to the snare assembly **14100**, which torque would cause additional drag during longitudinal translation on the shaft **11220**.

[0324] These three parts provide a mechanism that allows the snare (not illustrated here but appearing in further figures) to extend out from the distal end of the snare assembly to a distance that is a multiple of the distance that the snare-movement body **14130** moves with respect to the interior body **14120**. This feature is best shown in FIGS. **141** and **142**, in which a snare, for example with the shape shown in FIGS. **8**, **12**, **36**, and **37** but not illustrated in FIGS. **141** and **142**, is grounded at its proximal end at a grounding area **14132** within the movement body **14130**. In this exemplary embodiment, the grounding area **14132** is a proximal end of a first tube **14134** that is fixed to the movement body **14130** and in which the proximal end of the snare is fixed, e.g., crimped. The snare progresses proximally in a first extent through the first tube **14134** and then through a 180-degree first bend **14122** within the interior body **14120**. After the first bend **14122**, the snare continues through a second tube **14136** that is slidably received through a portion of the movement body **14130**. The snare then continues through a 180-degree second bend **14138**, which terminates at the proximal end of a snare-guiding tube **14140** that, in this exemplary embodiment is substantially in a J-shape. The distal snaring portion of the snare is collapsed within the snare-guiding tube **14140** while in the non-extended state of the snare—the state shown in FIG. **141**—with a terminal snare end (e.g., loop **12**) extending slightly out of the distal end of the snare-guiding tube **14140**. This configuration is referred to as a double trombone shape because it has two 180-degree U-turn bends (trombones). In essence, this configuration has three lengths traversing a total snare movement area. Therefore, motion of the snare by moving the movement body **14130** towards the interior body **14120** is amplified by a factor of three—thus, a 2 cm displacement of the movement body **14130** distally results in a 6 cm movement of the snare from its captured position within the snare-guiding tube **14140** to its final extended orientation outside the distal end of the snare assembly **14100**. If the first tube **14134** is removed to form a single trombone, then two lengths will cross the intermediate movement area and the ratio of snare movement to movement body displacement is 2:1. An alternative to this relatively planar trombone configuration is a non-illustrated three-dimensional spiral corkscrew track, which also provides an increase in snare end movement as compared to the travel distance of the movement body **14130**. FIG. **142** illustrates the snare assembly **14100** in the snare-extended state with the sleeve **14110** displacing the movement body **14130** distally to touch the proximal side of the interior body **14120** and, thereby, extend the snare distally out through a clip to its fullest extent.

[0325] Another feature of the snare assembly **14100** is that it provides various lockouts during movement along the shaft **11220**. The many different lockouts are provided by a single device

having a complex shape, which device interacts with other features within the snare assembly **14100** and the shaft **11220**. This exemplary embodiment of the multi-function lockout **14300** has a shape similar to a silhouette of a helicopter. Depending on the state of the snare assembly and/or on the state of the movement body **14130**, the lockout **14300** provides a different lockout function. [0326] In a first lockout state, it is desired to retain the snare in its fully retracted position and prevent it from extending. This first state exists while the snare assembly **14100** is proximal of its distal-most position. FIGS. **143**, **147**, and **151** show the multi-function lockout **14300** in this first lockout state in which the snare assembly **14100** is able to translate along the shaft **11220** from the handle to the distal end of the shaft **11200**. To fix the interior body **14120** in a single circumferential position about the shaft **11220**, a canopy **14302** of the lockout **14300** rides in a groove **11221** of the shaft **11220** to act as a key within the keyway of the groove **11221**. This groove **11221** is especially visible in FIG. **151**. The blade feature of the canopy **14302** that is positively engaged in the groove **11221** on the shaft **11220** can selectively become disengaged from the keyway at the distal-most position while the tail **14304** keeps the snare assembly **14100** in position and clocking. Alternatively, the blade feature of the canopy **14302** can be made to stay continuously engaged in the groove **11221**. In an alternative embodiment, there can be a separate key continuously engages the groove **11221**. Other embodiments for clocking the interior body **14120** can include a keyway that is internal or external to the shaft **11220**. Another exemplary embodiment for keeping the interior body **14120** clocked with respect to the shaft **11220** includes placing a secondary tube along the outside surface of the shaft **11220** to form a “snowman” cross-section. Likewise, that secondary tube can be replaced with an external blade or square wire or a hexagonal or other polygonal rod. The exterior shape of the shaft **11220** can also be altered to provide the keying feature. Other external configurations include a comb and slot or an integral stop such as a cross-pin, a horseshoe, or a fin on the shaft **11220**. In another exemplary embodiment, the entire snare assembly **14100** can be freely rotating proximal to a given point on the shaft **11220** but, after passing a set distal location, the interior body **14120** is forced to clock into a given orientation. This can be accomplished, for example, with a funnel and pin assembly. All of these various features together define a method for keeping the snare assembly **14100** clocked onto the shaft **11220**.

[0327] The lockout **14300** pivots about a pin **14301** that is oriented transverse to the shaft **11200**. The rotational orientation of the lockout **14300** shown in FIGS. **143** and **147** keeps the tail **14304** below the shaft **11220** because the tail **14304** has a width greater than the width of the groove and, therefore, it is also wider than the canopy **14302**. The cross-sectional views of FIGS. **143** and **144** do not allow the thickness of the tail **14304** or the sides of the lockout **14300** to be seen. Those features can be seen, however, in FIG. **147** and, especially in FIG. **151**, in which the width of the tail **14304** and the canopy **14302** are apparent and it can also be seen that one or more side pontoons **14303** of the lockout **14300** extend laterally from the side of the lockout **14300**. In this orientation, the pontoon **14303** opposes a blocking surface **14131** of the movement body **14130** to prevent the movement body **14130** from moving towards the interior body **14120**, thereby keeping the movement body **14130** in its proximal position in which the snare is retained in its retracted position and cannot extend.

[0328] FIGS. **145** and **149** illustrate how the pontoon(s) **14303** is(are) moved out of the way of the blocking surface **14131** by various other features of the snare assembly **14100**. First, the shaft **11220** defines a tail orifice **11223** just distal of a distal end **11225** of the groove **11221**. The tail **14304** cannot move into the tail orifice **11223** by itself because it is biased with a clockwise force (in the view of FIGS. **143** to **149**) by a non-illustrated bias device (e.g., a spring). What causes the desired tail-raising movement (i.e., counter-clockwise rotation of the lockout **14300**) is a cam action that occurs when the sloped rear canopy edge **14305** comes into contact with and continues to contact the distal end **11225** of the groove **11221**. Further distal movement of the interior body **14120** on the shaft **11220** causes the distal end **11225** of the groove **11221** to force the canopy

14302 downwards to thereby, move the tail **14304** into the tail orifice and, thereby, prevent any further distal movement of the interior body **14120**—because the distal edge of the tail orifice **11223** forcibly contacts the distal face of the tail **14304**. When this occurs, as shown in FIG. **149** and, especially, FIG. **150**, the lockout **14300** has pivoted to such an extent to move the pontoon(s) **14303** radially downwards sufficiently far to move out of the way of the blocking surface **14131**, thereby freeing the movement body **14130** from its fixed state with respect to the interior body **14120**. Simultaneously, the distal exit **14142** of the snare-guiding tube **14140** is at a position in which it can enter a snare access window **11228** in the shaft **11220**.

