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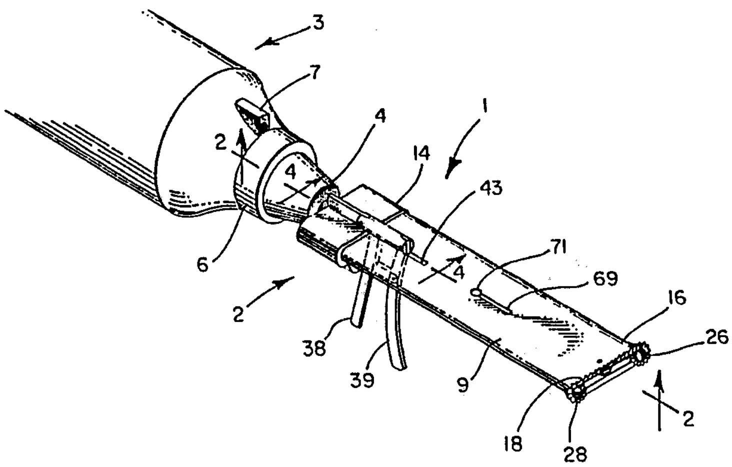

(57) Abstract

A curved bore hole drilling apparatus and method utilizing two poer driven drill shafts (21, 22) equipped with flexible shaft sections (23, 24) on the distal ends thereof with each flexible shaft section (23, 24) having a cutting tip (26). A semicircular channel shaped drill guide (153) loosely engages each flexible shaft end section (23, 24) and is caused to rotate through an approximately 90° angle as the cutting tips (26, 28) are advanced. The drill guides (53, 54) are pivotally mounted for rotation in substantially the same plane and, when rotated through an approximate 90° angle so as to meet, the cutting tips (26, 28) of the associated rotating flexible drill bits form a curved semicircular bore hole which may extend through 180°. The flexible shaft sections (23, 24) and guides (53, 54) are then backed out of the bore and the bore may be used for attachment of a tie such as a wire or a suture which is passed through the bore.

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CURVED BORE DRILLING METHOD AND APPARATUS

TECHNICAL FIELD

This invention relates to apparatus and methods for drilling a curved bore or hole into a hard material such as bone or other solid material. The invention is more particularly directed toward drilling apparatus which guides a normally straight, flexible drill shaft from a rectilinear approach path through a predetermined curved path as a cutting means is advanced into the material.

BACKGROUND ART

In the field of orthopedic surgery it is often desirable to: secure tissue such as ligament to a bone surface, to immobilize adjacent bone structures; and/or reduce a fracture by passing a filament such as suture or a wire through drilled holes in the bone. Scheller, Jr, et al. (United States Letters Patent No. 4,265,231; issued May 5, 1981) lists a number of specific examples of such operations wherein a curved bore is advantageous and describes one known method and apparatus for forming curved bore holes. The Scheller device is an example of the use of a flexible drill containing cannula of a predetermined curvature which may be hand-manipulated through its curved path within bone.

As may be appreciated, the manipulation of such a cannula requires a considerable amount of space and it is thus of limited utility where access is limited. The space requirement for operation of the instrument also necessitates a considerably larger skin incision. Not only does the manipulation of the hand held cannula and drive motor require additional space, but the cumbersome size and shape of the cannula itself severly limits the utility of the Scheller device.

Other examples of the use of a rigid curved cannula are illustrated in Barber (U.S. Letters Patent No. 2,541,423; issued September 17, 1985) and in Donohue (U.S. Letters Patent No. 4,312,337; issued January 26, 1982). These devices suffer from the same limitations discussed above with respect to the Scheller method and apparatus. In all of the cited methods and apparatus, the cannula is used to pull or advance the drill shaft through a curved path determined by the operator's manipulation of the entire instrument. Allowance must be made for the shape of the preformed cannula.

In spite of the various prior art devices discussed, the commonly used method of securing a suture or a wire to a bone is independently drilling two straight intersecting holes disposed at some angle less than 180°. A curved needle is then gradually forced through from one bore hole to the other. The problem with this type of approach is that it is often a hit or miss proposition. Such a procedure is very time consuming if the bore holes do not intersect or if the permitted working area is restricted. In some instances severe damage can also be caused to the bone and/or to the surrounding soft tissue. It is also possible to break a needle within the bone structure by using too much force, thus, necessitating additional time and inconvenience to retrieve the broken needle fragments. This greatly increases the expense to perform the operation. Additional anesthesia is also required which increases the risk associated with the operation.

