The invention is a hingeless tool (1) including an inner member, an intermediate member (5) surrounding the inner member (2) and an optional outer member (6) surrounding the intermediate member (5). The outer member (6) can be a sheath fixedly or removably connected to a handle and the intermediate member (5) is slidably axially in the sheath (6). The inner member includes a pair of hingeless spaced-apart jaws (3, 4) forming a unitary piece at a distal end thereof and a proximal end of the inner member is attached to a stationary part of the handle. The intermediate member (5) is an axially slideable tube and the proximal end of the tube is connected to a movable part of the handle. The stationary and movable parts of the handle are connected in a hingeless manner by a flexible part of the handle. The distal end of the tube slides over a portion of the jaws to elastically deform the jaws towards each. Thus, by moving the movable part of the handle, the intermediate member can be moved axially to press the jaws towards each other without axial movement of the jaws. The inner member can be provided in two parts which are detachably connected together. Thus, the working end of the inner member having various types of jaw configurations can be interchangeably used with the tool. For instance, the jaws can be designed to be used as graspers, scissors, or a needle driver useful in endoscopic surgery.
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HINGELESS TOOL USEFUL IN SURGERY

FIELD OF THE INVENTION

The invention relates to a hingeless tool having a pair of jaws which are movable towards each other. More particularly, the tool includes an inner member which can be used as a grasper, scissors, manipulator, needle driver, or other tool having general utility or especially adapted for use during a surgical operation.

BACKGROUND OF THE INVENTION

Current endoscopic instruments, such as graspers, scissors or manipulators, are either reusable or disposable. Reusable instruments must be sterilized between use, which is very difficult unless the instruments can be fully disassembled. Due to the complexities of design, disassembly can be time consuming, or even impossible. Disposable instruments avoid the sterilization problem, but tend to be extremely expensive overall since each surgical procedure involves the use of a new disposable instrument. Moreover, the constant attempt to reduce the costs of disposable instruments naturally reduces the quality, performance and versatility of the instruments.

In the instruments currently employed in conventional endoscopic surgery, the opening distance of the jaws is limited. Further, the length, flexibility and the maximum possible forces are limited whereas the stiffness and size is increased and can lead to less usefulness or clumsy functionality. In the case of endoscopic scissors, another problem is caused by the short length of scissor blades. That is, the tissue cannot be divided with the same precision as possible by conventional scissors used in open surgery. The major prerequisite of ideal scissors is the tension by which the blades are held together while sliding along each other. In conventional scissors this is achieved by increasing the length of the two cutting blades. Some manufacturers try to achieve this tension with a screw (e.g. Metzenbaum scissors), which is useful but delicate and susceptible to breakage under hard use.

In the case of endoscopic needle drivers, there is a risk of jaw breakage or deformation in ordinary steel and hence an inlet of tungsten alloy in the jaws' surface is used to apply adequate gripping friction and pressure to the needle. The very hard
surface of the tungsten alloy presents a risk of destroying the suture material by grasping it with tungsten inlaid needle drivers.

**SUMMARY OF THE INVENTION**

The invention provides a hingeless tool comprising an inner member, an intermediate member and an optional outer member. The inner member can comprise a rod which includes a pair of spaced-apart jaws extending axially at a distal end of the inner member. At least one of the jaws is elastically deformable towards the other jaw and both jaws form a unitary piece. The intermediate member can comprise a tube which surrounds the inner member and is slidable axially with respect to the inner member. A distal end of the intermediate member is engageable with the jaws such that at least one of the jaws is elastically deformed towards the other jaw as the intermediate member is moved over the jaws. The intermediate member causes the jaws to apply a grasping pressure not exceeding a threshold value to an object located between the jaws. The outer member can comprise a sheath which surrounds the intermediate member and supports the intermediate member such that the intermediate member can slide axially towards and away from the jaws.

The inner member can be formed from a unitary piece of a shape memory alloy which provides the jaws in an austenitic state in an unstressed condition but transforms to a stress induced martensitic state in a stressed condition. That is, the jaws are in the unstressed condition when the jaws are not elastically deformed toward each other and are in a stress induced martensitic state when the jaws are elastically deformed towards each other. Likewise, the intermediate member can be formed from a shape memory alloy which is in an austenitic state in an unstressed condition but transforms to a stress induced martensitic state in a stressed condition thus allowing highly elastic bending of the intermediate member. In either case, due to the stress induced martensitic state of the jaws and/or intermediate member it is possible to provide a grasping pressure of the jaws which does not exceed a threshold value and the inner member and intermediate member can be easily curved, formed and/or steered to a desired location.
The inner member can comprise first and second parts wherein the first part includes the jaws and the second part is detachably connected to the first part. Further, the first and second parts can be of the same or different materials.

