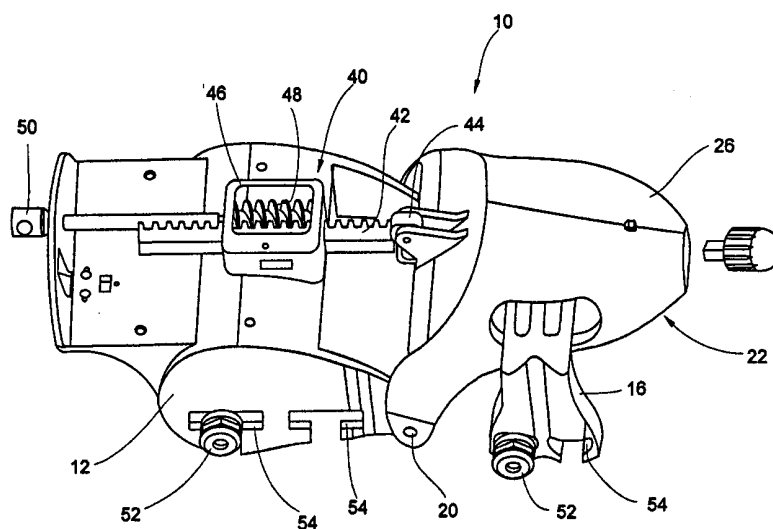


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(54) Title: DEVICES FOR PASSIVE MOTION OF JOINTS UNDER TRACTION**(57) Abstract**

A device (10) for generating passive motion of a joint while applying traction, includes a proximal bracket (12) for engaging at least one pin inserted into a bone proximal to the joint, and a distal bracket (16) for engaging at least one pin inserted into a bone distal to the joint. The device (10) also includes a tension hinge mechanism connecting between the proximal, and distal brackets (12, 16). The tension hinge mechanism (20, 22) includes a hinge (20) for permitting rotational movement of the distal bracket (16) relative to the proximal bracket (12) about a hinge axis. At least one of the proximal bracket (12), and the distal bracket (16) is implemented as a movable bracket sliding mounted so as to be displaceable in a direction generally perpendicular to the hinge axis. The tension hinge mechanism (20, 22) also includes a traction mechanism (22) for applying roughly constant force over a predefined range of positions of the movable bracket so as to apply tension across the joint. Also provided are jigs (120), for use during insertion of pins around joints for orthopedic devices.

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Devices for Passive Motion of Joints Under Traction

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to orthopedic surgical devices and, in particular, it concerns devices for moving joints while maintaining traction across
5 the joint.

It is known to employ traction across a joint in the treatment of intra-articular fractures. Especially where the bones are fragmented to an extent which precludes direct surgical procedures to stabilize the fragments, traction is known to induce *ligamentotaxis* in which the fragments re-align due to forces on their
10 ligamentous and volar plate attachments.

Traction across a fractured joint can be applied by pushing apart pins implanted in each of the adjacent bones. An example of a simple system for applying traction in this manner is the "S Quattro Flexible Mini External Fixator" commercially available from Surgicraft Ltd., England.

15 It has been found, however, that prolonged application of traction across a fractured joint without movement of the joint frequently results in loss of joint mobility due to irregular re-molding of the joint surfaces and soft tissue scarring (*fibrosis*). A number of attempts have therefore been made to develop traction systems which permit freedom of movement of the joint, referred to as "dynamic
20 traction" systems.

One approach to dynamic traction is set out in an article entitled "The Dynamic Traction Method: Combining Movement and Traction for Intra-Articular Fractures of the Phalanges" by Robert R. Schenck, MD (Hand Clinics 10 (2) May 1994). This describes a system in which rubber bands are mounted between a
25 transosseous wire located in the distal head of the middle phalanx and an external frame. In the primary example, the frame is formed as a large loop in the plane of movement of the joint. The point of connection of the rubber bands can then be slid manually around the loop to flex the joint while maintaining the applied

traction. Also discussed are adaptations of existing continuous passive motion devices to apply tension, also by use of rubber bands.

A particular shortcoming of the dynamic traction systems discussed by Schenck is the imprecision and inconvenience of adjustment of the tension applied. Adjustment is achieved primarily by adding or removing rubber bands, thereby giving large discrete jumps in the amount of tension. Although a possibility of twisting the rubber bands is mentioned, no mechanism is provided for such an adjustment. The systems also require professional supervision and demand a high degree of patient compliance and cooperation, making them unsuitable for home-treatment.

A second approach to dynamic traction systems is represented by a proximal interphalangeal joint hinge commercially available under the tradename Compass[®] from Smith & Nephew Richards Inc., USA. This hinge is secured by five pins drilled into the bones. Once positioned, an adjustment screw allows distraction of the joint. Once the desired degree of distraction is achieved, the pin blocks are fixed in position relative to the hinge. It is not possible to achieve a precise and measurable amount of traction. During normal operation of the hinge, no flexibility or elasticity is exhibited.

Although the Compass[®] system provides effectively continuously variable adjustment of the degree of distraction of the joint, the lack of flexibility in the system causes other shortcomings. Firstly, the hinge is extremely sensitive to misalignment. For this reason, a superfluous axial pin is drilled into the bone for alignment of the hinge. However, even with the extra pin, sufficiently precise positioning of the hinge is difficult to achieve. Additionally, even within the operative range of accuracy, a slight misalignment of the hinge may result in a large variation in the distraction of the joint during movement. In such circumstances, the lack of flexibility may cause extreme variations in the force applied to the joint, either in over-traction or compression, potentially resulting in severe damage to the joint. Finally, passive movement of the joint is achieved by

labor intensive manual operation of a worm-gear mechanism which demands a high degree of patient compliance.

There is therefore a need for a dynamic traction device for treatment of intra-articular fractures which applies traction elastically across the joint in a manner so as to render slight misalignments non-critical. It would also be advantageous to provide devices for aiding the accurate alignment of such a device.

SUMMARY OF THE INVENTION

The present invention is a dynamic traction device for treatment of conditions such as intra-articular fractures which provides substantially continuous adjustability of traction applied elastically across the joint. Preferred embodiments of the invention allow fully programmable control of a wide range of parameters relating both to the amount of traction applied and the range, speed and frequency of passive movement of the joint, thereby largely avoiding reliance on patient compliance.

According to the teachings of the present invention there is provided, a device for generating passive motion of a joint while applying traction, the joint having been prepared by insertion of at least one pin into each of a proximal and a distal bone adjacent to the joint, the device comprising: (a) a proximal bracket for engaging the at least one pin of the proximal bone; (b) a distal bracket for engaging the at least one pin of the distal bone; and (c) a tension-hinge mechanism connecting between the proximal bracket and the distal bracket, the tension-hinge mechanism including: (i) a hinge for permitting rotational movement of the distal bracket relative to the proximal bracket about a hinge axis, at least one of the proximal bracket and the distal bracket being implemented as a movable bracket slidingly mounted so as to be displaceable in a direction substantially perpendicular to the hinge axis, and (ii) a traction mechanism for applying substantially constant force over a predefined range of positions of the movable bracket so as to apply tension across the joint.

According to a further feature of the present invention, the traction mechanism includes at least one roll-spring.

According to a further feature of the present invention, the traction mechanism includes at least one mechanically-compensated spring.

5 According to a further feature of the present invention, each of the proximal and the distal brackets is configured for engaging two pins inserted in each of the proximal and distal bones, respectively.

10 According to a further feature of the present invention, at least one of the proximal and the distal brackets features a high tolerance pin clamp configured to provide at least one angular degree of freedom through a range of at least a few degrees in alignment of the at least one bracket relative to one of the pins.

15 According to a further feature of the present invention, there is also provided an actuator mechanism mechanically linked between the proximal bracket and the distal bracket for generating relative rotation between the proximal bracket and the distal bracket about the hinge.

20 According to a further feature of the present invention, the actuator mechanism includes a gear member associated with one of the proximal bracket and the distal bracket and a worm gear mounted rotatably about an axis of rotation associated with the other of the proximal bracket and the distal bracket, the worm gear being engaged with the gear member.

25 There is also provided according to the teachings of the present invention, a jig for use during insertion of at least one pin into each of a proximal and a distal bone adjacent to a joint prior to attachment of a motion-enabling orthopedic device, the jig comprising a drilling guide bracket including: (a) a proximal jig bracket portion providing at least one drilling guide tube; (b) a distal jig bracket portion providing at least one drilling guide tube; and (c) at least one alignment feature deployed between the proximal and the distal bracket portions and configured to facilitate alignment of at least one part of the drilling guide bracket with the joint.

According to a further feature of the present invention, there is also provided a connector connecting the distal jig bracket portion to the proximal jig bracket portion and configured to allow adjustment of an angle subtended at the at least one alignment feature by the drilling guide tubes of the distal and the proximal jig bracket portions.

According to a further feature of the present invention, the proximal and the distal jig bracket portions and the connector are configured such that the drilling guide tubes define substantially parallel drilling directions.

According to a further feature of the present invention, a major portion of each of the proximal and the distal jig bracket portions is formed from material substantially transparent to X-ray radiation, and wherein the at least one alignment feature includes a positioning element formed at least partially from material readily visible under X-ray imaging techniques.

According to a further feature of the present invention, each of the proximal and the distal jig bracket portions provides at least two drilling guide tubes.

According to a further feature of the present invention, the drilling guide tubes are slidably mounted within the proximal and the distal jig bracket portions to allow adjustment of an extent of projection of each of the drilling guide tubes.

There is also provided according to the teachings of the present invention, a jig for use during insertion of at least one pin into each of a proximal and a distal bone adjacent to a joint prior to attachment of a motion-enabling orthopedic device, the jig comprising a drilling guide block having: (a) at least one proximal drilling guide tube slidably mounted within the guide block to allow adjustment of an extent of projection of the at least one proximal drilling guide tube; (b) at least one distal drilling guide tube slidably mounted within the guide block to allow adjustment of an extent of projection of the at least one distal drilling guide tube; and (c) at least one positioning element formed at least partially from material readily visible under X-ray imaging techniques located between the proximal and the distal drilling guide tubes.

According to a further feature of the present invention, there is also provided a clamp configured for tightening around a region of a limb including the joint so as to immobilize the joint during insertion of pins.

According to a further feature of the present invention, the clamp includes
5 an alignment element formed at least partially from material readily visible under X-ray imaging techniques.

According to a further feature of the present invention, the clamp further includes an adjustment mechanism configured to allow adjustment of a position of the alignment element relative to the joint.