The primary problems with the apparatus and methods of the prior art are: the time consuming nature of the procedures; the inability to operate in a restricted area; and the possibility of severe damage to bone and/or to surrounding tissue. The results of these drawbacks may have far reaching effect in terms of the cost of the surgery, the degree of scarring, and the recovery and rehabilitation time required, as well as increased anesthesia risks.

Furthermore, modern day trends of reducing incision size and decreasing tissue violation do not lend themselves well to the sometimes crude and inexact methods currently in practice, or in any of the cited prior art. For example, in the practice of arthroscopic surgery an instrument is inserted into a joint cavity through an extremely small puncture incision which is only large enough to allow entrance of the instrument. The cavity and manipulation of the instrument is observed by means of a scope device inserted through a second near size incision. Curved bone drilling under these conditions is presently non-existant, and would be extremely difficult if not impossible with known bone drilling devices.

The inventor believes that the known prior art taken alone or in combination neither anticipate nor render obvious the present invention. These citations do not constitute an admission that such disclosures are relevant or material to the present claims. Rather, these citations relate only to the general field of the disclosure and are cited as constituting the closest art of which the inventor is aware.

DISCLOSURE OF INVENTION

The present invention provides apparatus and methods whereby a flexible drill shaft may be caused to enter the surface of a bone or other hard material in a first direction or approach path which is generally normal, or at a given angle, to the surface of the material to be drilled. The flexible drill shaft is then guided through a second or curvilinear path having a predetermined degree of curvature. With this method, it is unnecessary to alter the angle of approach of the drill shaft during the procedure, thus, making it possible to drill a cured bore in bone through a very small, deep incision.

The claimed apparatus and methods further contemplate bore drilling in connection with arthroscopic surgery. In one form of the apparatus, a single arcuate drill guide of approximately 180° circumference is first set in position to be insertable through an anchoring sleeve located in an extremely small incision which gives access to a joint cavity. Once located within the cavity, the 180° arcuate guide is returned to a start position and the flexible drill shaft is guided through an approximate 180° curvature bore or hole through the bone structure. The drill and guide are then backed out of the hole. The drill guide member is returned to an initial approach position, and is drawn back through the anchoring sleeve or is withdrawn with the sleeve from the joint cavity.

The flexible drill shaft section is connected to an elongated rigid shank or shaft section which in turn is driven by a conventional drive motor assembly. The drive motor assembly may comprise any one of many hand-held drive motor units commonly utilized in surgical or dental drilling procedures.

In one embodiment, the device provides for simultaneous advancement of the drill shaft and curved channel-shaped drill guide loosely coupled to the distal end of the flexible drill shaft section. In this manner, as the flexible drill shaft section advances, it is caused to follow the path of the preformed drill guide and form a curved bore within the material. The cured bore is achieved without requiring manipulation of drive motor assembly or changing the original angle of approach of the drill shaft. The drill shaft and the guide member are then withdrawn after forming the curved bore in the body of the material.

In one embodiment of the invention, two such drill shafts and guide units are operated simultaneously as corresponding curved drill guides are rotated. The curved drill guides are rotated within the same plane so that the drill shafts and cutting means cause the simultaneously formed curve bores to connect.

A linkage is provided whereby the drill shaft or shafts and the drill guide or guides are advanced simultaneously with a single hand motion. This mechanism is housed within the confines of a housing unit, the end or tip of which seats upon the surface to be drilled.

In a second embodiment of the invention, a spring-biased, slidable connection is provided in the drill shaft sections. Such connection permits the flexible shaft section to be pulled by means of the guide members through their arcuate paths to form the curved bores.

The drill guide units may be driven by means of worm and gear drives which are connected to the housing and are operated by a trigger mechanism in a hand-held device. Upon reverse-direction operation of the guide units, the flexible drill shaft sections are retracted from the bore by their spring connecting means and thus withdraw the cutting means.

In a third embodiment of the invention, a single, curved-channel drill guide of approximately 180° in circumference is utilized. The drill guide in this embodiment operates to pull the flexible drill section through its curved path and to push the cutter means into the material to create the curved bore. The drill guide unit is driven by a single-finger, trigger-operated, guide advancement means which powers the rotary drive means. Since the drilling pressure reaction forces are unbalanced, the single guide unit may be operated within an anchoring sleeve anchored to the bone surface by known pinning methods.