[0329] The snare-guiding tube **14140** is grounded at its proximal end to provide support to the snare while being able to flex. As shown in FIGS. **143** to **153**, the snare-guiding tube **14140** has a double bend **14144**, **14146** to provide clearance so that the distal exit **14142** can flex upwards (with regard to the views of the drawings) when the distal end of the snare-guiding tube **14140** is not present at the snare-access window **10424**, **11228** as shown in the difference between FIGS. **152** and **153**. The flexing movement of the distal end of the snare-guiding tube **14140** is illustrated in FIG. **152** with the double-headed arrow. An alternative to this exemplary shape is a recurve or S-tube that can align the exit opening more in line with the top surface of the bridge of the guide rail so that the snare is presented with less ricochet into the opening of the clip. The S-tube can provide features to vertically position its exit relative to the guide rail, relative to the shaft, and/or, relative to the snare assembly. Another alternative embodiment of the snare-guiding tube includes an open cut scoop or similar shape that deflects the snare and directs it toward the clip opening.

[0330] Because a distal extent of the snare-guiding tube **14140** is pre-bent with a bias towards the shaft **11220**, when the distal exit **14142** is not within the snare-access window **11228**, the distal exit **14142** rides along the top exterior surface of the shaft **11220**, as shown in FIG. **153**. The tube **14140** remains in that radially outward flexed state until the distal exit **14142** of the snare-guiding tube **14140** enters the snare access window **11228** (as shown in FIGS. **145**, **146**, **149**, **150**, and **152**), at which time, a radially extending cavity **14126** in which the distal extent of the snare-guiding tube **14140** resides allows that distal extent to spring radially inwards into the snare access window **11228** to an orientation in which the distal exit **14142** is aligned with the central opening of the clip that is loaded in the cord-securing location **10802**, **11222** ready to secure cords **2**, which orientation is especially visible in FIG. **152**. At the point when the pontoon **14303** lowers, no lock of the lockout **14300** prevent the movement body **14130** from translating distally all the way until its distal surface meets a proximal side **14124** of the interior body **14120** (as shown in FIGS. **146**, **150**, and **152**) at which time, the snare **14600** has extended out through the distal exit **14142** and, because the guide rail **10410**, **11210** is disposed within the shaft **11220** (not shown in FIGS. **143** to **150** but shown in FIG. **152**), the snare **14600** slides along the bridge **11214** of the guide rail **10410**, **11210** and exits through the central opening of the clip **11251** to open and be ready to capture cords **2** within the snare opening. It is noted that the snare **14600** is prevented from being exposed to the environment outside the interior body **14120** when in the middle of reloading due to the length of the snare access window **11228**, as shown in FIG. **153**.

[0331] When the snare assembly **14100** is at its distal-most position, the lockout **14300** releases forward movement of the snare **14600** but also locks the snare assembly at its distal-most position—the tail **14304** prevents both distal and proximal movement of the movement body **14130** when the snare **14600** is extended. This means that, when at this distal-most position, the snare assembly **14100** is locked on the shaft **11220** at all times when the snare is being extended or retracted. Only after the snare **14600** is fully retracted into the snare assembly **15100** (i.e., where a small eyelet remains outside the snare-guiding tube **14140** as shown in FIG. **153**), the lockout **14300** disengages the snare assembly **14100** from the end of the shaft **11220** but reengages fixation of the snare extension parts to prevent any movement of the snare when the snare assembly **14100** is not present at its distal-most, clip-snaring position on the shaft **11220**. Leaving a small eyelet of the snare **14600** exposed allows the cords **2** to slide freely as the snare assembly **14100** is moved

proximally along the shaft **11220**. A mechanism such as a ramp or cam can be used to further forcibly flex the tip of the snare-guiding tube **14140** away from the outside of the shaft **11200** to enable freer movement of the cords. This action can be increased to a point where the cords **2** are separated far enough from the shaft **11220** to assist the operator in being able to grasp the cords **2**. [0332] The snare can be of different shapes and diameters, some of which are shown in FIGS. **8**, **12**, **36**, and **37**. In an exemplary embodiment, the area of the oval/circle encapsulated by the snare is between approximately 5 and 15 cm.^{sup.2}, in particular, between approximately 8 and 10 cm.^{sup.2}. Preferably, the distal end of the snare defines a small catch that positively places the cord(s) to be secured at the distal-most end of the snare. An example of such a catch or loop is shown in FIGS. **8**, **12**, **36**, and **37**. This distal-most end always remains partially extended to prevent binding of the suture cords as shown in FIGS. **57** and **153**.

[0333] In operation of the snare, the snare-guiding tube houses the operative end of the snare and guides it through the tube opening of the shaft, along the upper surface of the guide rail, through the clip in the cord-securing location, and out the distal end of the multiple-clip securing device to be presented to the user for receiving one or more cords therein. The movement body ejects the snare out from the snare-guiding tube with enough force against guide rail to cause snare deflection along the top surface of the bridge of the guide rail (e.g., ricochet) and through the center of the securing device (e.g., the clip). In an exemplary embodiment, such as that shown in FIG. **152**, the distal exit of the snare-guiding tube is cut at an angle to assist with snare positioning to ensure that it passes through the clip. As described and/or shown herein, it is beneficial for the snare tip to be exposed out from the snare-guiding tube at all times to ensure that it passes through the clip each time the snare is extended.

[0334] The snare access window **10424**, **11228** can be of various shapes. FIGS. **104** to **111**, **121** to **123**, **127**, **128** show the window with a curve-cornered rectangular shape and FIGS. **112**, **119**, **125** show the window having a funnel shape. The window having a proximal funnel shape that decreases in width in the distal direction provides the snare-guiding tube with easier access into the window.

[0335] It is desirable to retain the snare assembly adjacent the handle as shown in FIG. **139**. One exemplary low-footprint embodiment for retaining this placement provides opposing magnets at both the distal end of the handle and the proximal end of the snare assembly. This retaining structure keeps the snare assembly parked in its most-proximal position. Locations **15400** for magnets forming the retaining structure can be found, for example, in FIGS. **139** and **154**. A switch that detects when the snare assembly is parked, i.e., parking switch **13900**, can be a hall-effect sensor that detects when the snare assembly is in its most-proximal position and the magnets at the locations **15400** can be used to trigger this hall-effect sensor. The sensor can be used to determine if the snare assembly **14100**, **15530** has been advanced away from the handle **13810**, **15510** when there is no clip in the ready-to-thread position. In this case, the drive system (e.g., **13850**, **13852**, **13854**) can move the inner tube **12540**, **15650** proximally by a small distance, which movement will make the openings **11223**, **15523** that are normally aligned for receiving the stop **14304**, **15664** to be closed by the inner tube **12540**, **15650**, thus entirely preventing extension of the snare.