10 BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 is a first isometric view of a dynamic traction device, constructed and operative according to the teachings of the present invention, for use in
15 surgical treatment of conditions such as intra-articular fractures in a wrist joint;

FIG. 2 is second isometric view of the device of Figure 1;

FIG. 3 is a partial isometric cut-away view of the device of Figure 1 showing a variable-force spring assembly;

FIG. 4 is a partial isometric view of a first variant of the device of Figure 1
20 employing a first constant-force spring assembly;

FIG. 5 is an exploded isometric view of the device Figure 4;

FIG. 6 is a cross-sectional view taken through the device Figure 4;

FIG. 7A is a partial isometric view of a second variant of the device of Figure 1 employing a second constant-force spring assembly;

25 FIG. 7B is an enlarged view of the region of Figure 7A designated "A";

FIG. 8 is an exploded isometric view of the device of Figure 4A;

FIG. 9A is a partial isometric view of a third variant of the device of Figure 1 employing a third constant-force spring assembly;

FIG. 9B is an enlarged view of the region of Figure 9A designated "A";

FIG. 10 first isometric view of a dynamic traction device, constructed and operative according to the teachings of the present invention, providing multiple mounting orientations;

FIG. 11 is second isometric view of the device of Figure 10;

5 FIG. 12 is an isometric view of a jig for use during insertion of pins for orthopedic clamping such as using the devices of Figures 1-11;

FIG. 13 is an exploded isometric view of the jig of Figure 12;

FIG. 14 is an isometric view of a jig for use during insertion of pins for orthopedic clamping of a finger; and

10 FIG. 15 is an exploded isometric view of the jig of Figure 14.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is a dynamic traction device. The device is useful for treatment of a range of conditions such as intra-articular fractures and any other pathological or post-operative condition (arthroplaty) in which traction and/or
15 early passive motion of the joints is indicated.

The principles and operation of devices according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, Figures 1-3 show a device, generally
20 designated **10**, for generating passive motion of a joint while applying traction. This device is generally parallel to that described in co-pending U.S. Patent Application No. 08/948,362, and parallel co-pending International Application No. PCT/US98/14748, (both unpublished on the date of filing of this application) which are hereby incorporated by reference as if fully set out herein.

25 Generally speaking, device **10** has a proximal bracket **12** for engaging pins drilled into a proximal bone adjacent to the joint, and a distal bracket **16** for engaging pins drilled into a distal bone adjacent to the joint. Brackets **12** and **16** are connected by a tension-hinge mechanism which includes a hinge **20** for permitting relative rotational movement of the brackets, and a traction mechanism

22. Traction mechanism 22, as described in the aforementioned applications, is configured to progressively deform a spring element so as to allow substantially continuous adjustment of the tension applied elastically across the joint.

Although device 10 can be used with minor adaptations for a wide range of
5 different joints, the particular example shown here is designed for use with a wrist joint.

It is a preferred feature of most embodiments of the present invention that most or all of the device is produced from X-ray transparent materials to allow imaging of the injured joint while the device is in place. A range of suitable
10 plastics and other polymer materials generally known in the art may be used.

Turning now to the features of device 10 in more detail, a preferred implementation of the tension-hinge mechanism is best seen in the cut-away view of Figure 3. In this case, the major distal portion 26 of device 10 is connected at rigid hinges 20 to proximal bracket 12. The relatively small distal bracket 16
15 which directly engages the distal pins is attached to distal portion 26 by an adjustable spring-loaded mounting 30. Specifically, spring-loaded mounting 30 includes a partially-threaded adjustment rod 32 which is aligned within bores through two support blocks 34, 36 so as to be free to slide axially. Rod 32 is biased by an elastic element, preferably a helical spring 38 towards a distally displaced
20 resting position. Bracket 16 has a threaded inner bore 39 within which a threaded part of rod 32 is engaged. Thus rotation of rod 32 by means of an adjuster 28 either adjusts the position of bracket 16 between the two support blocks or, if bracket 16 is held still, adjusts the tensile force exerted on bracket 16 by spring 38. Preferably, adjuster 28 is configured as a removable key to prevent unauthorized
25 adjustment of the device after it is positioned.

Device 10 preferably also provides an actuator mechanism 40 mechanically linked between proximal bracket 12 and distal bracket 16 for generating relative rotation between proximal bracket 12 and distal bracket 16 about hinge 20. This allows application of passive motion therapy while maintaining traction across a
30 joint. In a preferred implementation, actuator mechanism 40 includes a toothed

rack 42 driven by a worm gear 48. In the case illustrated here, rack 42 is pivotally linked to distal portion 26 through a linkage 44 while worm gear 48 is deployed in a housing 46 attached to bracket 12. In order to allow use of a straight rack 42, linkage 44 is preferably implemented as a pin-and-slot coupling to accommodate
5 the range of alignment occurring during flexing of the device about hinge 20.

Preferably, worm gear 48 is driven via a coupling 50 through a flexible drive cable by a portable control unit which can be strapped to the arm of a patient (not shown). The control unit typically includes an electric motor driven from batteries under the control of a programmable microprocessor unit. This allows a
10 surgeon to set and modify parameters of a passive exercise treatment program, including the extent and speed of rotation about an axis of rotation, the delay between successive movements, the length of each treatment session and the time between sessions. All of these parameters may be programmed to change progressively or in steps during the course of the treatment.

15 Optionally, the control unit may include a connection device, preferably in the form of a modem or tone-dialing connection to a telephone network, configured to form a connection with a central reprogramming station. This allows adjustment or reprogramming of the parameters of the treatment program within a home-care program without requiring the patient to attend a hospital or clinic.

20 In an alternative implementation, worm gear 48 may be manually operated to achieve passive movement of the joint.

As mentioned above, device 10 is skeletally anchored by pins which are inserted into a proximal and a distal bone adjacent to the damaged joint. In preferred implementations, it has been found valuable to employ two fixation pins
25 to positively align the bone on each side of the joint. To this end, at least one and preferably both of the proximal and distal brackets 12 and 16 are configured for engaging two pins inserted in the corresponding bones.

Preferably, some or all of the pins are received by high tolerance pin clamps configured to provide at least one degree of freedom of adjustment. This makes the
30 precision of positioning of the fixation pins less critical and renders attachment of

the device particularly easy. Linearly, adjustment of at least a few millimeters is readily achieved by mounting one or more pin using a flanged clamping sleeve 52 located within a slot 54.

At least some of the high tolerance pin clamps are preferably configured to provide at least one angular degree of freedom through a range of at least several degrees, and preferably, at least about 10°, in alignment of the pins relative to the bracket. This is achieved by providing curved surfaces around slot 54 and correspondingly curved abutment surfaces of sleeve 52 as shown here on distal bracket 16 as best viewed in Figure 2.

Although the device of Figures 1-3 provides considerable advantages over the prior art references described above, it does not provide a complete solution. Specifically, while the elasticity of the adjustment renders the precise location of hinge 20 less critical, it has been found that slight misalignments taken up by the spring elements may cause major variations in the traction applied across the joint during flexing. Major variations in the applied traction may render the device much less effective and could possibly be dangerous.

To address these problems, it is a particular feature of most highly preferred implementations of the present invention that device 10 is provided with a traction mechanism configured to apply substantially constant force over a predefined range of positions of the brackets. This allows the traction mechanism to take up any small displacements resulting from misalignment of the hinge position without adversely affecting operation of the device.

It should be appreciated in this context that the phrase “substantially constant force” is used to refer to any case in which the behavior of a spring system more closely resembles a constant force than a Hooke’s law linear variation over a given range of movement. This may be achieved either by use of a spring system which inherently generates constant or near-constant force, or by modifying the effect of a non-constant-force spring through its mechanical deployment and/or use of additional components to compensate at least partially for variations in force resulting from the state of the spring. An example of the

former will now be described with reference to Figures 4-6 while the latter will be exemplified with reference to Figures 7-9.

Turning now to Figures 4-6, there is shown a variant of device **10** in which the traction mechanism is implemented using a number of roll-springs **100**. As seen in Figure 5, each roll-spring **100** is a metallic strip which is formed with an inherent curvature so as to tend to roll onto itself. Each strip is wound about a rotatable drum **102** and may be pulled so as to progressively unwind the strip from the drum. This structure is known to provide a close approximation to a constant spring force over a considerable range of movement.

10 In one particularly convenient implementation, drums **102** and roll-springs **100** are mounted within a cartridge **104** which may be connected as part of distal bracket **16**. A rod **106** passes through cartridge **104** so as to delimit the direction of allowed relative motion between brackets **12** and **16**. In this case, however, rod **106** does not provide any adjustment feature since the applied force remains
15 substantially constant so long as the roll-springs are within their range of movement and bracket **16** does not become mechanically obstructed by the ends of the openings through distal portion **26** through which it passes. Adjustment of the traction force, when required, may be achieved either by changing the number of roll-springs operating, or by swapping the roll-springs for alternative roll-springs
20 of different strengths.

In order to position bracket **16** correctly during deployment of the device, rod **106** may optionally provide an adjustable displacement mechanism for temporarily holding bracket **16** in position. This option is illustrated in Figure 6. Specifically, an enlarged forward part of rod **106** is shown in threaded engagement
25 with an internally threaded housing **107** such that, by turning rod **106**, cartridge **104** is pushed rearwards (i.e., towards hinge **20**) against springs **100**. Once the device is deployed on the pins, rod **106** is turned so as to retract it to a withdrawn position as shown, thereby freeing springs **100** to function as described.

Turning now to Figures 7-9, these show second and third variants of device
30 **10** in which the traction mechanism is implemented using a number of

mechanically-compensated springs. Specifically, in the second variant illustrated in Figures 7A, 7B and 8, the traction mechanism shown employs two conventional helical compression springs **110** each deployed at a variable inclination to the direction of motion between a yoke **114** and an abutment surface **116** rigidly attached to, or integrally formed with, distal portion **26**. Yoke **114** is mechanically coupled to distal bracket **16** through a partially-threaded rod **118**. A variable component of the force of springs **110** acts along the direction of relative motion between distal bracket **16** and distal portion **26** varying as the cosine of the angle between the direction of the springs and the direction of motion. This angle becomes greater as the spring is compressed, thereby to a large extent offsetting the increased force exerted by the springs.

Although only providing a rather rough approximation to “constant force” characteristics, this implementation of the traction mechanism is particularly compact and can provide relatively large traction forces. The mechanism does, however, suffer from a limited range of movement. This is preferably addressed by providing screw adjustment via rod **118** to ensure that the traction mechanism is initially near the middle of its range of motion when the device is deployed.

Turning now to Figures 9A and 9B, there is shown a further variant in which two conventional helical springs **110**, deployed transverse to the direction of relative motion, act on two lever flaps **112** which are pivotally connected to yoke **114**. This structure results in a variable component of the springs’ forces being transferred to abutment surface **116** in such a way as to somewhat offset the Hooke’s law variation of tension in the springs themselves.