The advantage of using a single guide member is that the drilling apparatus may be inserted through an incision which is approximately one-half the size of what would otherwise be required for use of the double drill-guide embodiment. Utilization of the anchoring sleeve, enables this embodiment of the drilling apparatus to be inserted into extremely small incisions such as those used in arthroscopic surgery.

The present invention greatly simplifies conventional and arthroscopic surgery, and provides a curved bore or hole with extreme accuracy and with minimum damage to bone and tissue.

Due to pressure to reduce medical costs, greater emphasis is made to increase efficiency and reduce the time required to perform various procedures. Any reduction in time, and increase in accuracy and efficiency is therefor of great significance. Further, the modern trend is toward procedures which reduce incision size and tissue violation. The latter trend is demanded not only for cost reduction and shortened recovery time, but also to reduce pain, scarring, rehabilitation time, anesthesia risk, required pain medication, and wage loss during recovery. The invention also decreases post-operative therapy and expense.

The claimed apparatus and methods enable the attachment of filament to bone in an exact and efficient manner, saving time and cost, and permitting the operation to be performed within very small, deep incisions, heretofore impossible with prior art devices.

These and other objects and advantages of the present invention will become more readily apparent upon reading the following disclosure and referring to the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is an isometric view of a first embodiment of the drilling apparatus and power drive unit.

FIG. 2 is a cross-sectional view taken along lines 2-2 of FIG. 1.

FIG. 3 is a cross-sectional view similar to FIG. 2 which illustrates the operation of the drill guide advancing mechanism.

FIG. 4 is a cross-sectional view taken along lines 4-4 of FIG. 1.

FIG. 5 is a partially sectioned, end elevational view of the drill shaft drive gear arrangement.

FIG. 6 is a cross-sectional view taken along lines 6-6 of FIG. 2.

FIG. 7 is an isometric view of the flexible drill shaft section having a convex cutting tip and its relationship to the associated drill guide.

FIG. 8 is an isometric view of the flexible drill shaft section having a concave cutting tip and its relationship with the associated drill guide.

FIG. 9 is a partially sectioned, side elevational view of a second embodiment of the drilling apparatus according to the invention.

FIG. 10 is an exploded view of the slidable spring biased drill shaft connection.

FIG. 11 is a partially sectioned side elevational view showing the drive unit for the drilling apparatus of FIG. 9.

FIG. 12 is a partially sectioned, elevational view of a third embodiment of the invention wherein a single arcuate drill guide is utilized.

FIG. 13 is a cross-sectional view taken along line 13-13 of FIG. 12.

FIG. 14 is a partially sectioned, elevational view of the single drill guide of FIG. 12 with an anchoring sleeve arrangement for inserting the drill apparatus through a small incision.

FIG. 15 is a cross-sectional view taken along lines 15-15 of FIG. 14.

One should understand the drawings are not necessarily to scale and the elements are sometimes illustrated by graphic symbols, phantom lines, diagrammatic representations, and fragmentary views. In certain instances, the inventor may have omitted details which are not necessary for an understanding of the present invention or which render other details difficult to perceive.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to the first embodiment shown in Figures 1 through 8, the apparatus as illustrated in FIG. 1, includes: the drill shaft housing 1; the drill shaft and drill guide advancing mechanism 2; and the power drive unit such as an electric or pneumatic motor indicated generally at 3. The power drive unit 3 may be any one of many well-known electrical drive motors utilized in dental and surgical procedures which are of a size to be conveniently held in the hand of an operator. The power drive unit 3 includes the jaws 4 which may comprise an adjustable grip such as a collet type collar. The jaws 4 are operated by the adjustable ring 6 or by a Jacobs chuck in a conventional manner, as is well understood to those versed in the art. The power drive unit 3 will include an on/off switch 7 or a variable-speed trigger. The jaws 4 serve to connect the power drive unit 3 to an input drive shaft 8 for the drilling apparatus presently to be described in detail.

The drill shaft housing 1 may be constructed of thin sheet metal and, as seen in Figures 1, 2 and 6, is elongated and generally flat in cross-section having the flat spaced sidewalls 9 and 11 either connected to or integral with the internal tubular sections 12 and 13 which form the rounded side edges of the hollow housing. The upper end of the housing 1, as seen in FIG. 2, is smooth or flat to telescopically receive the gear housing portion 14 of the drill shaft and guide advancing mechanism 2 presently to be described. The gear housing 14 and the drill shaft housing 1 are in a slidable telescoping relationship.