[0336] Another exemplary embodiment for a multiple-clip securing device **15500** is shown in FIGS. **155** to **166**. Many of the features in this embodiment are similar or even the same as previous embodiments of the device. Even though such features may be referenced with a different numeral, that designation, alone, does not mean that the feature is different and can be the same. Likewise, where features are referenced with the numeral, that designation, alone, does not mean that the feature is the same and can be different.

[0337] In the multiple-clip securing device **15500**, a user handle **15510** includes a shaft **15520** in which resides a plurality of cord-securing clips described in detail below. Slidably disposed on the shaft **15520** is a snare assembly **15530**. As in the other exemplary embodiments herein, the securing process includes moving the snare assembly **15530** to the distal end of the shaft **15520**, as

shown in FIGS. **157** and **160**. When the cords are ready to be snared, the snare **15532** is extended by moving a snare-extender sleeve **15534** distally, as shown in FIG. **161**, the snare **15532** being represented diagrammatically with dashed lines. Moving the snare-extender sleeve **15534** proximally, as shown in FIG. **158**, withdraws the snare **15532** and captures the cords **2** within the snare assembly **15530** for movement through a securing clip **15550** and out the side of the shaft **15520** for manipulation by the user. Sliding the snare assembly **15530** proximally, as shown in FIGS. **162** and **163**, pulls the ends of the cords **2** through the clip **15550** and out a snare-access window **15522** of the shaft **15520** to an orientation that allows a user to manipulate the free ends **2'** of the cords **2**. In this exemplary embodiment, the snare-access window **15522** is at the bottom of the shaft **15520** but it can be at another orientation along the circumference of the shaft **15520**. Having the opening on the bottom allows the cords **2** to drape due to gravity and preferentially opening a loop that is easier for an operator to grasp. When the cords **2** are ready to be secured by the clip **15500**, a clip-securing trigger **15512** of the handle **15510** is depressed to install the clip **15500** and activate a cord-cutting assembly within the handle **15510** and the shaft **15520** as described in further detail below. Finally, a reload trigger **15514** is pressed to automatically reload a clip **15550** for a further clip-securing procedure.

[0338] The flow chart of FIG. **103** describes an exemplary process for completing a cord-securing procedure with the multiple clip-securing device **15500**. In order to initialize the device **15500**, the snare assembly **15530** is in its retracted home position at the handle **15510**. It is assumed that the clips **15550** come preloaded within the shaft **15520** before it is passed to a user, the clips **15550** being loaded, for example, at the manufacturer. Of course, there can be a pre-initialization requirement that has the user load the shaft **15520** with the clips **15550**. Once initialized, if the first clip **15550** (the distal-most one) is not already at a cord-securing location **15622**, it is advanced to the cord-securing location **15622**, examples of which are shown in FIGS. **156** and **158**. At this point, the device is ready to use.

[0339] An exemplary embodiment of a distal end of the shaft **15520** is depicted in FIGS. **155** to **163**. As can be seen, a set of clips **15550'** are installed on a guide rail **15540** for use in subsequent clip-securing operations. The guide rail **15540** is fixedly secured within the shaft **15520** through a rail block **15560**. Also disposed within the shaft **15520** is a distal portion of a cutting/reloading shaft **15650**, which is slidably disposed within the shaft **11220**. It is desirable to provide the outer surface of the shaft **15520** with the side window to allow a user to count the number of clips **15550'** remaining in the multiple-clip securing device **15500**, but that side window is not illustrated in the cross-sections of FIG. **155** et seq. and an example can be seen in FIGS. **104** to **111**.

[0340] To carry out the manual steps for capturing the cords **2**, the user distally extends the snare assembly **15530** from a proximal position at the handle **15510** (seen in FIG. **155**). During this movement, a snare-guiding tube **15610** will move from a position where the distal exit **15612** is sliding along the outer surface of the shaft **15520** to a radial-inward position in which it enters a snare access window **15522** of the shaft **15520**, to place the distal exit **15612** of the snare-guiding tube **15610** just proximal of the distal-most clip **15550** to be used in the present clip-securing operation. In such an orientation, the distal exit **15612** is aligned with the opening within the clip **15550**. Therefore, when the user distally extends the snare **15532** after the snare assembly **15530** reaches its distal end stop on the shaft **15520**, the snare **15532** passes through the opening of the clip **15550** and opens up to receive cords **2** therein to be secured. The user manually captures the cord(s) **2** within the snare **15532** by, for example, threading sutures through the central opening of the snare **15532**. Capturing is completed when the user retracts the snare **15532** proximally to hold the cord(s) **2** at the distal end of the snare assembly **15530**. Assuming the user is satisfied with the way that the cords **2** are captured in the snare **15532**, the user will, then, return the snare assembly **15530** proximally back to its proximal position at the handle **15510** to present the free ends **2'** of the cord(s) **2** outside the shaft **15520**. If the snaring is not acceptable, the snare **15532** is extended again for acceptable recapture. An orientation when the snare assembly **15530** has moved

proximally back to the handle **15510** and has threaded the cords **2** through the clip **15550** in this ready-to-secure state is depicted in FIG. **162**.

[0341] The distal end of the shaft **15520** is then slid distally along the cord(s) **2** to a place where the user desires to set the clip **15550** housed inside the distal end of the shaft **15520**. For example, where the cord **2** is a surgical suture, a securing point of the clip **15550** is as close to the surgical site as possible with no length of the suture between the clip and the tissue. In such a case, the user moves the distal end of the shaft **15520** up against the tissue to place the clip **15550** in a ready to be fixed location. Automatic clip securement can now occur. The user presses the clip-securing trigger **15512** and, in doing so, two actions occur. First, the clip **15550** is fixed to the cords **2** and, second, the cord(s) **2** is/are cut, the latter of which is depicted in FIG. **163**. Movement of the multiple clip-securing device **15500** away from the securing site reveals to the user that the clip **15550** is secured on the cords **2** and the cords **2** are cut on the side of the clip **15550** facing away from the site. The multiple clip-securing device **15500** indicates (by visual, audible, tactile measures) that a cutting action has completed but a user can actuate the clip-securing trigger **15512** again, if desired, and the cutting action will repeat.