The tool can include a handle and the outer member can be fixedly or removably attached to the handle. The handle can include a stationary grip and a movable grip. Preferably, the movable grip and stationary grip are of a single piece of material and are connected together in a hingeless manner, e.g. by a flexible section of the handle. A portion of the stationary grip can be fixed to a proximal end of the inner member and a portion of the movable grip can be fixed to a proximal end of the intermediate member. Thus, the intermediate member can be moved with respect to the inner member by moving the movable grip. In addition, the handle can be removably attached to the inner member and the intermediate member for cleaning thereof.

The jaws can include at least one step thereon and the intermediate member can include at least one constriction engageable (e.g. by snap fit) with the steps of the jaws by moving the intermediate member axially with respect to the inner member. The inner member and intermediate member can include means for limiting axial movement of the inner member with respect to the intermediate member so that the intermediate member can engage no more than one-half of the axial length of the jaws. The opposing surfaces of the jaws can be separated by a clearance when the jaws are elastically deformed towards each other to a maximum extent by the intermediate member. Alternatively, the jaws can have surfaces capable of gripping tissue when the jaws are elastically deformed towards each other. According to one aspect of the invention, the jaws can be designed such that only one of the jaws is elastically deformed by the intermediate member. According to another aspect of the invention, both jaws are elastically deformed by engagement with the intermediate member.

The inner member can include various features. For instance, a protection spring can be provided between the jaws at a location intermediate distal and proximal ends of the jaws. According to one embodiment, the inner member can comprise a cutter or scissors wherein at least one of the jaws can include a cutting edge. For example, both jaws can include cutting edges which slide past each other when the jaws
are elastically deformed by the intermediate member. The cutting edges can have any
desired shape such as rectilinear or curved cutting edges. According to another
embodiment, the inner member can comprise a needle driver wherein one of the jaws
optionally includes a cutting blade which is slidably received in a corresponding slot in
the other jaw. The cutting blade can have a cutting edge facing the mating surface of
the other jaw and both jaws can have a layer of a soft martensitic shape memory alloy
to provide improved gripping of a needle.

The various parts of the tool can comprise various materials. For instance, the
inner member, the intermediate member and the outer member can be of a material
selected from the group consisting of a shape memory alloy such as Ni-Ti or a Ni-Ti
based alloy, a copper alloy such as Be-Cu, a nickel alloy such as Be-Ni, titanium or a
titanium alloy such as β-titanium, spring steel, a polymer, polymer alloy, polymer
composite or a polymer/metal composite. Preferably, the intermediate member and
outer member are each of a nickel-titanium based shape memory alloy and the outer
member includes a coating of an electrically insulating material such as a polymer
coating on an outer periphery thereof.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 shows a tool in accordance with the invention wherein the hingeless
jaws are in the open condition;

Figure 2 shows the tool of Figure 1 wherein the jaws are in the closed position;

Figure 3 shows a handle which can be used to manipulate the tool shown in
Figure 1;

Figures 4 and 5 show various embodiments of jaw designs for a replaceable
element of the tool shown in Figure 1;

Figure 6 shows an embodiment of the tool of Figure 1 wherein the jaws include
a locking mechanism;

Figure 7 shows an embodiment of the tool of Figure 1 wherein a protection
spring is provided between the jaws;

Figures 8 and 9 show embodiments wherein the jaws of the tool according to
the invention can include cutting edges; and
Figures 10-12 show an embodiment of a tool in accordance with the invention wherein the jaws are used as a needle driver.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The invention provides a tool having hingeless and elastically activated jaws. According to one aspect of the invention, the tool can be especially adapted for use in endoscopic surgical operations. Such a tool can overcome the design restrictions of conventional endoscopic instruments. In particular, with the tool according to the invention, tissue can be grasped with definite and limited grasping pressure.

The invention also provides a handle wherein the movable grip opens and closes at 90° to the longitudinal axis so that no resulting longitudinal movement of the hand is transmitted leading to change of the position of the jaws or blades of the instrument. An outer member in the form of a sheath is supported by the handle and keeps the instrument stable when the jaws are activated. An inner member which is actually a part of the jaws has to be the passive component of the action while an intermediate member in the form of a tube is moved forward and backward to close and open the jaws.