Referring now briefly to Figures 10 and 11, there is shown a variant implementation of device **10**, generally designated **118**. Device **118** is generally similar to device **10** except that each of brackets **12** and **16** is formed with at least two sets of slots **54** configured for clamping pins at different angles relative to hinge **20**. It has been found that, in certain cases, it is desirable to generate flexing motion of the joint in directions other than the flexion and extension (up-down) motion provided by device **10**. Clearly, individual devices according to the

principles of the present invention could be designed for each intended application. However, device **118** provides a more convenient and economical solution by allowing the use of a single device for motion in more than one direction.

Turning now to further aspects of the present invention, the present invention also preferably provides a jig to facilitate accurate drilling during insertion of at least one pin into each of a proximal and a distal bone adjacent to a joint prior to attachment of a motion-enabling orthopedic device. While the jig may be used to advantage with a wide range of different motion-enabling orthopedic devices, it is believed to be particularly valuable when used in combination with a device constructed and operative according to the principles of the present invention described above and in the above-incorporated applications.

Features of the jig of the present invention will now be described with reference to two preferred examples. The first, intended primarily for a larger joint such as a wrist or elbow, will be described with reference to Figures 12 and 13, while the second, particularly suited to a smaller joint such as an inter-phalangeal joint, will be described with reference to Figures 14 and 15.

Turning now to Figures 12 and 13, there is shown a jig implemented as a drilling guide bracket **120**. In this case, the drilling guide bracket is made up of separate proximal and distal jig bracket portions **122** and **124**, each providing at least one, and preferably two, drilling guide tubes **126**. The bracket portions are attached by a connector **128** which is configured to allow adjustment of the angle between them. Connector **128** is preferably associated with slots in one or both of proximal and distal jig bracket portions **122** and **124** to allow some degree of adjustability of the distance between the connector and the drilling guide tubes.

Preferably, drilling guide bracket **120** includes at least one alignment feature **130** deployed between the proximal and the distal bracket portions, preferably at or aligned with connector **128**, and configured to facilitate alignment of at least one part of the drilling guide bracket with the joint. Preferably, alignment feature **130** is implemented as an element which is readily visible under some real-time or near-real-time medical imaging technique such that it can be

used by a surgeon to align the bracket correctly relative to the joint. Examples include elements which are either partially opaque or particularly reflective to appropriate types of radiant energy such as X-ray or ultrasound. In the preferred example illustrated here, alignment feature is implemented as a metallic shaped washer associated with connector **128** and shaped to provide an easily identifiable center under X-ray imaging techniques. The major portion of each of the proximal and the distal jig bracket portions is correspondingly formed from material substantially transparent to X-ray radiation, while drilling guide tubes **126**, themselves, are typically made from metallic material, preferably stainless steel, which is also readily visible under X-ray.

The proximal and the distal jig bracket portions **122** and **124** and connector **128** are preferably configured such that drilling guide tubes **126** define substantially parallel drilling directions. Tubes **126** are preferably slidably mounted within proximal and distal jig bracket portions **122** and **124** to allow adjustment of the extent to which each of the drilling guide tubes projects. This allows alignment of the tubes to conform to the contour of the body so that they each contact the surface of the skin prior to drilling. Once correctly aligned, they are fixed in position by tightening clamping screws **132**. Each drilling guide tube preferably features a plurality of sharp end features **127** to ensure positive location of the guide tubes against the skin prior to drilling.

Turning now to Figures 14 and 15, there is shown a second jig including a drilling guide bracket, in this case featuring proximal and distal jig bracket portions formed as part of a drilling guide block **134**. As with drilling guide bracket **120**, drilling guide block **134** includes at least one, and preferably two, proximal drilling guide tubes **126** and at least one, and preferably two, distal drilling guide tubes **126**, preferably slidably mounted, within the proximal and distal portions of guide block **134**, respectively. At least one positioning element **136** formed at least partially from material readily visible under X-ray imaging techniques is located between the proximal and the distal drilling guide tubes.

As an alternative to the articulated construction of drilling guide bracket **120**, this jig preferably supplements drilling guide block **134** with a clamp **138** configured for tightening around a region of a limb including the joint so as to straighten and immobilize the joint during insertion of the pins.

- 5 Preferably, clamp **138** includes an alignment element **140** formed at least partially from material readily visible under X-ray imaging techniques, and an adjustment mechanism configured to allow adjustment of a position of alignment element **140** relative to the joint.

Referring to the example illustrated here in more detail, clamp **138** is here
10 formed from a base **142** with two lateral clamping jaws **144** which open and close by sliding along two guide rods **146** under control of a threaded actuator rod **148**. To provide more efficient and symmetrical clamping action, actuator rod **148** preferably features counter-threaded portions **150** and **152** which engage correspondingly threaded bores in jaws **144**.

15 The adjustment mechanism for alignment element **140** is here implemented as a slide **154** mounted on a threaded adjustment rod **156** within a slot **158** in base **142**. Additionally, the assembly of clamping jaws **144** and actuator rod **148** is free to slide relative to base **142** in a direction perpendicular to slot **158** until actuator rod **148** is locked by a lateral bolt **160**. Thus, by moving clamping jaws **144**
20 relative to base **142** and turning adjustment rod **156**, the position of alignment element **140** can be adjusted in two dimensions until it lies in direct alignment with the desired part of the joint as viewed by X-ray. By then positioning drilling guide block **134** with positioning element **136** aligned with both the joint and alignment element **140**, a high degree of precision can readily be achieved.

25 The inventors have found the preference of surgeons consulted to-date to be an implementation in which drilling guide block **134** and clamp **138** are mechanically independent, thereby leaving a large degree of control in the hands of the surgeon. However, alternative and possibly preferred implementations may readily be constructed in which drilling guide block **134** is mechanically linked to

clamp 138 so as to allow controlled adjustment of their relative positions while maintaining certain aspects of alignment therebetween.

It will be appreciated that the above descriptions are intended only to serve as examples, and that many other embodiments are possible within the spirit and
5 the scope of the present invention.

WHAT IS CLAIMED IS:

1. A device for generating passive motion of a joint while applying traction, the joint having been prepared by insertion of at least one pin into each of a proximal and a distal bone adjacent to the joint, the device comprising:

- (a) a proximal bracket for engaging the at least one pin of the proximal bone;
- (b) a distal bracket for engaging the at least one pin of the distal bone; and
- (c) a tension-hinge mechanism connecting between said proximal bracket and said distal bracket, said tension-hinge mechanism including:
 - (i) a hinge for permitting rotational movement of said distal bracket relative to said proximal bracket about a hinge axis, at least one of said proximal bracket and said distal bracket being implemented as a movable bracket slidingly mounted so as to be displaceable in a direction substantially perpendicular to said hinge axis, and
 - (ii) a traction mechanism for applying substantially constant force over a predefined range of positions of said movable bracket so as to apply tension across the joint.

2. The device of claim 1, wherein said traction mechanism includes at least one roll-spring.

3. The device of claim 1, wherein said traction mechanism includes at least one mechanically-compensated spring.

4. The device of claim 1, wherein each of said proximal and said distal brackets is configured for engaging two pins inserted in each of the proximal and distal bones, respectively.

5. The device of claim 1, wherein at least one of said proximal and said distal brackets features a high tolerance pin clamp configured to provide at least one angular degree of freedom through a range of at least a few degrees in alignment of said at least one bracket relative to one of the pins.

6. The device of claim 1, further comprising an actuator mechanism mechanically linked between said proximal bracket and said distal bracket for generating relative rotation between said proximal bracket and said distal bracket about said hinge.

7. The device of claim 6, wherein said actuator mechanism includes a gear member associated with one of said proximal bracket and said distal bracket and a worm gear mounted rotatably about an axis of rotation associated with the other of said proximal bracket and said distal bracket, said worm gear being engaged with said gear member.

8. A jig for use during insertion of at least one pin into each of a proximal and a distal bone adjacent to a joint prior to attachment of a motion-enabling orthopedic device, the jig comprising a drilling guide bracket including:

- (a) a proximal jig bracket portion providing at least one drilling guide tube;
- (b) a distal jig bracket portion providing at least one drilling guide tube; and
- (c) at least one alignment feature deployed between said proximal and said distal bracket portions and configured to facilitate alignment of at least one part of said drilling guide bracket with the joint.

9. The jig of claim 8, further comprising a connector connecting said distal jig bracket portion to said proximal jig bracket portion and configured to allow adjustment of an angle subtended at said at least one alignment feature by said drilling guide tubes of said distal and said proximal jig bracket portions.

10. The jig of claim 9, wherein said proximal and said distal jig bracket portions and said connector are configured such that said drilling guide tubes define substantially parallel drilling directions.

11. The jig of claim 8, wherein a major portion of each of said proximal and said distal jig bracket portions is formed from material substantially transparent to X-ray radiation, and wherein said at least one alignment feature includes a positioning element formed at least partially from material readily visible under X-ray imaging techniques.

12. The jig of claim 8, wherein each of said proximal and said distal jig bracket portions provides at least two drilling guide tubes.

13. The jig of claim 8, wherein said drilling guide tubes are slidably mounted within said proximal and said distal jig bracket portions to allow adjustment of an extent of projection of each of said drilling guide tubes.

14. A jig for use during insertion of at least one pin into each of a proximal and a distal bone adjacent to a joint prior to attachment of a motion-enabling orthopedic device, the jig comprising a drilling guide block having:

- (a) at least one proximal drilling guide tube slidably mounted within said guide block to allow adjustment of an extent of projection of said at least one proximal drilling guide tube;
- (b) at least one distal drilling guide tube slidably mounted within said guide block to allow adjustment of an extent of projection of said at least one distal drilling guide tube; and
- (c) at least one positioning element formed at least partially from material readily visible under X-ray imaging techniques located between said proximal and said distal drilling guide tubes.

15. The jig of claim 14, further comprising a clamp configured for tightening around a region of a limb including the joint so as to immobilize the joint during insertion of pins.

16. The jig of claim 15, wherein said clamp includes an alignment element formed at least partially from material readily visible under X-ray imaging techniques.

17. The jig of claim 16, wherein said clamp further includes an adjustment mechanism configured to allow adjustment of a position of said alignment element relative to the joint.