[0342] To reload the device **15500**, the user presses the reload trigger **15514** and a procedure for placing a now distal-most clip **15550'** at a cord-securing location **15622** at the distal end of the shaft **15520** can begin. The device **15500** automatically moves the cutting/reloading shaft **15650** rearward to a position where the clip-movement arms catch the clip **15550'**. Then, the cutting/reloading shaft **15650** extends distally to place the clip **15550'** at the cord-securing location **15622**. The securing and cutting operations are repeated as before to secure the second clip **15550** on new cords **2** and move the clip **15550** off of the guide rail **15540**. The clip-securing processes are repeated for as many times as needed in a given procedure. In the exemplary embodiment of FIGS. **155** to **163**, there is one clip **15550** and twenty reload clips **15550'** illustrated. As can be understood, the cutting/reloading shaft **15650** moves a distance proximally that increases for each new clip that is being reloaded. The clips are loaded with a known and fixed separation distance between each clip. In this example, they are disposed 0.050" apart. The drive mechanism includes a position sensor so that the device knows precisely its position along the central axis, which can include, for example, a linear encoder or a rotary encoder on the motor or drive pinion. In such a case, the control system would know exactly how to move the clip positioning mechanism a distance incremented by the spacing (0.050" in this example) with each subsequent clip that it is picking up. The movement algorithm is set within the device **9800**, **11200**, **15500** and starts in a ready position by holding a clip with the cutting/reloading shaft (i.e., the reloader) at the distal end of the shaft. This position aligns the shaft and the cutting/reloading shaft in a way that allows for snare access and securing of a cord or cords. When the user triggers the device to dispense the clip (e.g., by pulling in the clip-securing trigger), the cutting/reloading shaft is moved distally until the clip falls free from the guide rail and the two cord cutting edges closed. This movement is determined by a fixed displacement. The cutting/reloading shaft returns to a ready position upon release of the clip-securing trigger and waits for further user input. Upon triggering a reload (i.e., by depressing the reloading trigger), the reloader retracts proximally by a predetermined amount to a location of the next distal-most clip in the stack, which amount is incremented each time another distal-most clip is moved distally and dispensed. The reloader completes the movement sequence by moving distally and returning to the ready position.

[0343] With regard to the connection between the cutting/reloading assembly and the securing devices, e.g., the clip **10400**, **10800**, **11250**, **11251**, **15550**, various exemplary embodiments include a cutting/reloading shaft **15650** that slides back and forth within the shaft **9820**, **11220**, **15520**, a body of that cutting/reloading shaft **15650** having, at its distal end, two non-illustrated clip-movement arms. Exemplary embodiments of the clip-movement arms **10442**, **11242**, **12560** and how they interact with the clip **10400**, **10800**, **11250**, **11251**, **15550** in order to carry out the cord-securing processes of the device **9800**, **11200**, **15500** are illustrated FIGS. **129** to **134**. The

cutting/reloading shaft **1550** has all of the features of the arm-carrying tube of the cutting/reloading assemblies described above and/or shown and is, therefore, not repeated here. [0344] The guide rail **1540** is similar to the other exemplary embodiments of the guide rail **10410**, **11210**. The guide rail **1540** also possesses features that enhance the clip-securing processes of the exemplary systems **9800**, **11200**, **15500**. For ease of understanding, only guide rail **1540** will be referred to but this single reference applies to all embodiments of the guide rail.

[0345] In contrast to the exemplary embodiment of FIG. **136**, the clip-holding guide rail **1540** is rectangular in cross-section with no intermediate bridge or opposing walls. The rectangular shape allows the clips **1550** to be held open with a virtually complete contact area between the two opposing, interior clipping surfaces of the clip **1550** and the upper and lower surfaces of the guide rail **1540**. This configuration can prevent damage to the clip **1550** as it is being slid over the length of the guide rail **1540**. Polishing and surface treatments can further reduce any friction and/or wear that occurs during the sliding movement of the clips **1550**. The open space through which the cord-capturing snare **1532** is to be passed to slide along the upper surface of the guide rail **1540** and pass through the proximal face of the open clip **1550** is defined by a tapered slope **1542**. The angle of the slope **1542** can be set at any value, however, one beneficial angle is a value that is approximately equal to the angle that the lower internal flexing wall **13300** of the clip **1550** makes with respect to the upper/lower surface of the guide rail **1540**. In this way, if the snare **1532** slides against the upper surface of the guide rail **1540** and then down the slope **1542**, having the surface of the lower internal flexing wall **13300** match the slope **1542** permits travel of the snare **1532** substantially without friction or snagging. This is especially true if the central edge of the wall **13300** is just below the distal end of the slope **1542**.

[0346] During manufacture of the multiple-clip securing device **15500**, it is desirable to preload all of the clips **1550** onto the guide rail **1540** before the guide rail **1540** is installed in the handle **15510**. To assist with this preloading, the proximal end **15544** of the guide rail **1540** is ramped or chamfered. The ramp can start from a point or from almost a point and can taper outwards (up/down) until reaching a height that is desirable for extending the snare **1532** through the opening within the clip **1550**. This means that the thickness of the guide rail **1540** (top/bottom) can be variable over the longitudinal length of the guide rail **1540** that starts small to place a lower load on the internal features of the clip **1550**, for example, for storage purposes, and only place the higher load on the internal features when the clip **1550** is at the distal end of the guide rail **1540** ready to be used. For manufacturing ease, one or more retainer holes **15546** can be bored in the guide rail **1540**. These holes **15546** can also be used to support the guide rail **1540** as the clips **1550** are loaded thereon. Shapes other than a rectangular cross-section of the guide rail **1540** can be used to hold the clips **1550** as mentioned herein.

[0347] The guide rail **1540** can be fabricated in the various production methods described and/or shown with respect to guide rail **11210**, with the materials that can be used to form the guide rail **1540** and the surface finishing being selected from the same variations as well.

[0348] The handle **15510** of the multiple-clip securing device **15500** can be configured to contain the various features described with regard to other exemplary embodiment described and/or shown herein, including, for example, the single, drop-in, circuit board **13820**, the power supply **13860**, the motor **13850**, pinion **13852** and rack **13854**, and the side-mounted switches. As opposed to the clip-securing trigger **13830** which pivots about a pivot pin **13832**, in this exemplary embodiment, the clip-securing trigger **15512** is a sliding trigger to provide a longer stroke than the pivoting trigger **13830** and to give the user time to decide if firing should be cancelled, which makes the device less sensitive to inadvertent clip firing.

[0349] FIGS. **98** to **102** and **141** to **153** illustrate exemplary embodiments of a movable snare assembly **9830**, **14100**. FIGS. **155** to **165** depict another exemplary embodiment of the snare assembly **15530**. The snare assembly **15530** provides various complex functions. First, it is disposed on the shaft **15520** so that it can move longitudinally thereon from a retracted proximal

position at the handle **15510** to an extended distal position in which the snare is extended through the snare access window **9822**, **10424**, **11228**, **15522** and through the clip **10400**, **11250**, **15550** to a position distal of the shaft **15520** for capture of the cords **2**. Second, the snare assembly **15530** provides various lockouts during this movement along the shaft **15520**, for example, to prevent extension of the snare at all times except when the snare-guiding tube **15610** is correctly positioned just proximal of the clip **10400**, **11250**, **15550**. Third, the snare assembly **15530** extends the snare **15532** to a distal position that is maximized for easy cord snaring by a user but, at the same time, is to be as physically compact as possible for good human ergonomics.