This concept of hingeless instruments leads to a standardized modular principle that has further advantages. First, the instrument is easy to disassemble and reassemble. Second, all parts can be designed with similar interfaces so that an exchange is possible and the surgeon can be provided with updates of jaws design. Third, the standardized interface can be connected to cleaning and rinsing devices, so that by contrast to the available instrumentation, an automated optimal cleaning will be facilitated. Fourth, a functional check of all parts is easy and is automatically achieved on each application, which leads to reduced events of intraoperative instrument failures. Fifth, the manufacturer is able to use a minimal number of parts which reduces cost. Sixth, the simple design of the jaw action allows an expanding selection and updating of the jaw designs for new applications. Seventh, the manufacturer can provide the surgeon with all parts so that in case of wear or breakage only the defective component needs to be exchanged. Eighth, the simple design reduces wear and breakage because the number of hinges and pivots of the standard tools are reduced or eliminated.
Ninth, the elasticity of the jaws action mechanism and the jaws themselves allow a precise, physiologic grasping pressure, which minimizes the risk of organ perforation or tissue damage caused by the grasper.

Basically, the handle function can be described by coaxial and transaxial actions. In conventional handles, the grips have finger rings positioned 90° to the longitudinal axis to provide transaxial movement. Hence, the action of fingers relative to the hand are transmitted in longitudinal movements. As a result, the complete instrument moves. This unintended action requires manual dexterity to compensate. However, with the grip according to the invention, such movement can be minimized since the jaws move in a direction 90° to the longitudinal axis, hence, the force vector in longitudinal direction is zero. The resulting movement along the longitudinal axis is reduced due to the fixation of the outer member and the inner member to a stationary part of the grip. The grips and handles can be provided with or without closed finger rings but open finger rings are preferable because they allow easier manipulation.

The tool and handle of the invention provide reduced play (close to zero), reduced wear and tear, reduced number of parts and hysteresis. To achieve the capability of all functions being carried out by one hand, however, the use of drives such as pneumatic cylinders or servo motors can also be incorporated in the tool of the invention.

According to various features of the invention, the inner member and/or intermediate member can include a certain ramp or hump design in the elastic part of the jaws to facilitate incremental closing and retaining of position of the jaws and thus obviate the need for a ratchet attachment mechanism in the grip. The inner member can be individually shaped according to the surgeon's wishes or the anatomical situation. Also, the jaws can be individually shaped and curved according to the surgeon's desire or the anatomical situation. The jaws can be designed as one piece with the elastic action element. Regular stainless steel jaws can be mounted, welded, or glued at the action element. The jaws can be shaped as different types of scissors (hook, serrated, curved, etc.).

Although it is preferred that the jaws be closed by sliding the intermediate member over the proximal end of the jaws, the jaws can also be closed by moving the
inner member and pulling the jaws into the intermediate member. The jaws can be shaped as one piece with a longitudinally extending rod or the jaws and rod can be separate pieces which are removably or fixedly held together in any suitable manner (e.g., welded, crimped, glued, etc.). The outer member can be of any biocompatible material such as polymer, metal, shape memory alloy, polymer/metal composite or polymer coated metal. The outer member can be removably connected to the grip by using a spring loaded attachment, screw, bayonet, etc. The jaws can be made by injection molding plastic in a suitably shaped die or by wire electrostatic discharge machining of a stock wire, rod or other shaped material. Polymer jaws and other parts of the instrument (grip) can be improved by inserting elastic metal parts in the polymer.

According to a preferred embodiment, the tool comprises a modular surgical instrument with improved cleanability and reliability through a reduced number of parts and improved handling through reduced "play", and which is self-locking by design (without ratcheting means). The instrument preferably includes at least three concentric members including an inner rod, an intermediate tube and an outer sheath. However, the outer sheath can be omitted, if desired. The rod has a distal end and a proximal end, the distal end being configured as a hingeless tool (grasper, needle holder, scissors, retractor, dissector, surgical forceps, etc.) with jaw movement substantially perpendicular to the axis of the instrument, and the proximal end is configured to allow easy engaging and disengaging with a handle through a quick-release mechanism. The tube is movable relative to the fixed center rod and the proximal end of the tube is configured to allow easy engaging and disengaging with a handle through a quick-release mechanism. The outer sleeve is fixed and not movable with the proximal end of the sleeve being configured to allow easy engaging and disengaging with a handle through a quick-release mechanism. The distal end of the center rod is composed of at least one member made from an elastic material. The opening and closing of the distal end jaws is accomplished by the relative movement of the concentric movable tube. The distal end of the jaws can be configured to allow self-locking of the tool without ratcheting means when the movable tube is moved forward. The jaws can be integral with the fixed center rod, or the jaws can be removably attached to the fixed center rod.
by crimping or other releasable joint means. The jaws are preferably made from a Ni-Ti based shape memory alloy.