1/15

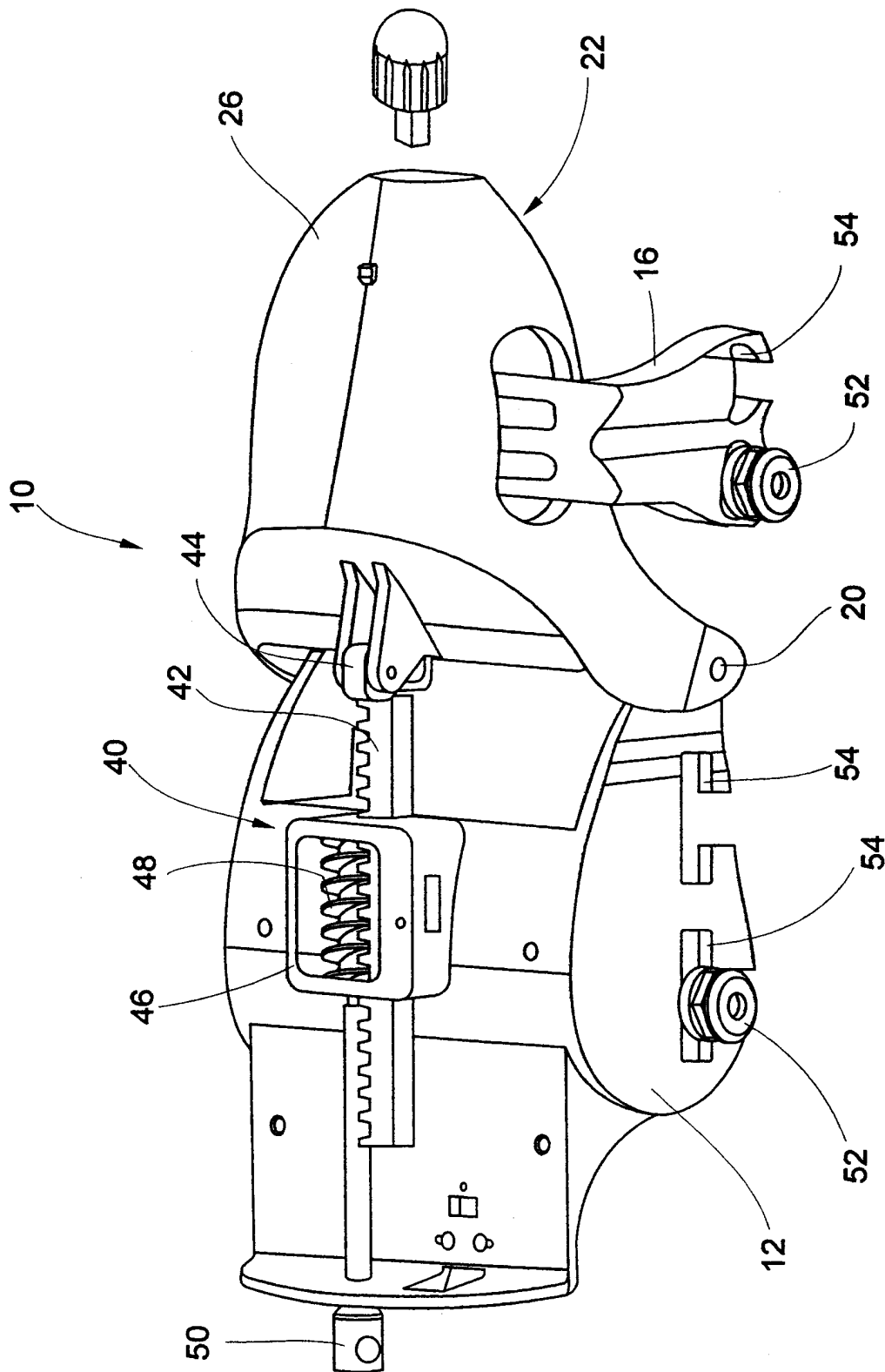


Fig. 1

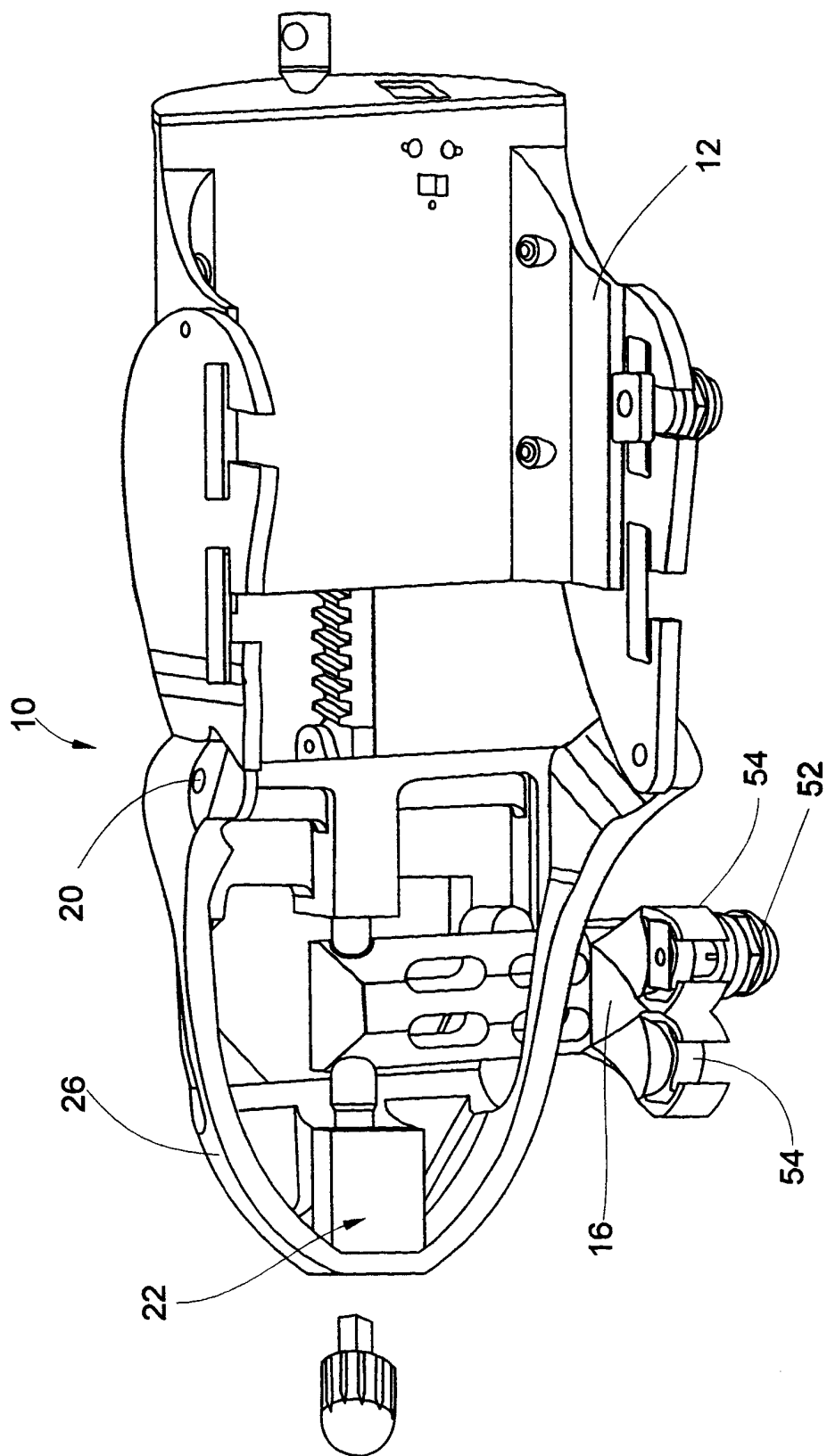


Fig. 2

3/15

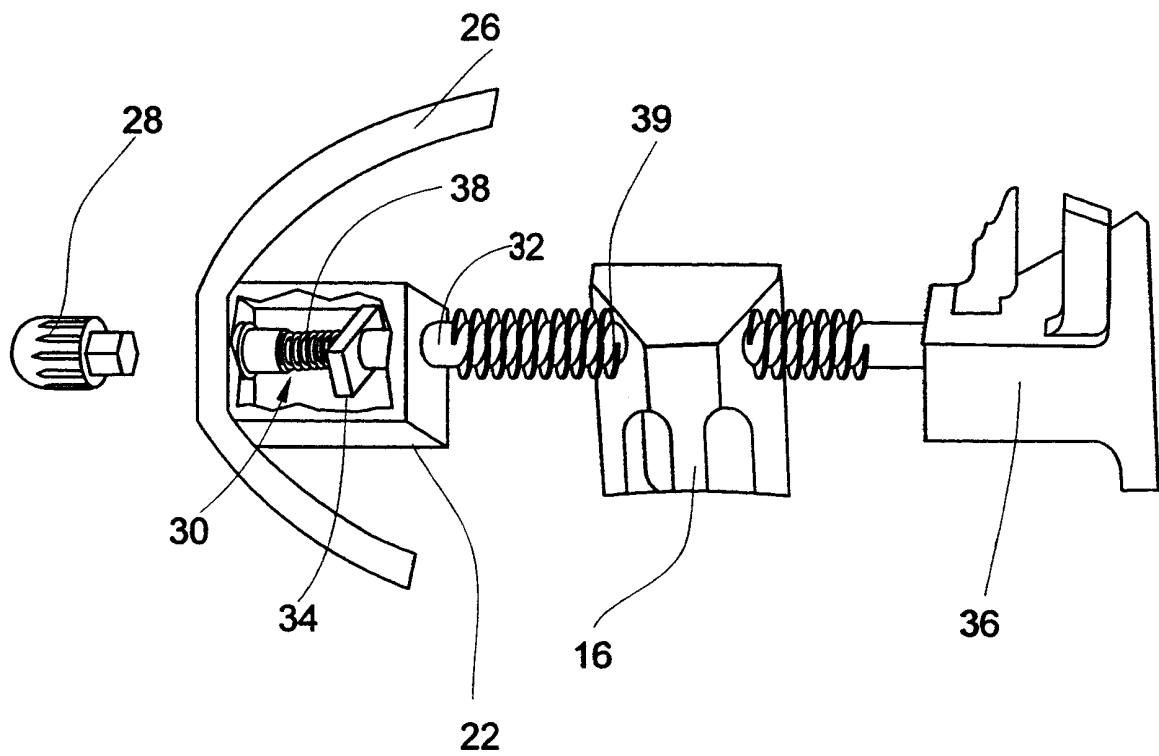


Fig. 3