[0350] How the snare assembly **15530** extends the snare **15532** to a distance while the actual snare assembly **15530** is relatively small is explained with respect to other embodiments and is not repeated herein.

[0351] The snare assembly **15530** comprises three main parts, including the outer snare-extending sleeve **15534** that freely rotates about an interior body **15620**, which is connected to a snare-movement body **15630**. The ability of the snare-extending sleeve **15534** to rotate freely about the interior body **15620** allows the user to not be concerned about how his/her hand is placed on the sleeve **15620** as the device is being rotated constantly during a surgical procedure. Free rotation also prevents torque from being imparted to the snare assembly **15530**, which torque would cause additional drag during longitudinal translation on the shaft **15520**.

[0352] These three parts provide a mechanism that allows the non-illustrated snare to extend out from the distal end of the snare assembly **15530** to a distance that is a multiple of the distance that the snare-movement body **15630** moves with respect to the interior body **15620**. As in the previous embodiments, motion of the snare **15532** occurs by moving the snare-movement body **15630** towards the interior body **15620** resulting in a movement of the snare **15532** from its captured position within the snare-guiding tube **15610** to its final extended orientation outside the distal end of the snare assembly **15530**. The snare **15532** progresses through the distance multiplication features and terminates at the proximal end of the snare-guiding tube **15610** that, in this exemplary embodiment is substantially in a J-shape. The distal snaring portion of the snare **15532** is collapsed within the snare-guiding tube **15610** while in the non-extended state of the snare **15532**—the state shown in FIGS. **155** to **159**—with a terminal snare end (e.g., loop **12**) extending slightly out of the distal end of the snare-guiding tube **15610**.

[0353] In FIG. **159**, the lockout **15660** is in a position that exists during sliding of the snare assembly **15530** along the shaft **15520**. In this position, the anti-rotation fin **15662** acting as a key is engaged in the groove **15521** along the length of the shaft **15520**. As the snare assembly **15530** reaches the distal end of the shaft **15520**, the sloped distal fin edge **15668** hits the terminal wall of the groove **15521** and forces the lockout **15660** to pivot, thereby moving the stop **15664** into the stop orifice **15523** to halt motion of the snare assembly **15530** along the shaft **15520**. FIGS. **160** and **161** illustrate the snare assembly **15530** in the snare-extended state with movement of the sleeve **15534** displacing the snare-movement body **15630** distally to touch the proximal side of the interior body **15520** and, thereby, extend the snare **15532** distally out through a clip to its fullest extent.

[0354] Grounding of the snare **15532** is illustrated in FIG. **164**. The snare **15532** is grounded at its proximal end at a grounding area **15624** within the interior body **15620**. In this exemplary embodiment, the grounding area **15624** is a crevice having a Z-shape that corresponds to an outer shape of a grounding end **16412** of a snare-grounding tube **16410**. The grounding end **16412** is fixed to the interior body **15620** (e.g., with a screw **16420**) and in which the proximal end of the snare **15532** is fixed, e.g., crimped. Also with respect to FIG. **164** and FIG. **165** as well, it can be seen that the outer tube of the shaft **15520** and the inner tube of the cutting/reloading shaft **15650** are flush at the distal end of the multiple-clip securing device **15500**. This is desirable to allow a positioning of the clip **15550** flush to the inner and outer tube ends to aid in tensioning the device on cords **2** to be secured with the clip **15550** and to present the most blunt edge possible to the

sewing cuff or tissue that is being affixed.

[0355] Another feature of the snare assembly **15530** is that it provides various lockouts during movement along the shaft **15520**. The many different lockouts are provided by a single device having a complex shape, which device interacts with other features within the snare assembly **15530** and the shaft **15520**. This exemplary embodiment of the multi-function lockout **15660** is a rocker pivoting about a pivot **15626** on the interior body **15620** and having fins and varying surface features and heights. Depending on the state of the snare assembly **15530** and/or on the state of the snare-movement body **15630**, the lockout **15660** provides a different lockout function.

[0356] In a first lockout state, it is desired to retain the snare **15532** in its fully retracted position and prevent it from extending. This first state exists while the snare assembly **15530** is proximal of its distal-most position. FIGS. **155** to **159** show the multi-function lockout **15660** in this first lockout state in which the snare assembly **15530** is able to translate along the shaft **15520** from the handle **15510** to the distal end of the shaft **15520**. To fix the interior body **15620** in a single circumferential position about the shaft **15520**, an anti-rotation fin **15662** of the lockout **15660** rides in a groove **15521** of the shaft **15520** to act as a key within the keyway of the groove **15521**. The blade feature of the fin **15662** that is positively engaged in the groove **15521** on the shaft **15520** is selected to have a length that remains within the groove **15521** at all times. In an alternative embodiment, the fin **15662** can selectively become disengaged from the keyway at the distal-most position while another portion of the lockout **15660** (e.g., the stop **15664**) keeps the snare assembly **15530** in position and clocking. In a further alternative embodiment, there can be a separate key on parts of the snare assembly **15530** that continuously engages the groove **15521**. Other embodiments for clocking the interior body **15620** can include a keyway that is internal or external to the shaft **15520**. Another exemplary embodiment for keeping the internal body **15620** clocked with respect to the shaft **15520** includes placing a secondary tube along the outside surface of the shaft **15520** to form a “snowman” cross-section. Likewise, that secondary tube can be replaced with an external blade or square wire or a hexagonal or other polygonal rod. The exterior shape of the shaft **15520** can also be altered to provide the keying feature. Other external configurations include a comb and slot or an integral stop such as a cross-pin, a horseshoe, or a fin on the shaft **15520**. In a further exemplary embodiment, the entire snare assembly **15530** can be freely rotating proximal to a given point on the shaft **15520** but, after passing a set distal location, the internal body **15620** is forced to clock into a given orientation. This can be accomplished, for example, with a funnel and pin assembly. All of these various features together define a method for keeping the snare assembly **15530** clocked onto the shaft **15520**.