The present invention is intended to solve problems associated with conventional endoscopic devices by providing an instrument without complex parts and small hidden cavities that could entrap biological debris, and that can be very easily disassembled and reassembled. This is accomplished by using a closing tube which moves forward to actuate the distal end of a tool. The tube can be driven forward by any of a variety of grips or handles. Note that since the tube is driven forward instead of the tube being withdrawn, the distal end of the working tool will not move axially to any significant extent. This feature is important to the surgeon as it allows accurate and predictable positioning of the distal end of the tool. When used for endoscopic surgical operations, the overall length of the tool can range from 12 to 16 inches and the diameter of the outer sheath can range from 1.5 mm to 1/4 inch, for example.

By properly designing the proximal end of the tool, it is possible to have a "quick release" feature, which allows separation of the tool from a distal end of a support rod. This also leads to a "modular" instrument concept, wherein the various components can be individually replaced, allowing for a selection of more customized tools, disposable or single-use components, replacement for wear or breakage, or design updates and modifications.

Due to the nature of the tool, it is highly advantageous to make the distal end of the tool from a material with a large elastic range. Towards these ends, one might use a titanium alloy (especially the β-titanium alloys), or shape memory alloys (especially Ni-Ti based alloys). Shape memory alloys in the pseudoelastic, superelastic or optimized elastic state (as those terms are defined in U.S. Patent No.4,896,955) have the additional advantage of producing a substantially constant closing force due to the formation of a stress induced martensitic microstructure - this is a result of their characteristic of exhibiting a nearly constant stress over a wide strain range. This attribute is able to provide tools with a more physiological, or compliant feel. This is a particularly valuable feature of these tools in that the gripping force is controlled by design, and not by the pressure the surgeon is applying at the grip end of the tool.
An additional advantage of this type of tool is that it has very little, if any, 
"play", or backlash: tools with many moving parts, and hinges and pivots invariably 
have some annoying "play", preventing the desired one-to-one positional 
correspondence between handle and distal end movement.

5 It has also been observed that complex instruments with many small moving 
parts are susceptible to breakage. The current invention should significantly reduce the 
risk of failure during operation as well as cleaning.

By forming flat sections, or detents, along the length of the distal end, the 
instrument can be designed to have tactile "stops" to aid the surgeon. This could take 
the form of tactile clicks to provide positional feedback, or a position in which the tool 
would lock, instead of springing back to its open position.

The invention is now described with reference to the drawings wherein non-
limiting examples of embodiments in accordance with the invention are shown.

Figure 1 shows one embodiment of a tool 1 in accordance with the invention.

15 The tool 1 includes an inner member 2 having a pair of spaced-apart jaws 3, 4 at one 
end thereof, an intermediate member 5 and an outer member 6. In operation, the jaws 
3, 4 can be placed around an object to be engaged with the tool and the intermediate 
member 5 can be slid axially to close the jaws and clamp the object. Thus, the jaws 3, 
4 can be accurately positioned and closed without axial movement of the inner member

20 2. That is, the jaws 3, 4 move in a lateral direction which is perpendicular to the axial 
movement of the intermediate member 5 and an even grasping pressure not exceeding a 
threshold value can be applied to the object along the length of the jaws 3, 4.

As shown in Figure 2, when the jaws 3, 4 are closed, part of the jaws (such as 
at least one half of the jaws) extend outwardly beyond the distal end of the intermediate 
member and opposing surfaces of the jaws are slightly separated by a clearance sized to 
accommodate the object to be gripped. To avoid overgripping and damaging of an 
object between the jaws, the exposed parts of the jaws (beyond the distal end of the 
intermediate member) are free to flex away from each other. Thus, overgripping is 
avoided due to the clearance and resilient nature of the exposed ends of the jaws. In 
contrast, hinged devices wherein jaws are pivoted together provide a greater grasping
pressure at positions located closer to the pivot and it is not possible to limit the grasping pressure to a particular value.