The lower or bottom end of the drill shaft housing 1 is flared around its outer periphery as indicated at 16 in Figures 2 and 3. Likewise the inner curved ends of the tubular sections 12 and 13 will also be flared as at 17. The bottom edge of the flared sections 16 and 17 are also provided with serrations or saw tooth formations 18 which permits the housing 1 to be seated firmly upon the surface of a material, such as a bone material 19, which is to be drilled. Serrations 18 insure that a slight down pressure against the housing 1 will firmly engage the bottom end of the housing against the surface to prevent slippage.

In the embodiment illustrated in Figures 1 through 8, each tubular housing 12 and 13 is equipped with an elongated drill shaft section 21 and 22, respectively, which extends along the full length of the housing. Each drill shaft 21 and 22 is provided with a flexible distal end portion 23 and 24, respectively, which may be displaced along a curvilinear path to form a curved bore or hole. The rigid drill shaft sections 21 and 22 may be formed of any suitable material such as of stainless steel which is commonly used in orthopedic drilling procedures. Drill shaft sections 21 and 22 may range in diameter size from 1/16 of an inch to 1/4 inch, depending upon the particular procedure or bore diameter requirement. Larger or smaller shaft sections may also be used.

The flexible shaft sections 23 and 24 may be welded or otherwise attached to the bottom ends of the rigid drill shaft sections and may be formed from helically grooved or slotted small diameter rods as illustrated in the present embodiment or, in some instances, may be formed from coil spring as is well known in the art of curved bore drilling.

The distal end of each flexible section 23 and 24 is provided with a cutting tip or burr which does the actual cutting as it is advanced through the material. In the present embodiment, the cutting tip 26 is made from a flattened metallic material which has been suitably hardened for the cutting function. As shown in Figures 2, 3 and 8, the tip 26 may have a concave cutting surface 27. The flexible end section 24 is provided with a flattened cutting tip 28, shown in detail in FIG. 7. Cutting tip 28 may have a convex cutting surface 29 such that, when the cutting tips are brought into proximity, a bore hole is completed as shown in FIG. 3.

The upper ends of the drill shafts 21 and 22 are provided with gears 31 and 32, respectively, and are journal mounted to the inside surface of the end plate 33 of the housing 14 so as to move with the housing 14 when the housing 14 is moved telescopically relative to the housing 1. Journal blocks 34 and 36 may be provided for this purpose.

The gears 31 and 32 are driven by a drive gear 37 mounted on the end of the input shaft 8 gripped by the jaws 4 of the electrical motor. The input shaft 8 may be suitably journaled in the end plate 33. With this arrangement, it will be noted, that the drill shafts 21 and 22 are rotated in the same direction during the drilling operation and may be advanced and retracted by producing relative movement between the housing 14 and the housing 1.

As shown in Figures 1 and 4, the housing side wall 11 is provided with a fixed handle or grip 38 which may be welded or otherwise anchored to the housing wall. A second curved movable handle 39 is pivoted at 41 along its mid-section to an extension 42 of the handle 38, with its upper end extending through the slots 43 and 44 in the walls 9 and 11, respectively.

The upper end of the handle or lever 39 is pivotally connected at 46 to a pull rod 47 which is in turn pivoted at 48 to an upstanding rib 49 affixed to the top wall of the housing 14.

A compression spring 51 is seated against a housing shoulder 50, carried by the housing 14, and a dog 52 is mounted on the top surface of the housing wall 9, as shown in FIG. 4.

With this arrangement, the housing 14 and the housing 1 are biased apart by the spring 51 to the extent allowed by the movement of the lever 39, as shown in FIG. 4, and the two housings are telescoped together, as illustrated by the dotted line portions in FIG. 4, by operation of the lever 39 when it is pivoted toward the fixed lever 38 by hand motion. The reciprocal movement of course advances the drill shafts.

Referring in particular to FIG. 2, the drill shaft guides comprise the arcuate channel shaped members 53 and 54 mounted on the radius arms 56 and 57, respectively. These arms are pivotally connected to the housing wall members 9 and 11, as illustrated in FIG. 6. Each drill guide 53 and 54 comprises a curved, cross-sectional channel, as illustrated more clearly in detail in Figures 7 and 8, and are provided with end collars or rings 58 and 59, respectively. The collars loosely engage the flexible drill sections 23 and 24, respectively, as shown in Figures 7 and 8. The open side of the channels permits the drill guide member to intersect the path of the flexible drill sections. The loose rings or collars on the end of the channels retain the rotating flexible drill shaft sections within the guide channels as the guide channels are pivoted through their arcuate paths to form the curved bores. The arcuate drill guides 53 and 54 extend through suitable slots 61 and 62 in the lower ends of the tubular sections 12 and 13, respectively, as shown most clearly in FIG. 3.