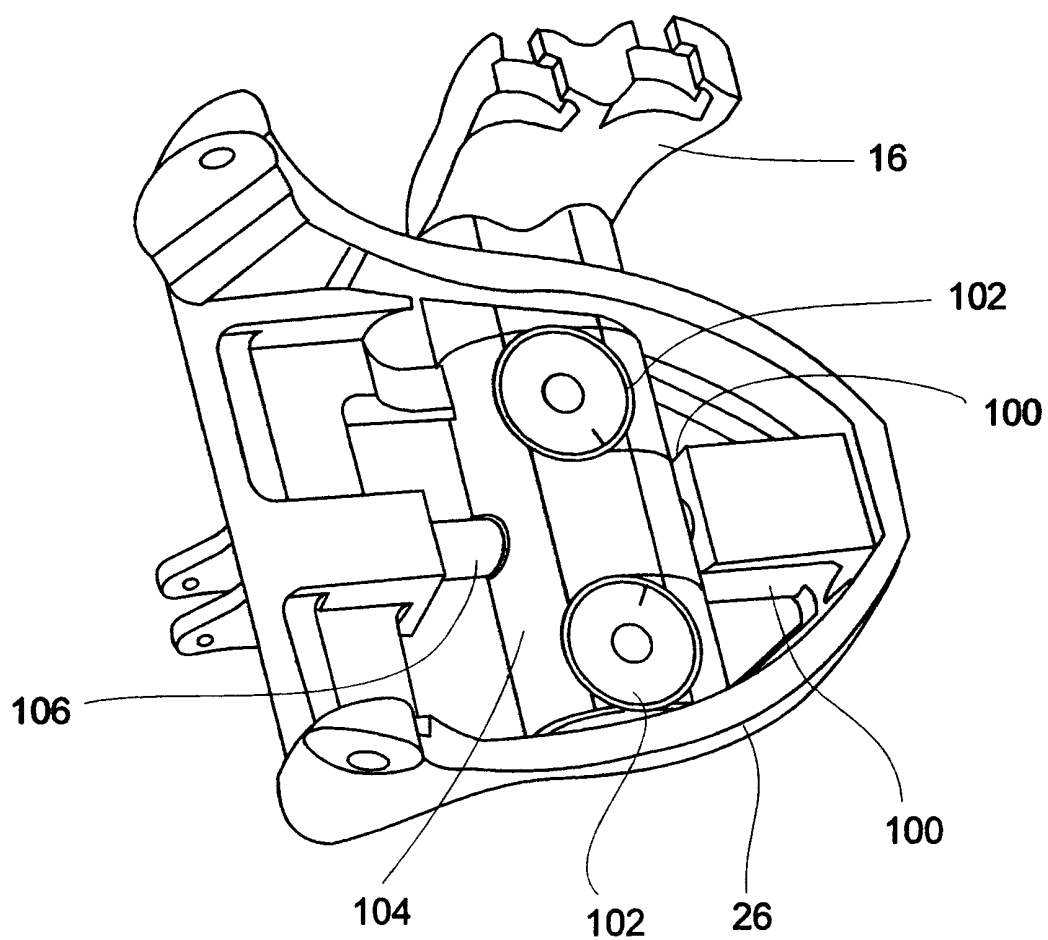


Fig. 4

5/15

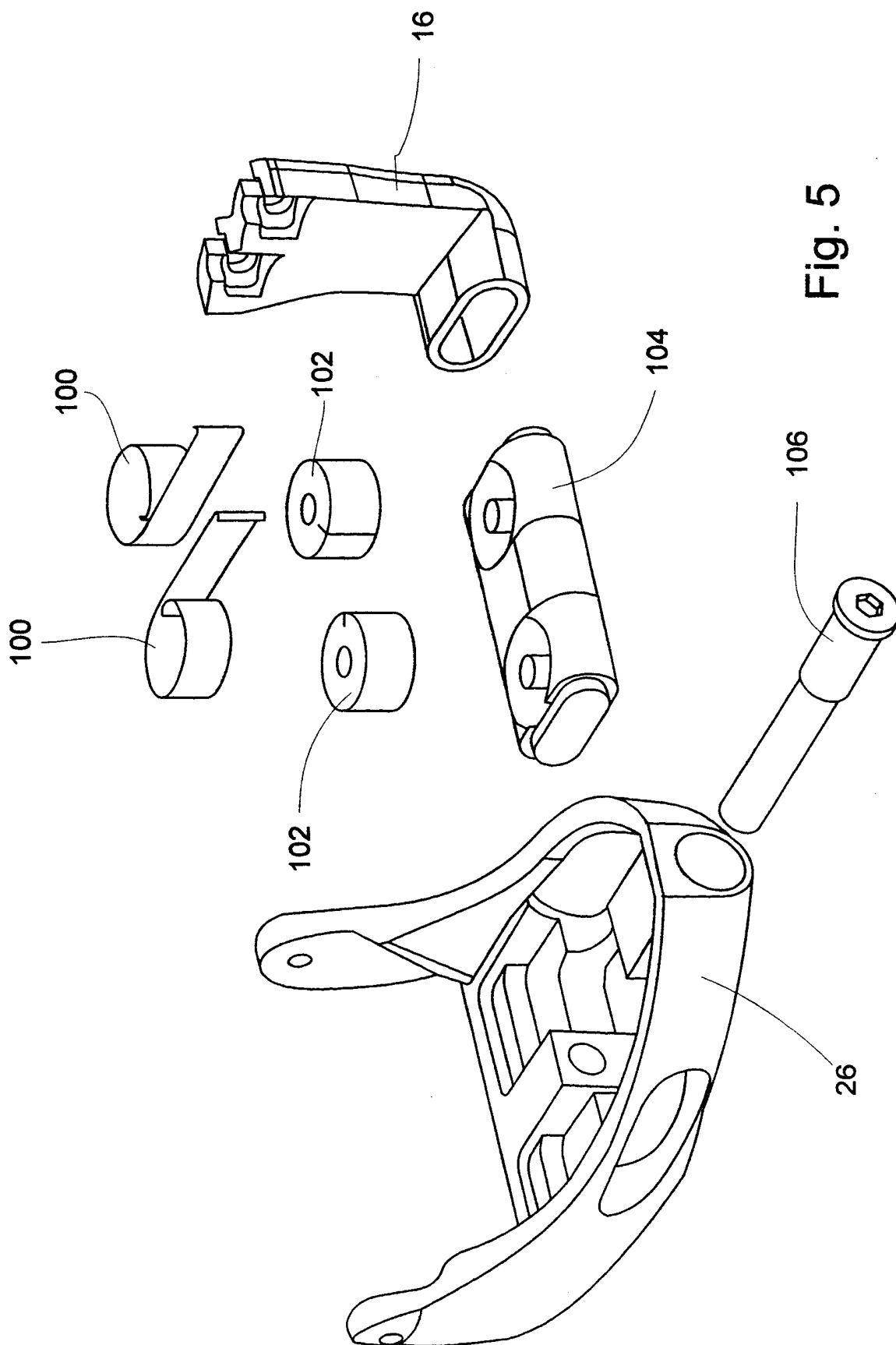


Fig. 5

6/15

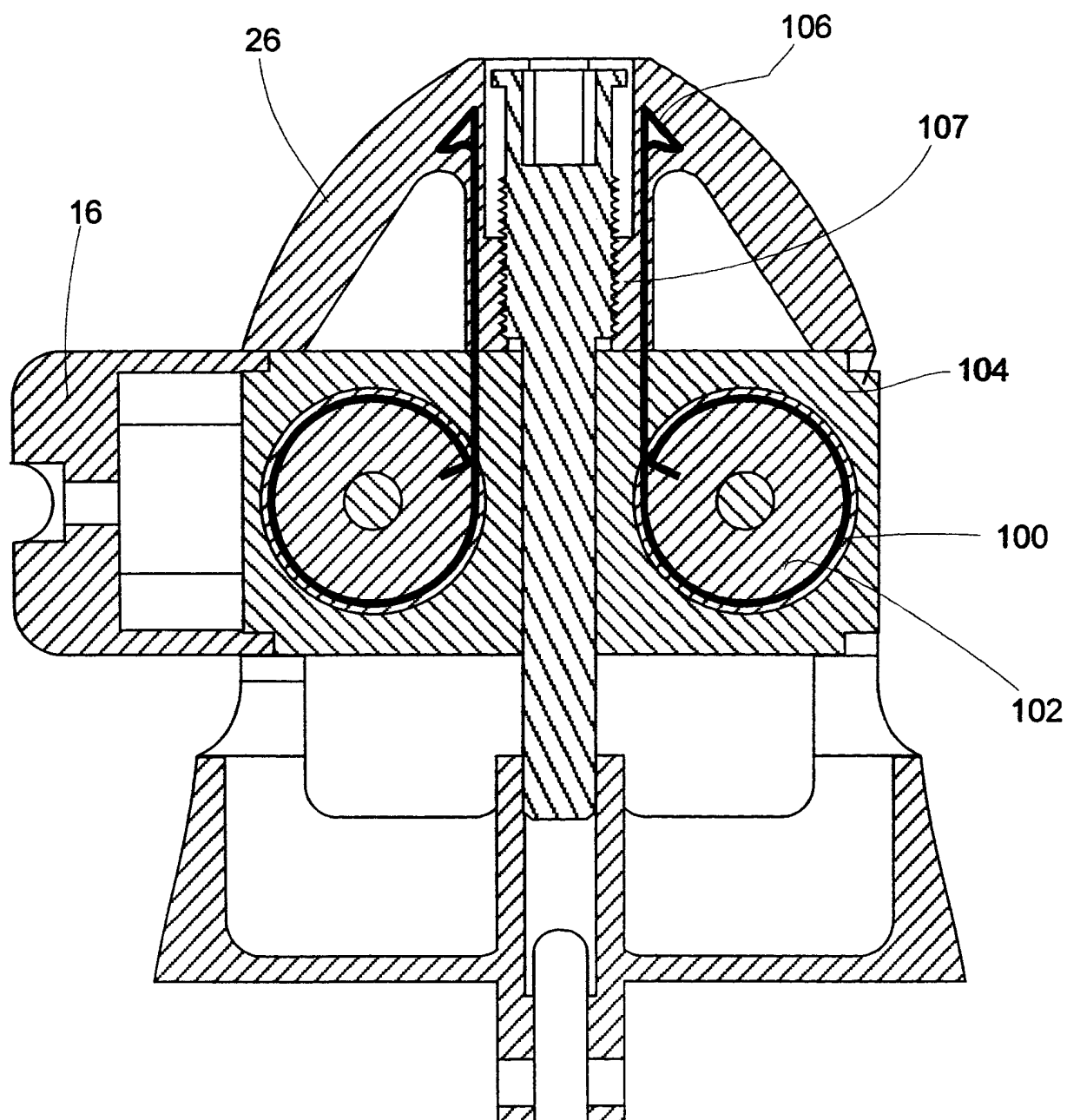


Fig. 6

7/15