As explained above, the jaws of the inner member apply a grasping force which does not exceed a threshold value to an object therebetween when the intermediate member is slid axially partially over and presses the jaws towards each other. The threshold value can be varied by appropriate selection of the material of the inner member (e.g. metal such as Ti, Ti alloy such as a β-Ti alloy, spring steel, a copper alloy such as BeCu, a nickel alloy such as BeNi, shape memory alloy such as NiTi, polymer, polymer alloy, polymer/metal composite), the shape of the jaws, the relative dimensions of the inner and intermediate members and combinations thereof. For instance, spring steel has a relatively high modulus but lower elasticity than BeCu or BeNi alloys whereas a polymer material has a much lower modulus but high strain limits and lower yield strength. A superelastic, pseudoelastic or optimized elastic shape memory alloy, on the other hand, has both wide strain limits and a substantially higher modulus than polymers. Thus, the grasping force can be determined by the elastic strain limits of the jaw material. Likewise, the intermediate member can be dimensioned to partially close the jaws to a predetermined degree or gradually close the jaws incrementally as the intermediate member is advanced towards the jaws.

In order to provide steerability/bendability of the tool, the inner member, the intermediate member and/or the outer member can be of a shape memory alloy which undergoes a stress induced martensitic transformation. As the martensitic microstructure is softer than the austenitic microstructure, such a shape memory alloy can provide better steerability and/or bendability of the tool which allows it to be steered to difficult-to-reach sites, particularly during endoscopic surgery.

The tool shown in Figure 1 includes several optional features. For instance, in order to limit the axial movement of intermediate member 5, the outer member 6 can include a step 8 separating a distal portion of the outer member from an enlarged proximal portion of the outer member 6. The intermediate member 5 can include a flange 7 at a proximal end thereof for engagement with the step 8. In such a case, in order to manipulate the intermediate member 5, the intermediate member 5 could include a projection which extends radially outwardly through a longitudinal slot in the
outer member 6. Thus the jaws 3, 4 can be closed, as shown in Figure 2, by sliding the intermediate member 5 until the flange 7 engages the step 8.

The inner member 2 can include a quick release mechanism at a proximal end thereof. For instance, as shown in Figure 1, the inner member 2 can include a fitting 9 defined by a groove 10. Thus, a support member having a socket or constriction at the distal end thereof can be used to snap fit over the fitting 9 whereby a variety of inner members having different jaw designs can be used with the tool 1.

The inner member 2 can include a gap 11 separating the jaws 3, 4 at proximal ends thereof. As shown in Figure 2, the gap 11 separates the jaws 3, 4 even when the jaws are closed by the intermediate member 5. However, the gap 11 can be omitted, if desired.

Figure 3 shows a handle usable with the tool 1. The handle 12 includes a stationary grip 13 and a movable grip 14 connected by a flexible part of the handle. The movable grip 14 includes a portion 15 which engages the intermediate member 5 whereby intermediate member 5 can be moved axially by pressing movable grip 14 towards stationary grip 13. The portion 15 can include a slot or axially extending hole therethrough for receiving a proximal end of the intermediate member 5. The intermediate member 5 can include a projection 16 which engages a distal side of the portion 15 and a projection 17 which engages a proximal side of the portion 15. The projections 16, 17 can be integral with the tube 5 or can comprise removable parts such as snap rings, etc. whereby the intermediate member 5 can be separated from the handle 12. The stationary grip 13 includes a portion 18 for engaging a proximal end of the inner member 2. The inner member 2 can include a pin 19 which is received in a hole in the portion 18 whereby the inner member 2 can be separated from the handle 12. In use, the handle 12 can be used to direct the jaws 3, 4 of the inner member 2 to a desired location and the jaws 3, 4 can be closed by squeezing the movable grip 14 towards the stationary grip 13, i.e., the movable grip 14 moves the intermediate member 5 axially such that the distal end of the intermediate member 5 engages and slides over the jaws 3, 4. The handle 12 can also include finger grips 20, 21 in addition to the handle grip 13, 14.
Figure 4 shows an embodiment of an inner member 2a wherein the jaws 3a, 4a have surfaces 22 capable of gripping tissue. In this case, the jaws 3a, 4a include a series of projections and recesses which interengage each other when the jaws are closed. The jaws 3a, 4a are separated by a gap 11a located at a proximal end of the jaws. The inner member 2a includes a groove 10a and a fitting 9a which can be snap fitted in a distal end of a support rod 23 which forms an extension of the inner member 2a. In use, the proximal end of the rod 23 can be fixed to the portion 18 of the handle 12.