The linkage for simultaneously operating the arcuated drill guides with the forward movement of the drill shafts is illustrated in Figures 2 and 3. As previously described, the drill guides 53 and 54 are carried on radius arms 56 and 57, respectively. The radius arms are pivotally mounted at a common pivot point 63 near the bottom end of the drill shaft housing.

As shown in FIG. 3, when the radius arms 56 and 57 are rotated from the vertical to the horizontal position, the channels 53 and 54 move with the advancing flexible drill shaft cutting tips to form a continuous bore through the surface and body of the material 19. It will be understood that, in the particular embodiment illustrated, the channel numbers 53 and 54 do not pull the flexible drill shaft sections through the curved path but, rather, are caused to move substantially simultaneously with the drill shafts as they are advanced by the drill guide advancing mechanism 2, which has been previously described. The collars 58 and 59 on the ends of the channels 53 and 54, respectively, guide the flexible drill shaft sections through their curved path while allowing the cutting tips 26 and 28 to rotate.

As shown in FIG. 3, the width of the cutting tips are slightly larger than the diameter of the guide channels so as to provide adequate clearance for the channels as they are advanced through the bores formed by the cutting tips. The concave and convex forward cutting surfaces 27 and 29, respectively, on the cutting tips enable the drill shafts to make a complete through bore upon being brought into close proximity.

In order to advance the drill guides simultaneously with the advancing of the drill shafts 21 and 22, the movable handle 39 is pivotally connected adjacent its upper end to push rod 64 to provide the downward motion for moving the drill guides. The push rod 64 is connected at its distal end to the drill guides by means of the crossarm 66 and pivoted drive links 67 and 68. The push rod 64 is guided in its rectilinear motion by means of the slot 69 in the housing wall 9. A pin member 71 extends through the push rod 64 and crossarm 66 and is retained within the slot 71, as shown in FIG. 1. The crossarm 66 is held ridged or fixed to the rod 64 by means of the pin 71, or crossarm 66 may be otherwise rigidly connected to the push rod.

As viewed in Figures 2 and 3, the two pivoted links 67 and 68 have their upper ends pivotally connected to the crossarm 66 and their lower ends are connected, respectively, to one of the drill guide arms at the junction of the associated guide arm and its radius arm. The link 67 is connected to the guide 54. Link 68 is pivotally connected to the guide 53. As the push rod 64 is advanced simultaneously with the drill shafts, the links 67 and 68 serve to rotate the guide channels and radius arms in opposite directions about the pivot 63.

Once the bore has been completed, handles 38 and 39 may be released and the spring 51 will return the gear housing 14 which pivots the lever 39 counterclockwise, as seen in FIG. 4, to simultaneously retract the push rod 64.

The overall operation of the device shown in Figures 1 through 8 is rapid and simple. In a typical surgical procedure the location for the bore hole is selected, the instrument is placed on the bone surface and held in place with one hand by grasping the drive unit 3. To prevent slippage of the instrument during drilling, the serrated bottom edge 18 of the drill shaft housing is placed against the bone or other surface without requiring the application of excess pressure. With the other hand, the operator simply grasps the handles 38 and 39, and, with the drive motor in operation, squeezes the handles together. The hand-held drive unit is allowed to follow the advance of the drill shafts. The device is held in this position throughout the drilling operation and need not be further manipulated. This is of great importance in a restricted access situation, as in the case of when a deep incision is made to gain access to a bone surface. The drill shafts 21 and 22 will advance in unison and simultaneously the push rod 64 will operate to pivot the guide channels 53 and 54 through their arcuate paths until the cutting tips 26 and 28 have completed their course of travel and are in close proximity, as shown in FIG. 3. Once the bore hole is completed, the handles 38 and 39 are released and the drill shafts retract by action of the spring 51. The device may then be lifted from the surface leaving the completed bore hole ready for a suture or other attachment means.