[0357] The lockout **15660** pivots about the pivot **15626** that is oriented transverse to the shaft **15520**. The rotational orientation of the lockout **15660** shown in FIGS. **143** and **147** keeps the stop **15664** below the shaft **15520** because the stop **15664** has a width greater than the width of the groove **15521** and, therefore, it is also wider than the fin **15662**. The cross-sectional views of FIGS. **155** to **165** do not allow the thickness of the stop **15664** or the sides of the lockout **15660** to be seen. Nonetheless, the width of the stop **15664** is greater than the fin **15662** so that the stop **15664** remains in the position shown in FIGS. **155** to **159** until the lockout **15660** moves distally to align the stop **15664** with a stop orifice **15523** of the shaft **15520**. Also seen in FIGS. **155**, **156**, **159**, and **161** is a side boss **15666** extending laterally from at least one side of the lockout **15660**. In the orientation shown in these figures, the side boss **15666** rests within a slot **15634** of the snare-movement body **15630** to prevent the snare-movement body **15630** from moving either towards or away from the interior body **15620**, thereby keeping the snare-movement body **15630** in its proximal position in which the snare **15532** is retained in its retracted position and cannot extend.

[0358] FIGS. **157** and **158** illustrate how the side boss **15666** is moved out of the slot **15634** by various other features of the snare assembly **15530**. First, the shaft **15520** defines the stop orifice **15523** just distal of a distal end of the groove **15521**. The stop **15664** slides along the outside surface of the shaft **15520** and, because the stop **15664** is wider than the groove **15521**, a non-

illustrated bias device (e.g., a spring) keeps the lockout **15660** biased in a counter-clockwise position (in the view of FIGS. **155** to **163**) until it comes to the stop orifice **15523**. What causes the desired fin-raising movement (i.e., clockwise rotation of the lockout **15660**) is a cam action that occurs when the sloped distal fin edge **15668** comes into contact with and continues to contact the distal end of the groove **15521**, which is depicted in FIG. **159**. Further distal movement of the interior body **15620** on the shaft **15520** causes the distal end of the groove **15521** to force the fin **15662** upwards and, thereby, move the stop **15664** into the stop orifice **15523**, which prevents any further distal movement of the interior body **15620**—because the distal edge of the stop orifice **15523** forcibly contacts the distal face of the stop **15664**. When this occurs, as shown in FIGS. **158** and **161**, the lockout **15660** has pivoted to such an extent to move the side boss **15666** radially upwards sufficiently far to move out of the slot **15634**, thereby freeing the snare-movement body **15630** from its fixed state with respect to the interior body **15620**. Simultaneously, the distal exit **15612** of the snare-guiding tube **15610** is at a position in which it can enter a tube opening **15522** in the shaft **15620**.

[0359] The snare-guiding tube **15610** is grounded near its distal end by a pivot supporting tube guide block **15810**, which allows the snare-guiding tube **15610** to move freely up and down through an arc similar to that accomplished by the previously proximally grounded tube but with and advantage of a much shorter length, because the area of flexing of the tube is also part of the length of the trombone tube that is used to extend the snare. As shown in FIGS. **155** to **161**, the snare-guiding tube **15610** has a bend **15614** to provide clearance so that the distal exit **15612** can flex downwards (with regard to the views of the drawings) when the distal exit **15612** of the snare-guiding tube **15610** is not present at the snare-access window **15522** as shown in the difference between FIGS. **158** and **158**. The flexing movement of the distal end of the snare-guiding tube **15610** is illustrated in FIG. **158** with the double-headed arrow, a corresponding movement being carried out with the tube guide block **15810** that slides within a block cavity **15628** of the interior body **15620**. An alternative to this exemplary shape is a double-bend or a recurve or S-tube that can align the opening of the distal exit **15612** more in line with the top surface of the guide rail **15540** so that the snare **15532** is presented with less ricochet into the opening of the clip **15550**. Such an S-tube can provides features to vertically position its exit relative to the guide rail **15540**, relative to the shaft **15510**, and/or, relative to the snare assembly **15530**. Another alternative embodiment of the snare-guiding tube **15610** includes an open cut scoop or similar shape that deflects the snare **15532** and directs it toward the clip opening.

[0360] Because a distal extent of the snare-guiding tube **15610** is pre-bent with a bias towards the shaft **15620**, when the distal exit **15612** is not within the snare-access window **15522**, the distal exit **15612** rides along the top exterior surface of the shaft **15620**, as shown in FIG. **156**. The snare-guiding tube **15610** remains in that radially outward flexed state until the distal exit **15612** of the snare-guiding tube **15610** enters the snare-access window **15522** (as shown in FIGS. **157**, **158**, **160**, and **161**), at which time, a radially extending cavity **15629** in which the distal extent of the snare-guiding tube **15610** resides allows that distal extent to spring radially inwards into the snare-access window **15522** to an orientation in which the distal exit **15612** is aligned with the central opening of the clip **15550** that is loaded in the cord-securing location **10802**, **11222**, **15622** ready to secure cords **2**, which orientation is especially visible in FIG. **158**. At a point when the side boss **15666** raises, no lock of the lockout **15660** prevents the snare-movement body **15630** from translating distally all the way until its distal surface meets a proximal side of the interior body **15620** (as shown in FIGS. **160** and **161**) at which time, the snare **15532** has extended out through the distal exit **15612** and, because the guide rail **15540**, is disposed within the shaft **15620**, the snare **15532** slides along the surface of the guide rail **15540** and exits through the central opening of the clip **15550** to open and be ready to capture cords **2** within the snare opening. It is noted that the snare **15532** is prevented from being exposed to the environment outside the interior body **15620** when in the middle of reloading due to the length of the snare-access window **15522**, as shown in FIG. **159**.

[0361] Also shown in FIG. 159 is a secondary lock that prevents the lockout 15660 from rotating clockwise during the reloading operation. In particular, when the cutting/reloading shaft 15650 moves proximally, which it must do during any reloading operation, the opening in the cutting-reloading shaft 15650 that is aligned with the snare-access window 15522, is no longer aligned and, therefore, completely covers the stop orifice 15523 to prevent the stop 15664 from entering the stop orifice 15523. This, in turn, completely prevents the user from attempting to move the snare-movement body 15630 distally and deploy the snare 15532 while reloading.

[0362] To summarize the movement, when the snare assembly 15530 is at its distal-most position, the lockout 15660 releases forward movement of the snare-movement body 15630 (i.e., the snare 15532) but also locks the snare assembly 15530 at its distal-most position—the stop 15664 prevents both distal and proximal movement of the snare-movement body 15630 when the snare 15532 is extended. This means that, when at this distal-most position, the snare assembly 15530 is locked on the shaft 15520 at all times when the snare 15532 is being extended or retracted. Only after the snare 15532 is fully retracted into the snare assembly 15530 (i.e., where only the small eyelet remains outside the snare-guiding tube 15610 as shown in FIG. 153), the lockout 15660 disengages the snare assembly 15530 from the end of the shaft 15520 but reengages fixation of the snare extension parts to prevent any movement of the snare 15532 when the snare assembly 15530 is not present at its distal-most, clip-snaring position on the shaft 15520.