Figure 5 shows an embodiment of the inner member 2b wherein the jaw surfaces are flat and one jaw 3b includes a thick jaw portion 24 and the other jaw 4b includes a thin jaw portion 25. In the case where the inner member 2b is formed from a shape memory alloy, the jaw 4b having the thin jaw portion 25 can be treated such that only jaw 4b moves when engaged by the intermediate member 5. In particular, the jaw 4b can be processed to be the only movable jaw of the inner member 2b by deforming jaw 4b away from jaw 3b and subjecting the inner member 2b to a heat treatment wherein the deformed condition of jaw 4b is memorized. As an example, inner member 2b can be formed from a nickel titanium shape memory alloy and jaw 4b can be bent outwardly from jaw 3b, heated to a temperature such as 450°C, and cooled while preventing jaw 4b from moving towards jaw 3b.

Figure 6 shows an embodiment wherein the intermediate member 5b can be locked with respect to the inner member 2c. In particular, intermediate member 5b includes a constriction 26 at a distal end thereof for engaging a series of steps 27, 28 on an outer periphery of jaws 3c, 4c. Thus, intermediate member 5b can be advanced axially along inner member 2c and the constriction 26 will snap fit in one of the steps 27, 28.

Figure 7 shows an embodiment wherein the inner member 2d includes a protection spring 29 extending between the jaws 3d, 4d. The projection spring 29 prevents material from moving into gap 11.

Figure 8 shows an embodiment wherein the tool comprises scissors and the inner member 2e includes jaws 3e, 4e which include cutting edges 30, 31, respectively.
In use, intermediate member 5 slides axially toward the jaws 3e, 4e to move the jaws toward each other and cut material located between cutting edges 30, 31.

Figure 9 shows a top view of an embodiment wherein the inner member 2f includes jaws 3f, 4f having cutting edges 31a, 31b having the shape of a hook 32. In the arrangement shown in Figure 9, the jaws 3f, 4f move in a direction perpendicular to the plane of the Figure.

Figures 10-12 show an embodiment wherein the tool comprises a needle driver. In particular, one of the jaws 4g includes a cutting blade 33 having a cutting edge 34. The other jaw 3g includes a slot therein for receiving the cutting blade 33 when the jaws 3g, 4g are closed by sliding the intermediate member 5 axially towards a distal end of the jaws 3g, 4g. Figure 11 shows a top view of jaw 4g. Figure 12 shows a side view of the jaws 3g, 4g in the open position wherein the cutting edge 34 is separated from the jaw 3g and the cutting blade 33 is partially received in a corresponding slot in the jaw 3g. The mating surfaces of the jaw 3g, 4g can be plated with a soft layer of material for gripping a needle. The mating jaw surfaces can be smooth or patterned with ridges, etc. The soft material is preferably a martensitic nickel titanium shaped memory alloy. The thickness should be sufficient to grip a needle and the thickness can be on the order of 0.2mm. In use, the soft martensitic layer will be deformed by a needle gripped by the jaws 3g, 4g. An advantage of the soft martensitic layer is that it can be returned to its original shape by a sterilizing treatment such as by heating the inner member 2g to a temperature such as 130°C.

The foregoing has described the principles, preferred embodiments and modes of operation of the present invention. However, the invention should not be construed as being limited to the particular embodiments discussed. Thus, the above-described embodiments should be regarded as illustrative rather than restrictive, and it should be appreciated that variations may be made in those embodiments by workers skilled in the art without departing from the scope of the present invention as defined by the following claims.
WHAT IS CLAIMED IS:

1. A hingeless tool comprising:
   an inner member, the inner member including a pair of spaced-apart hingeless jaws extending axially at a distal end of the inner member, at least one of the jaws being elastically deformable towards the other jaw and both jaws forming a unitary piece; and
   an intermediate member surrounding the inner member, the intermediate member being slidable axially with respect to the inner member a distal end of the intermediate member being engageable with the jaws such that at least one of the jaws is elastically deformed towards the other jaw as the intermediate member is moved over the jaws, the intermediate member causing the jaws to apply a grasping pressure not exceeding a threshold value to an object located between the jaws.