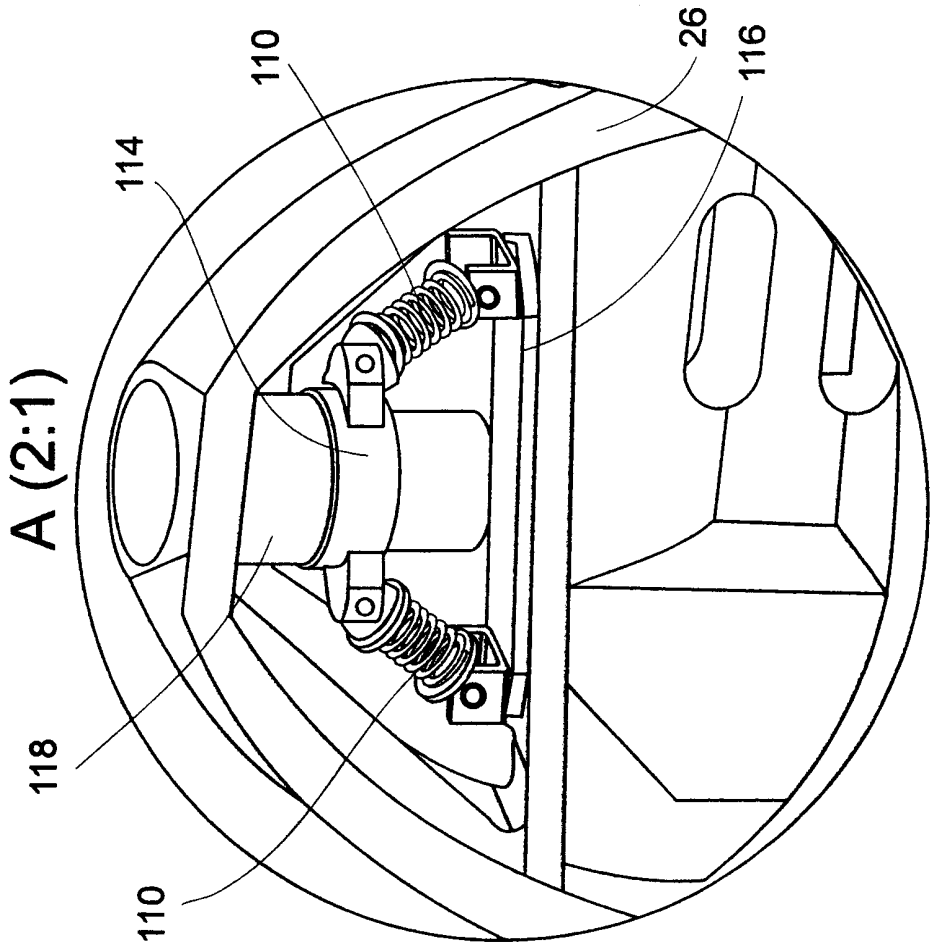


Fig. 7b

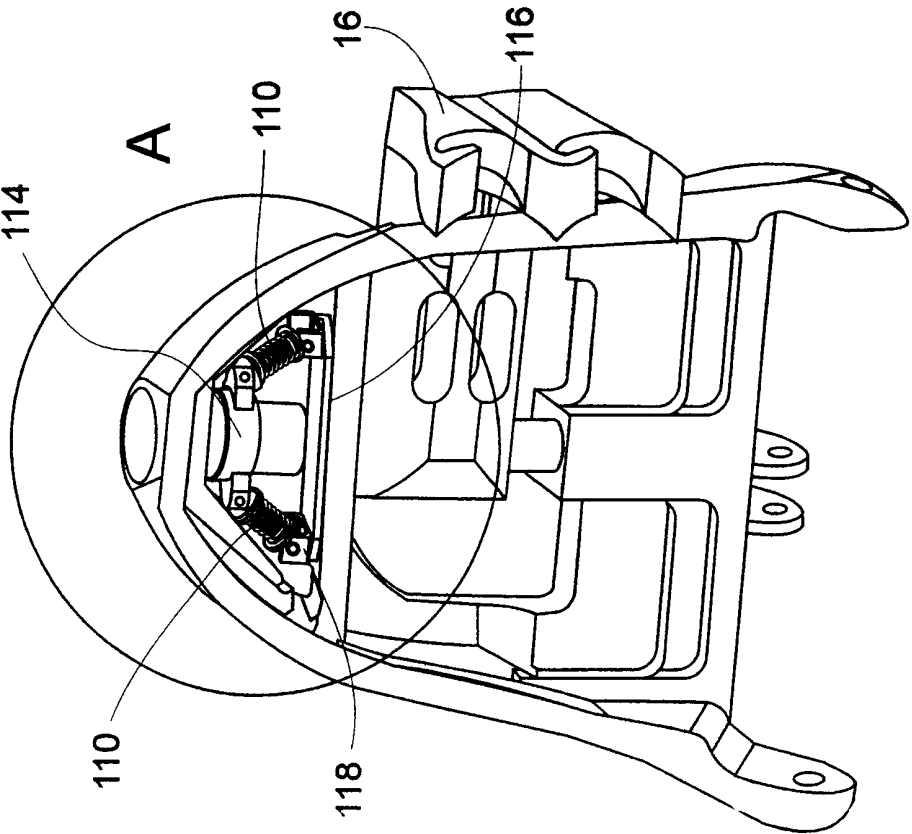


Fig. 7a

8/15

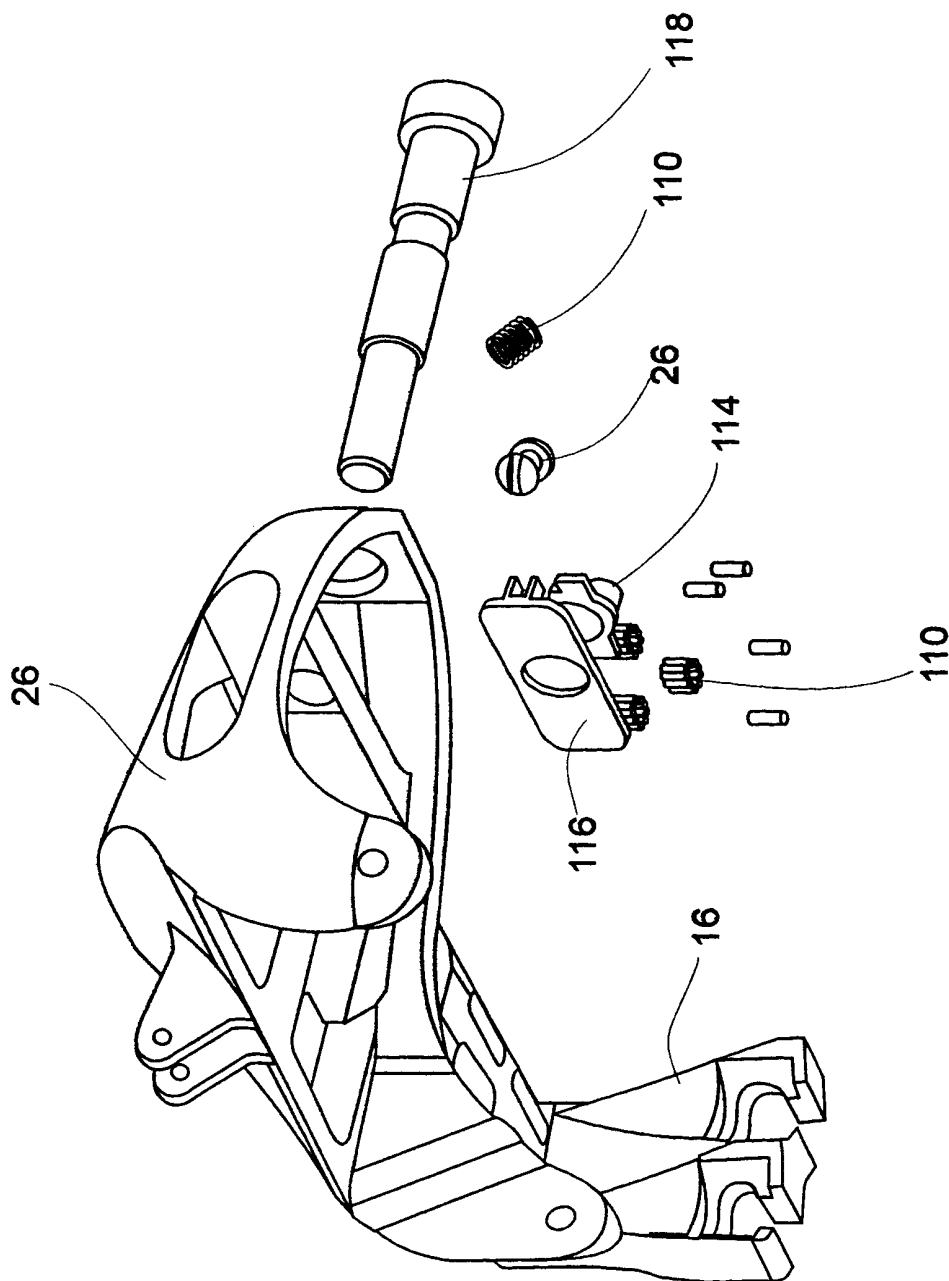


Fig. 8

9/15

A (2:1)