Figures 9 through 11 illustrate a second embodiment of the curved bore drilling apparatus, wherein the flexible shaft sections and cutting tips are respectively pulled and pushed through their arcuate paths by the action of the shaft guide members. The flexible and rigid shaft sections have a spring biased sliding connection which allows the flexible sections to be pulled through their curved paths against spring pressure and to be returned by the same spring pressure upon the return of the arcuate guide members.

Referring to FIG. 9, this embodiment comprises: a drill shaft housing unit shown generally at 71, which may be rectangular in cross-section similar to the housing 1 of the previous embodiment, having a hollow central tubular section 72; an upper shaft support and bracing cap 73; and a bottom drill guide housing section 74. The drill shaft housing 71 is received in the outdrive fitting 76 of a hand-held drive unit indicated generally at 77 in FIG. 11. The cap 73 may be received in a suitable socket in the fitting 76 by means of a press fit or any other suitable retention means.

As seen in FIG. 9, the outdrive fitting 76 provides support for the two rigid rotary drill shafts 78 and 79 as well as the drill guide rotary drive shafts 81 and 82, presently to be described in detail. These four shafts are provided with suitable mating supports (not shown) within the housing body 83 of the unit 77 as shown in FIG. 11. The drive shafts 78 and 79 include large diameter lower end portions 84 and 86, respectively, which extend through the cap 73 and are mounted for rotation therein. Likewise, the drill guide drive shafts 81 and 82 pass through the cap 73 and into the lower tubular section 72 of the housing. It will also be understood that the shafts 81 and 82 are mounted for rotation within the cap 73. The four rotary shafts are supported along their length within the upper extent of the hollow tubular section 72 by means of the spanner bearing support and shaft brace 87 in a well known fashion. The lower ends of the drill guide drive shafts 81 and 82 are supported in a second spanner bearing support and shaft brace 88 in the drill guide housing 74.

The spanner bearing support and shaft braces may be of any conventional design well known in the art and are designed to rotatably support the respective shafts within the housing. The lower ends of the drive shaft sections 84 and 86 pass through suitable bores or channels in the lower end of the housing section 72 and the drill guide housing section 74. These bores or channels will be of sufficient diameter to permit rotation of the drive shafts and reciprocation of the drill shafts during the drilling operation. FIG. 10 illustrates the details of the slidable coupling of the drill shafts and it will be understood that the same connection is utilized with respect to drill sections 91 and 86.

Referring to FIG. 10, the flexible drill shaft sections

89 and 91 may be formed from any well known materials, such as has been described with respect to the embodiment shown in Figures 1 through 8. The cutting tips 92 and 93 may be identical to those described for the previous embodiment.

In order to provide for a sliding fit between the flexible section 89 and the rigid section 84, the flexible section 89 is connected to the rigid coupler portion 94 of the rigid shaft section 84. The coupler 94 includes a flat extension 96 which is telescopically received within an elongated slot 97 located within the drive shaft section 84. In this manner, well known in the art, the drive shaft 84 transmits rotary motion to the flexible drill shaft portion and allows for a linear sliding movement of the coupler 94 and the flexible shaft.

In order to bias the coupler 94 into engagement with the shaft section 84, the tension spring 98 surrounds the lower end of the shaft section 84 and the upper end of the coupler 94 and will be attached to the two members by means of the eyelets 99 and 101 formed in suitable brackets on the mating members. This relationship is shown by the exploded view of FIG. 10. It will also be understood that the bores or channels in the housing 72 and 74 are of sufficient diameter to permit rotation of the shafts with these protrusions.

Although the slidable connection is shown and described as being between the coupler and rigid shaft sections, it will be obvious to those skilled in the art that such a connection may be provided at any point along the rigid or flexible shafts in order to allow the flexible shaft to be pulled through its arcuate path and returned.

The drill guide housing 74 as previously described includes the spanner bearing support and shaft bracing block 88 for receiving the drive shafts 81 and 82. The drill guide housing may be connected to the tubular section 72 in any suitable manner such as the circumferential flange 102 and the clip member 103 which is a well understood expedient in the art. The lower end of the housing 74 is open to permit operation of the flexible drill sections and drill guides as previously described in relation to the embodiment shown in Figures 1 through 8.

The bottom peripheral edge face 104 may also be knurled (not shown) or otherwise serrated or roughened in order to provide a gripping engagement on the surface of a bone or other material to which the drilling unit is applied. The bottom end of the housing 74 is provided with a cross shaft 106 for mounting the rotatable drill guide members 107 and 108 on a common rotary axis.