[0363] In operation of the snare 15532, the snare-guiding tube 15610 houses the operative end of the snare 15532 and guides it through the snare-access window 15522, along the upper surface of the guide rail 15540, through the clip 15550 in the cord-securing location 15622, and out the distal end of the multiple-clip securing device 15500 to be presented to the user for receiving one or more cords 2 therein. The snare-movement body 15630 ejects the snare 15532 out from the snare-guiding tube 15610 with enough force against guide rail 15540 to cause snare deflection along the top surface thereof (e.g., ricochet) and through the center of the securing device (e.g., the clip).

[0364] In this exemplary embodiment, the snare 15532 can be of different shapes and diameters as explained herein. These features are not repeated. Likewise, the snare access window 10424, 11228, 15522 can be of various shapes. FIGS. 156 and 161 show the window 15522 with a curve-cornered rectangular shape but the window 10424, 11228, 15522 can be of any desired shape including those described and/or shown herein.

[0365] It is desirable to retain the snare assembly 15530 adjacent the handle 15510 as shown in FIGS. 155, 162, and 163. One exemplary low-footprint embodiment for retaining this placement provides opposing magnets at both the distal end of the handle 15510 and the proximal end of the snare assembly 15530. This retaining structure keeps the snare assembly parked in its most-proximal position. Locations 15632 for magnets forming the retaining structure can be found, for example, in FIGS. 156 and 158. A switch that detects when the snare shuttle is parked, i.e., parking switch, can be a hall-effect sensor that detects when the snare assembly is in its most-proximal position and the magnets at the locations 156320 can be used to trigger this hall-effect sensor.

[0366] All together, the various features of the handle 13810, 15510 provide ways to minimize the so-called footprint of the multiple-clip securing device. An alternative embodiment to the pistol-shaped handle of FIGS. 98 to 102, 138, and 155 is a pear-shaped ball (similar to a conductor's wand) that can be rotated within a user's hand in all pitch, roll, and yaw axes.

[0367] With regard to the securing devices themselves, in general, they are stored-energy devices that use the stored energy to secure the cords. The clips have no stored energy before being forced onto the guide rail. However, when forced thereon and opened before firing, the energy for clipping is stored in the clip. The entire amount of energy can be stored right as the clip is slid onto the guide rail, or a variable amount can be store depending on where the clip is placed on the H-rail. Also envisioned is an E-shaped clip that uses a rail different from the H-rail.

[0368] Various clips have been mentioned herein and exemplary embodiments of the clip have been shown. One exemplary embodiment of the clip 11251, 15550 shown within other parts in

various figures is shown by itself in FIGS. **171** and **172**. For ease of understanding, reference numeral **17100** will be used to describe the clip **17100**, which is in its rest or steady state in FIG. **171**. Portions of this clip **17100** include a base **17110** having a cutout shape **17112** that defines an upper internal flexing wall **17120** and a lower internal flexing wall **17130**. Here, the cutout shape **17112** has variations, the shape of which creating teeth **17122**, **17132** on the opposing cord-securing surfaces **17124**, **17134**. As shown in FIG. **172**, when the clip **17100** is installed on a guide rail, for example, the upper and lower internal flexing walls **17120**, **17130** flex outward to define an opening **17140** and create a securing location between the opposing cord-securing surfaces **17124**, **17134** and imparting cord-securing energy for future use of the clip **17100**. The body **17110** of the clip **17100** can also be formed with handling surfaces **17114** for loading the clip **17100** onto a guide rail. Alternative exemplary embodiments of the cutout shape in a clip **17100** are depicted in FIGS. **173**, **174**, and **175**. FIG. **173** illustrates ports **17300** and does not include teeth. FIG. **174** includes variations **17400** in the cord-securing surfaces. Finally, FIG. **175** shows a variation of a tooth **17500** formed by the cord-securing surfaces.

[0369] Motion of the securing devices (e.g., the clips) can be accomplished in various ways. Exemplary embodiments of a rack-and-pinion drive are shown in FIGS. **138** to **140** and **155** to **163**. In another exemplary embodiment shown in FIGS. **167** to **169**, linear-motion of the clips can be imparted by a screw drive and/or a variable pitch screw within the handle for high speed on exchange and high force for firing/cutting. Only the screw drive components are shown in FIGS. **167** to **169** for clarity but these components are envisioned to replace other drive components described and/or shown herein. In particular, an exemplary embodiment of a screw drive **16700** contains a motor **16710** (which can have an internal gear box **16712**) having an output shaft **16714**. A screw assembly **16720** includes a drive connector **16722** connected to the output shaft to receive the rotational movement thereof. The drive connector **16722** is fixedly connected or connected through a non-illustrated clutch to a screw **16724**, which can have a constant or variable pitched thread **16726** depending on the circumstances of use. The outer shaft **9820**, **11220**, **15520** of the device is held immovable with respect to the motor **16710** and the screw **16724** by a frame **16730** that longitudinally holds the drive connector **16722** in place while allowing the drive connector **16722** to freely rotate along with the output shaft **16714**. The cutting/reloading assembly/shaft **10440**, **11240**, **12424**, **15650** has an internal guide with a correspondingly pitched internal thread (not illustrated) to the exterior threads **16726** of the screw **16724**. In this way, rotation of the screw **16724** in a first direction will move the cutting/reloading assembly/shaft **10440**, **11240**, **12424**, **15650** distally, as shown in the transition from FIG. **167** to FIG. **168**, or proximally if rotated in the opposite direction. One advantage of a screw drive is the compactness of the long stroke because it submerges the screw into shaft.

[0370] To track motion of the any drives described and/or shown herein, an encoder can be mounted on the motor. Alternatively or additionally, a linear encoder can be mounted on the rack to determine absolute position independent of the motor. With a drive screw directly mounted to the motor, as shown in FIGS. **167** to **169**, an encoder can be associated with the drive screw. A screw/nut drive also can be used. One drawback to this particular configuration is that two-times the stroke is needed or the screw needs to be buried inside the shaft. It is possible to have the nut small enough to be embedded within the shaft to shorten the handle length. An encoder can also be mounted on the main circuit board. For calibration of the drive, in an exemplary embodiment, position can be calibrated based on a sacrificial clip.

[0371] FIG. **170** illustrates an exemplary embodiment of an electro-mechanical way to deploy securing devices and to only use the gearbox for reloading and positioning the next securing device. This has the advantage of possibly improving the tactile feel by the user of deploying the securing device. This exemplary embodiment of a multiple-firing securement device **17000** has a motor-controlled screw mechanism **17010** that turns a screw **17012** to move the inner cutting/reloading assembly/shaft **10440**, **11240**, **12424**, **15650** to thereby grasp various securing

devices (e.g., clips) installed on the guide rail **17020** retainer at successively further distances on the guide rail **17020** from the securement-installing location **17022** and a mechanical lever **17030** that moves the entire cutting/reloading assembly/shaft **10440**, **11240**, **12424**, **15650** distally to perform cutting of the cords **2**.