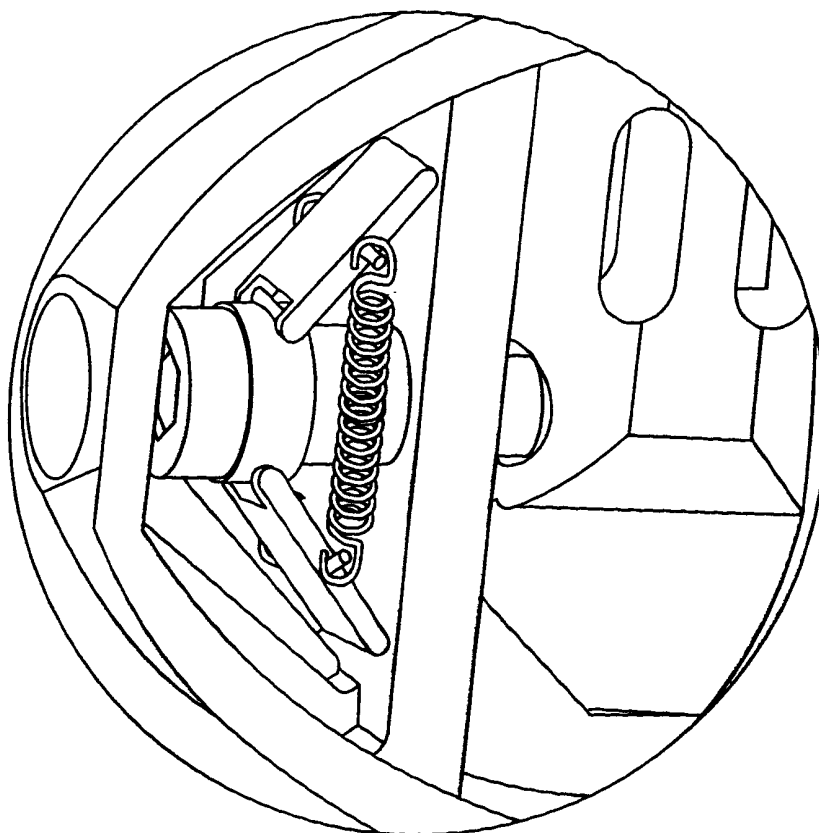


Fig. 9b

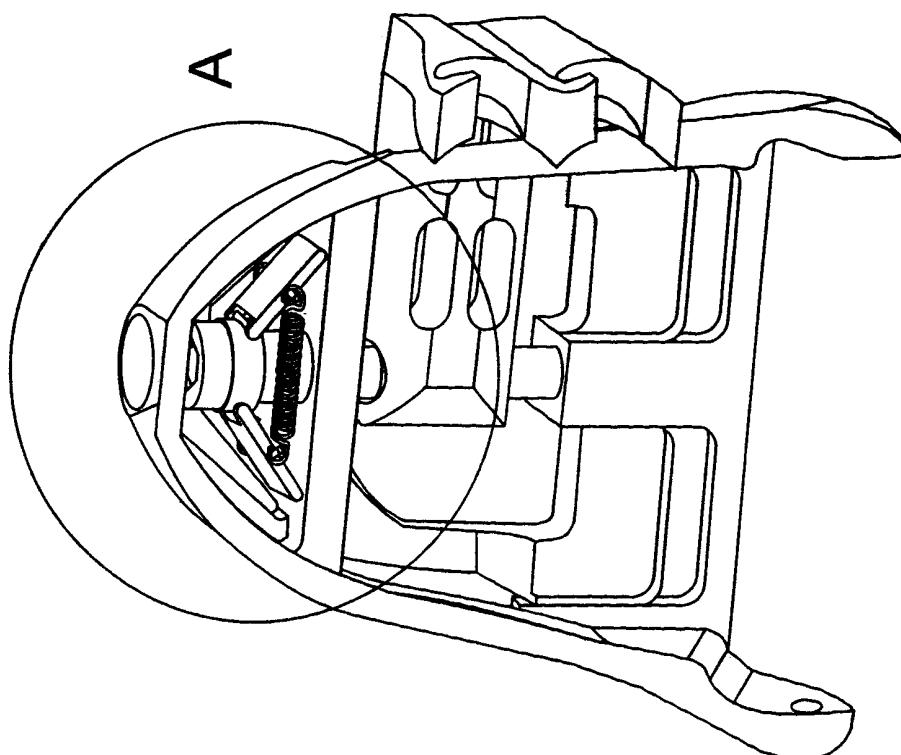


Fig. 9a

10/15

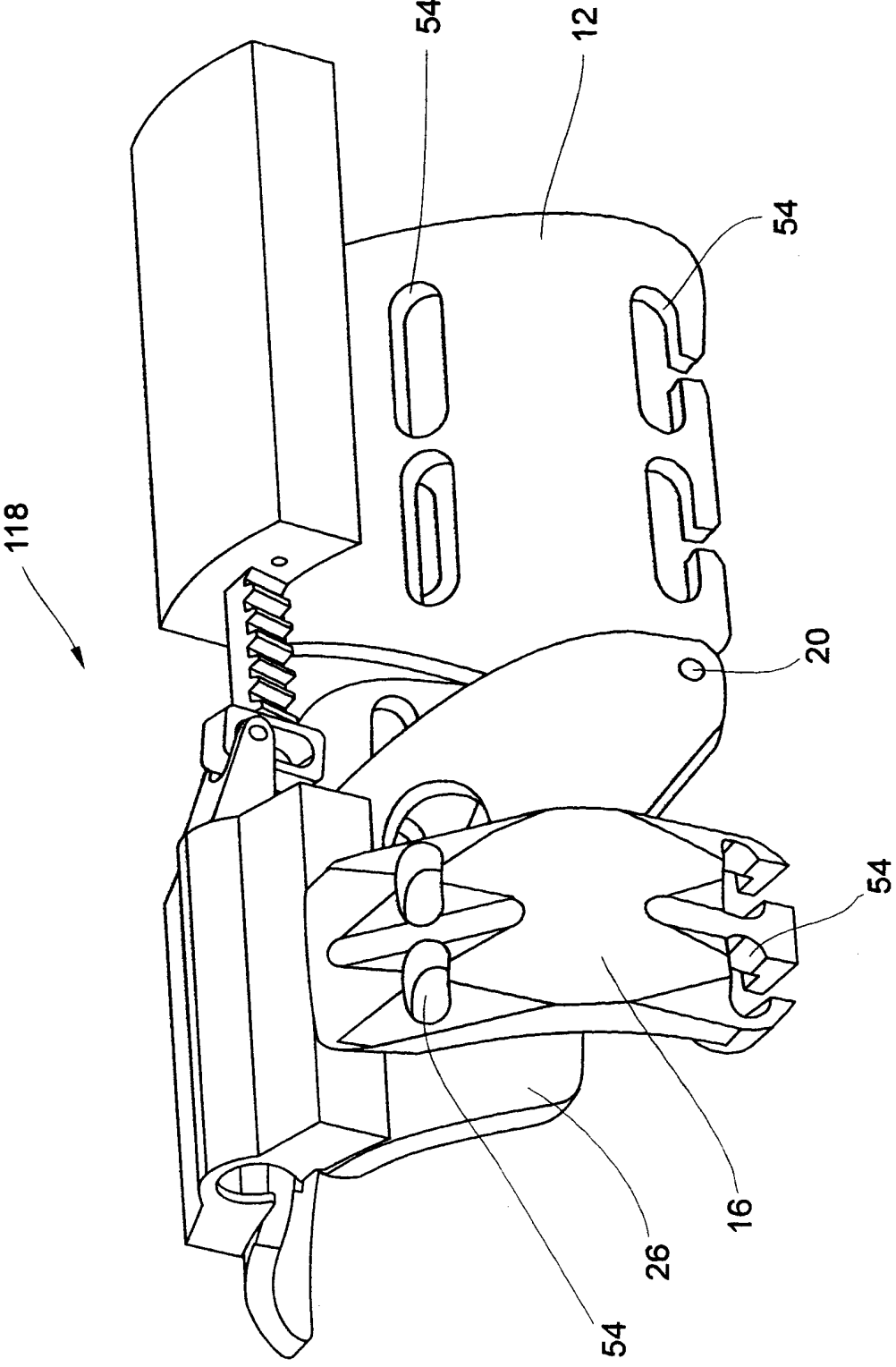


Fig. 10

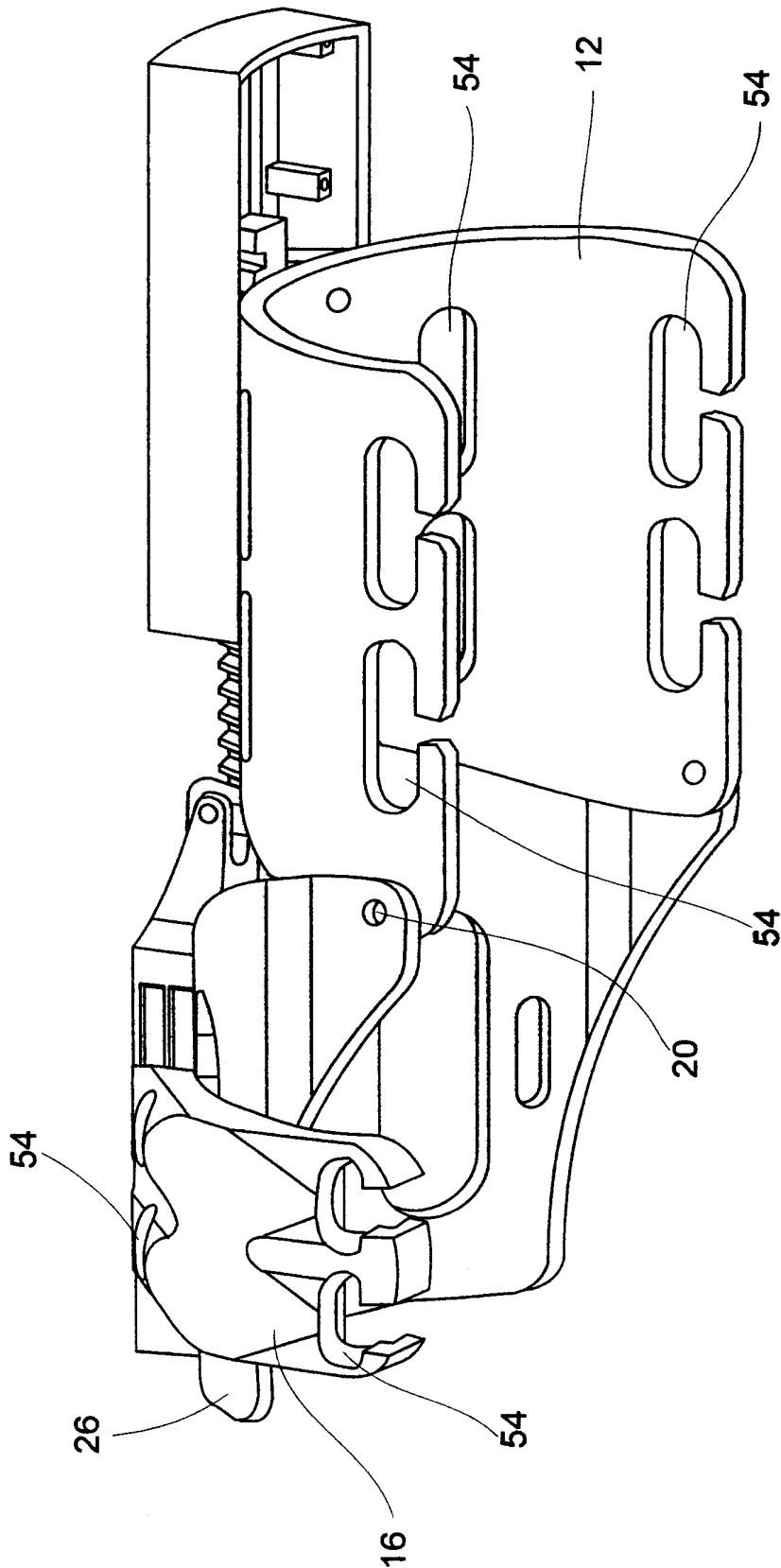


Fig. 11

12/15

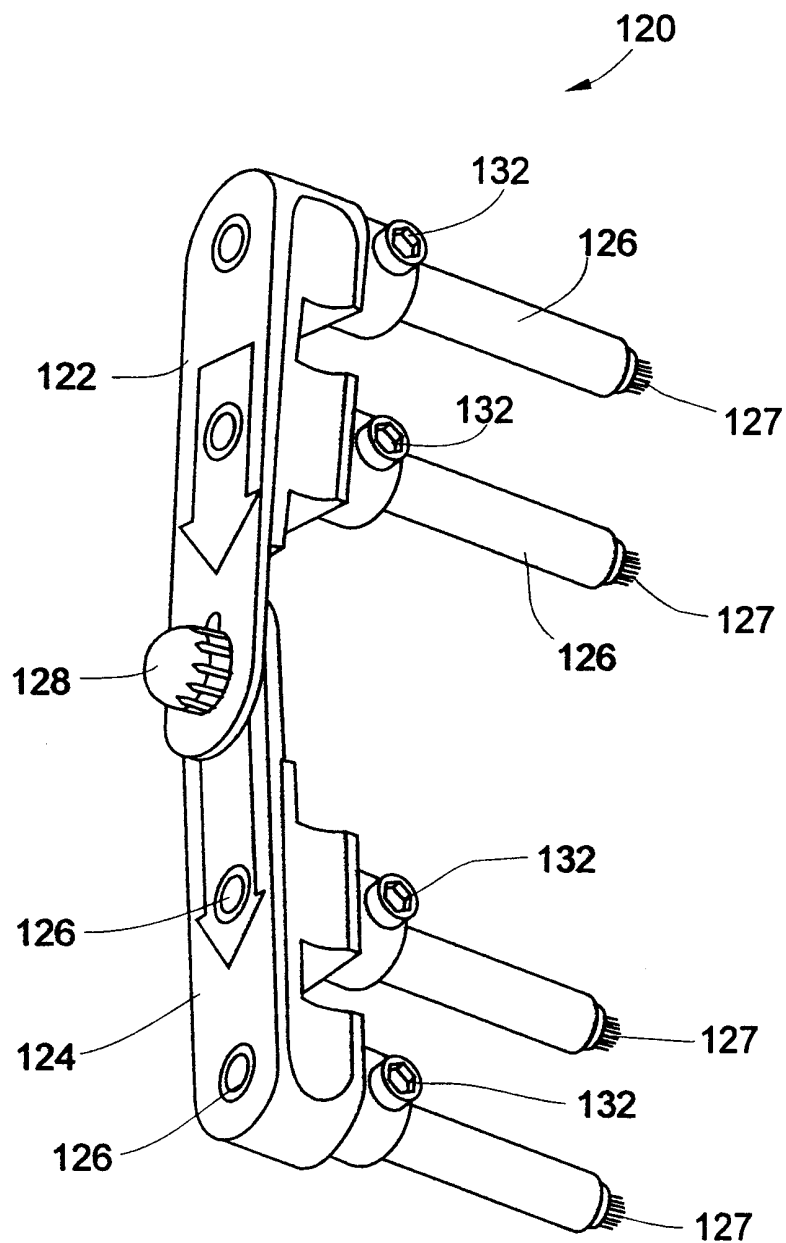
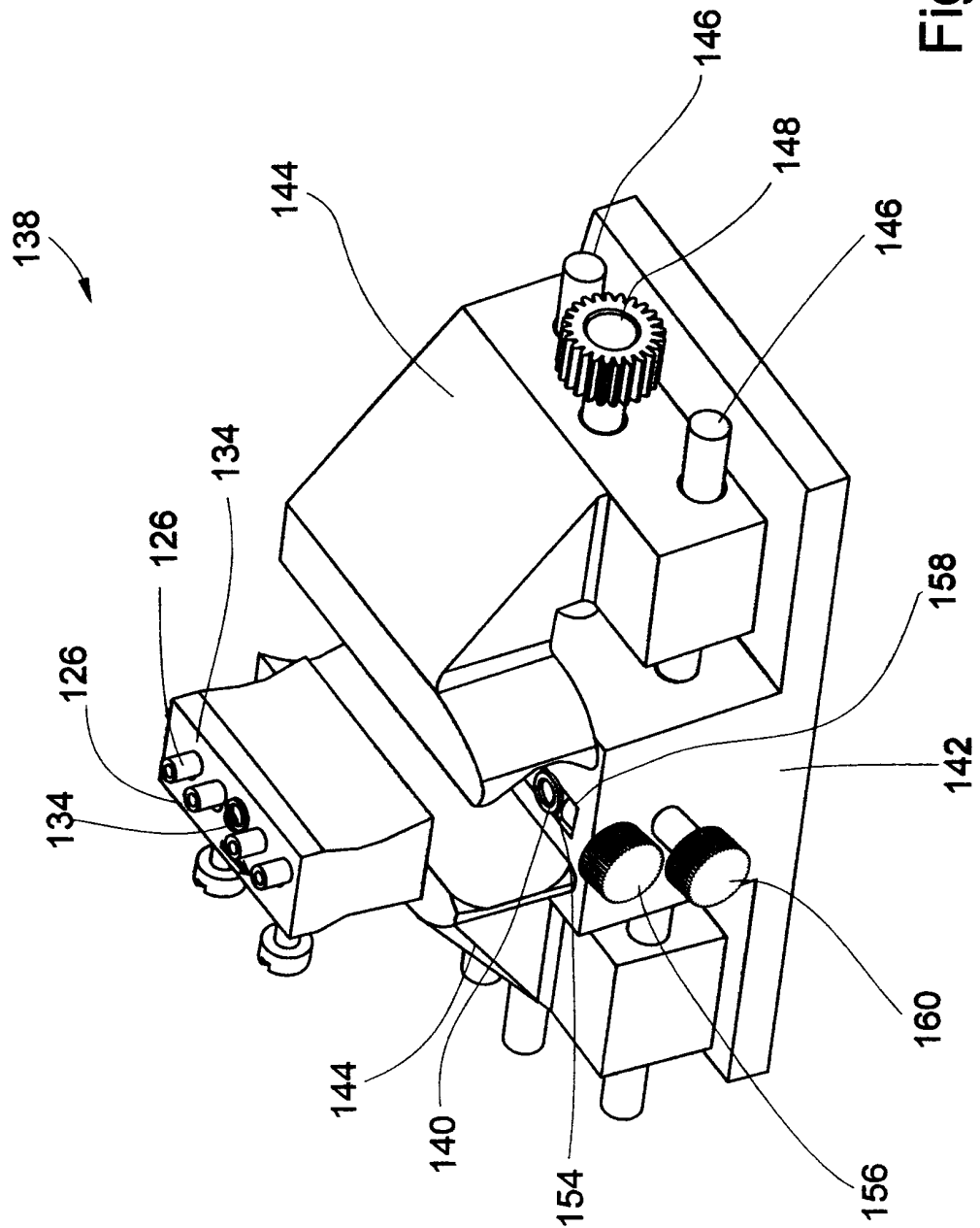
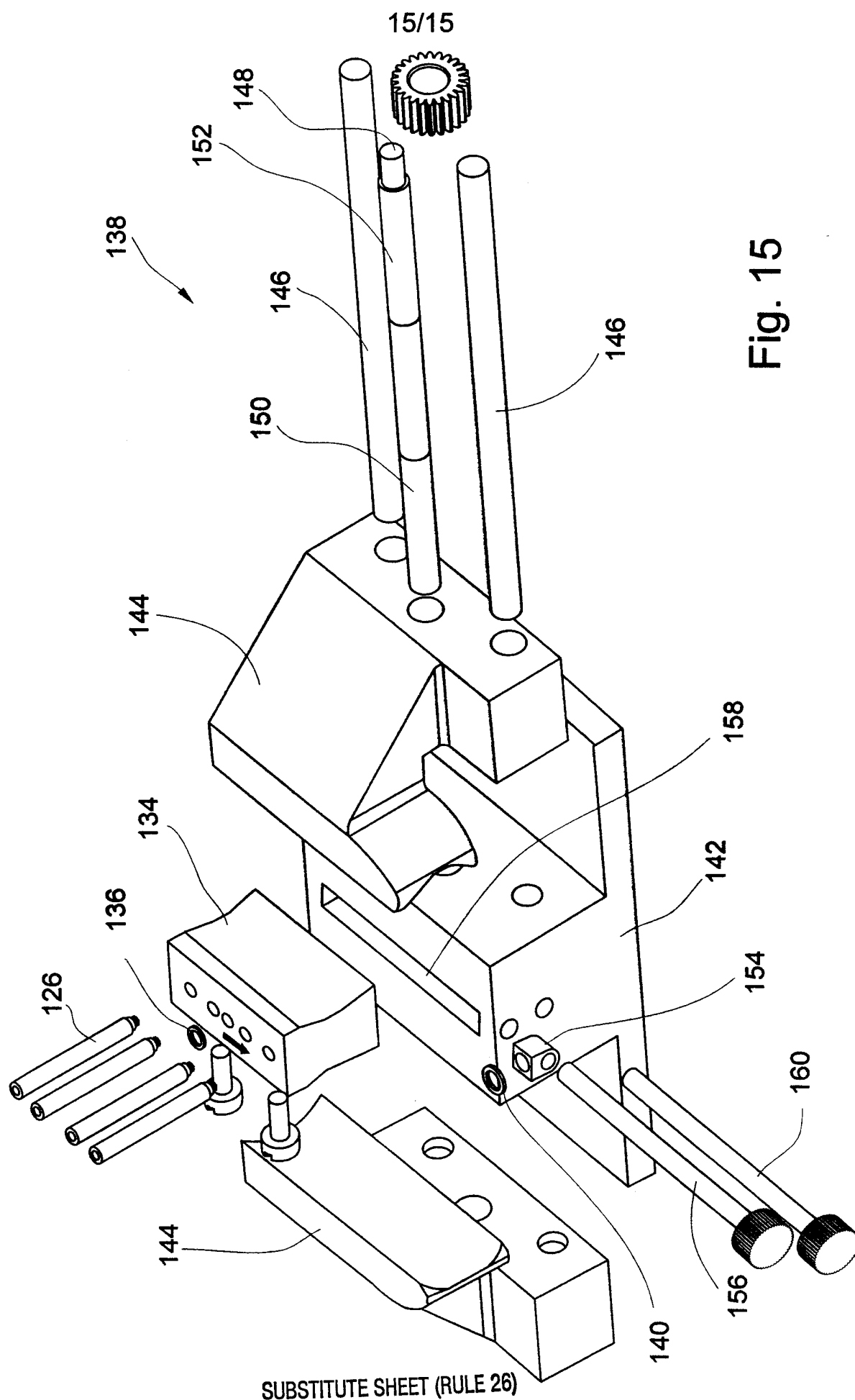


Fig. 12

14/15





INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/08822

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : A61B 17/56

US CL : 606/57

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)

U.S. : 408/72R; 606/54, 55, 57, 58, 96-98

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2,214,686 A (WEEDY) 10 September 1940, whole document.	8-17
X	US 5,100,403 A (HOTCHKISS et al.) 31 March 1992, whole document.	1, 4-7
X	US 4,604,997 A (De BASTIANI et al.) 12 August 1986, whole document.	1, 4-7
X	US 5,846,245 A (McCARTHY et al.) 08 December 1998, whole document.	1, 4-7



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:		"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

02 JUNE 2000

Date of mailing of the international search report

21 JUN 2000

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