2. The hingeless tool of Claim 1, wherein the inner member and intermediate member are each of a flexible material selected from the group consisting of Ti, Ti alloy, β-Ti alloy, spring steel, Cu alloy, BeCu, nickel alloy, BeNi, shape memory alloy, polymer, polymer alloy, polymer composite and polymer/metal composite.

3. The hingeless tool of Claim 1, wherein the inner member is formed from a unitary piece of a shape memory alloy, the jaws being in an austenitic state in an unstressed condition and transforming to a stress induced martensitic state in a stressed condition, at least part of the jaws being in the unstressed condition when the jaws are not elastically deformed toward each other and being in the stress induced martensitic state when the jaws are elastically deformed towards each other.

4. The hingeless tool of Claim 1, wherein the intermediate member is formed from a unitary piece of a shape memory alloy, the intermediate member being in an austenitic state in an unstressed condition and transforming to a stress induced martensitic state in a stressed condition.
5. The hingeless tool of Claim 1, wherein the inner member comprises first and second parts, the first part being attached to the second part.

6. The hingeless tool of Claim 5, wherein the first and second parts are of different materials.

7. The hingeless tool of Claim 5, wherein the first part includes the jaws and the first and second parts include means for detachably connecting the first part to the second part.

8. The hingeless tool of Claim 1, wherein the intermediate member and the inner member include means for limiting axial movement of the intermediate member with respect to the inner member so that the intermediate member can engage no more than one-half an axial length of the jaws.

9. The hingeless tool of Claim 1, wherein the jaws include at least one step thereon and the intermediate member includes at least one constriction engageable with the steps of the jaws by moving the intermediate member axially with respect to the inner member.

10. The hingeless tool of Claim 1, wherein opposing surfaces of the jaws are separated by a clearance when the jaws are elastically deformed towards each other to a maximum extent by the intermediate member.

11. The hingeless tool of Claim 1, wherein the jaws have surfaces capable of gripping tissue when the jaws are elastically deformed towards each other.

12. The hingeless tool of Claim 1, wherein only one of the jaws is elastically deformed by engagement with the intermediate member.
13. The hingeless tool of Claim 1, wherein both jaws are elastically deformed by engagement with the intermediate member.

14. The hingeless tool of Claim 1, wherein a protection spring extends between the jaws at a location intermediate distal and proximal ends of the jaws.

15. The hingeless tool of Claim 1, wherein at least one of the jaws includes a cutting edge.

16. The hingeless tool of Claim 1, wherein the jaws include cutting edges which slide past each other when the jaws are elastically deformed by the intermediate member.

17. The hingeless tool of Claim 16, wherein the cutting edges are curved.

18. The hingeless tool of Claim 1, wherein one of the jaws includes a cutting blade which is slidably received in a corresponding slot in the other jaw, the cutting blade having a cutting edge facing the mating surface of the other jaw.

19. The hingeless tool of Claim 1, further comprising an outer member surrounding the intermediate member, the outer member supporting the intermediate member such that the intermediate member can slide axially towards and away from the jaws.

20. The hingeless tool of Claim 19, further comprising a handle, the outer member being fixedly or removably attached to the handle.

21. The hingeless tool of Claim 20, wherein the handle includes a stationary grip and a movable grip interconnected by a flexible portion of the handle, a portion of the stationary grip being attached to a proximal end of the inner member and a portion of the movable grip being attached to a proximal end of the intermediate member.
22. The hingeless tool of Claim 21, wherein the movable grip is movable axially with respect to the inner member so as to move the intermediate member axially with respect to the inner member.

23. The hingeless tool of Claim 19, wherein the intermediate member and the outer member are each of a nickel-titanium based alloy and the outer member includes an electrically insulating coating on an outer periphery thereof.
## INTERNATIONAL SEARCH REPORT

### A. CLASSIFICATION OF SUBJECT MATTER

**IPC(6):** A61B 17/00  
**US CL:** 606/207  

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

**Minimum documentation searched (classification system followed by classification symbols):**  

**Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched:**  
NONE

**Electronic data base consulted during the international search (name of data base and, where practicable, search terms used):**  
NONE

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>Y</td>
<td>WO, A, 91/02493, (MIDDLEMAN ET AL.), 07 March 1991. See Figs. 10a-10-c, and pages 4 and 5.</td>
<td>2-4, 15-17</td>
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☐ Further documents are listed in the continuation of Box C.  
☐ See patent family annex.

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