[0372] Software of the control circuit of any of the exemplary embodiments can perform various functions for operating the multiple-clip securing device. First, error checking can be done based on the draw of current, which measures the torque that the motor is experiencing. Also, a distal detent position can be sensed using either or both of torque and current. Sensing of high current can be used to indicate that the device has picked up more than one or multiple clips. Sensing of low current can be used to indicate that the clip has been missed and not picked up by the reloading process. A self-clearing function can be added to the knife action based on a measurement of drag. Counting the number of securing devices can be done with a program that determines movement of the snare assembly before enabling the ability to fire the device and install the securing device. Based on a position of the parking switch, the device can lock out any reloading or firing if the snare assembly is not parked in the distal position. An alarm can be included to indicate motion of the snare assembly before a reload occurs. The LED on the circuit board as a user-interface can indicate (by color, flashing, patterns, etc.) various and many different states of the device. Also, voltage can be sensed on the battery to determine various operating conditions. These are only a few examples of how software can be used to monitor, report, display, and otherwise control use of the multiple-clip securing device.

[0373] With regard to powering on any of the multiple-clip securing devices, the multiple-clip securing device can be placed in packaging that, when the multiple-clip securing device is removed, a grenade pin is pulled or remains with the packaging to enable and, thereby power-on, the device. A battery-drain feature can also be provided to prevent multiple uses after a set amount of time occurs when the multiple-clip securing device has been removed from the packaging.

[0374] When any motors are described and/or shown herein, they also include, where desirable, any gearing or transmissions that are necessary to reduce the motor turns rate to affect the function of that motor. These transmissions are not described herein in further detail.

[0375] It is noted that various individual features of the inventive processes and systems may be described only in one exemplary embodiment herein. The particular choice for description herein with regard to a single exemplary embodiment is not to be taken as a limitation that the particular feature is only applicable to the embodiment in which it is described. All features described herein are equally applicable to, additive, or interchangeable with any or all of the other exemplary embodiments described herein and in any combination or grouping or arrangement. In particular, use of a single reference numeral herein to illustrate, define, or describe a particular feature does not mean that the feature cannot be associated or equated to another feature in another drawing figure or description. Further, where two or more reference numerals are used in the figures or in the drawings, this should not be construed as being limited to only those embodiments or features, they are equally applicable to similar features or not a reference numeral is used or another reference numeral is omitted.

[0376] The foregoing description and accompanying drawings illustrate the principles, exemplary embodiments, and modes of operation of the devices and methods. However, the devices and methods should not be construed as being limited to the particular embodiments discussed above. Additional variations of the embodiments discussed above will be appreciated by those skilled in the art and the above-described embodiments should be regarded as illustrative rather than restrictive. Accordingly, it should be appreciated that variations to those embodiments can be made by those skilled in the art without departing from the scope thereof as defined by the following claims.

Claims

1. A surgical suture-snaring device, comprising: a handle body; an automated carriage movement assembly that moves a carriage conveyor proximally and distally relative to the handle body, the automated carriage movement assembly comprising at least a first crimp; an end effector body extending distally relative to the handle, the end effector body having a distal end defining a distal opening through which suture material is snared and an internal crimp loading position into which the first crimp can be loaded prior to crimping; an outer tube surrounding the end effector and movable proximally and distally relative to the handle body and the end effector body; an automated crimping assembly actuatable to deform the first crimp onto snared suture material adjacent the crimp loading position to crimp the first crimp to the snared suture material; and a cutting assembly actuatable to cut the snared suture material on a proximal side of the first crimp, thereby separating the first crimp and the snared suture material distal of the first crimp from the device.
2. The device of claim 1, wherein the automated carriage movement assembly comprises a carriage motor operable to move the carriage conveyor proximally and distally relative to the handle body.
3. The device of claim 1, wherein the carriage conveyor is linked by a coupler to a crimp carriage, and wherein the crimp carriage is operable to shuttle crimps distally and to move the first crimp to the crimp loading position.
4. The device of claim 1, further comprising a snare movement device for moving a snare distally relative to the end effector body to snare suture material and moving the snare proximally to draw the snared suture material into the device.
5. The device of claim 1, wherein the automated crimping assembly comprises a crimping motor and a hammer.
6. The device of claim 5, wherein the outer tube is moved distally to a holding position to slightly engage the hammer with the first crimp and to hold the first crimp in the crimp loading position.
7. The device of claim 5, wherein the outer tube is moved distally to a crimping position to move the hammer against the first crimp in the crimp loading position and deform the first crimp onto the snared suture material.
8. The device of claim 1, wherein the automated crimping assembly comprises a clutch, a flying gear and a pinion.
9. The device of claim 1, further comprising a control assembly that controls operation of the automated carriage movement assembly, the automated crimping assembly and the cutting assembly.
10. The device of claim 1, further comprising at least one of a visual indicator, an audio indicator and a haptic indicator for indicating at least one state of the device to a user.
11. The device of claim 1, wherein the cutting assembly comprises a movable pushrod and fixed blade.
12. A surgical suture-snaring device, comprising: a handle body; an automated carriage movement assembly that moves a carriage conveyor proximally and distally relative to the handle body, the automated carriage movement assembly comprising at least a first crimp; an end effector body extending distally relative to the handle, the end effector body having a distal end defining a distal opening through which suture material is snared and an internal crimp loading position into which the first crimp can be loaded prior to crimping; an automated crimping assembly actuatable to deform the first crimp onto snared suture material adjacent the crimp loading position to crimp the first crimp to the snared suture material; a cutting assembly actuatable to cut the snared suture material on a proximal side of the first crimp, thereby separating the first crimp and the snared suture material distal of the first crimp from the device; and a control assembly that controls operation of the automated carriage movement assembly, the automated crimping assembly and the

cutting assembly.

13. The device of claim 12, further comprising a force-measuring and indicating assembly connected to the control assembly and positioned between the distal end and the handle, wherein the force-measuring and indicating assembly is configured to measure a tying force in the suture material imposed on the end effector body.

14. The device of claim 13, wherein the end effector is grounded to the handle.

15. The device of claim 13, wherein the tying force is defined by contact between the end effector body and a surgical site while the user is pulling on ends of the suture material from a side of the device.

16. The device of claim 13, wherein the force-measuring and indicating assembly comprises a load cell.

17. The device of claim 13, wherein the force-measuring and indicating assembly is configured to enable crimping when the detected tying force is within a predetermined tying force range.

18. The device of claim 13, wherein the force-measuring and indicating assembly is configured to automatically trigger crimping to occur upon detecting that the tying force is within a predetermined range.

19. The device of claim 13, wherein the force-measuring and indicating assembly is configured to cause at least one of a visual, audio or haptic signal to occur upon detecting that the tying force is at least equal to a predetermined minimum tying force.

20. The device of claim 13, wherein the force-measuring and indicating assembly is configured to lock out operating of the automated crimping assembly if the detected tying force is above or below a predetermined tying force range.