As viewed in FIG. 9, the drill guides may be identical and mirror images of each other so as to operate in opposite directions through an approximate 90° angle and in substantially the same generally vertical plane. To accomplish this, each drill guide includes a gear sector and an arcuate guide member laterally offset therefrom. Thus, the drill guide 107 has a gear sector 109 and a channel shaped arcuate guide 111 and the drill guide 108 has a reversely positioned gear sector 112. The arcuate channel guide 113 is located on the opposite side of the gear sector

109, as viewed in FIG. 9. With this arrangement, the drill guide 107 may be rotated approximately 90° in the clockwise direction and the drill guide 108 may be rotated approximately 90° in the counter clockwise direction, as viewed in FIG. 9. The gear sectors 109 and 112 are provided with meshing pinions 114 and 116 respectively which are mounted on laterally offset stub shafts so as to be positioned in mesh with worm drives 117 and 118 respectively. As shown in FIG. 11, the drive shafts 81 and 82 are laterally offset in opposite directions so as to place the worm drives in full mesh with the laterally offset pinions 114 and 116.

The completion of an approximately 180° curved bore into and out of a bone or other surface utilizing the embodiment of Figures 9 through 11 will be substantially the same as that described for the previous embodiment. As illustrated in Figures 9 and 11, one method of driving the rigid drill shafts 78 and 79, wherein the shafts 78 and 79 are provided with bevel gears 122 and 123, respectively, is to mesh bevel gears 122 and 123 with mating bevel gears 124 and 126. The bevel gears 124 and 126 are driven by a common bevel drive gear 127 on the drive shaft 128 of a rotary pneumatic motor 129. The motor 129 may be of any well known commercially available design. This drive arrangement will rotate the drive shaft 78 and 79 in the same direction to drive the flexible drill shafts and cutting tips as described relative to the previous embodiment.

A trigger type rack and pinion drive is provided for rotating the drill guide members through their arcuate paths.

In order to drive the shafts 81 and 82 in the same rotary direction the drive trains are substantially identical. The shafts 81 and 82 have pinions 131 and 132 respectively in mesh with spur gears 133 and 134 respectively. As illustrated most clearly in FIG. 9, each spur gear 133 and 134 has a bevel gear portion in mesh with bevel gears 136 and 137 respectively fixed to shafts 138 and 139. The opposite ends of the drive shaft 138 and 139 are provided with spur gears 141 and 142 respectively. This arrangement may be seen in FIG. 11. These spur gears mesh with rack driven spurs 143 and 144, respectively. The spur gear 143 is rotated by means of the rack 146 and the spur 144 is driven by the parallel adjacent rack 147. Cross shafts for mounting the various spur gears and bevel gears described will be suitably journaled within the housing 83 in any manner well known to the art. The racks 146 and 147 are fixedly mounted on a trigger bar 148 slidably received in the housing 83. As illustrated, the trigger bar 148 is biased in the outward direction by means of the compression spring 149.

In the position illustrated in FIG. 9, the drill guide units 107 and 108 are in their retracted positions. Upon depressing the trigger 148 against the pressure of the spring 149, the racks 146 and 147 activate the drive shafts 81 and 82 to rotate the guide members 107 and 108 through their arcuate paths by means of the worm drives 117 and 118. As the guide members 107 and 108 advance through their arcuate paths, the rotating flexible drill sections 89 and 91, by virtue of the sliding connection in the shaft sections, are caused to advance through arcuate paths against the tension of spring 98.

When the trigger bar 148 is released, the spring 149 returns the trigger bar to its original position, shown in FIG. 11, which reverses the direction of the worm drives and consequently retracts the guide members 107 and 108.

As the guide members return to their positions, shown in FIG. 9, the springs 98 cause the flexible drill sections to return to their original positions. With this arrangement, the curved bore hole drilling is accomplished with one hand in a rapid and efficient manner utilizing the extremely small skin incision necessary to insert the drill shaft housing 71.

Figures 12 and 13 illustrate a third embodiment of the invention, wherein an arcuate drill guide channel of approximately 180° may be utilized to form a curved bore into-an-out-of a bone surface. Another advantage of the single 180° drill guide is the ability to construct the drilling apparatus and housing so as to require only one-half the width of the double arcuate guide embodiments described. This ability for smaller space requirements enables the single 180° drill guide to be utilized effectively in arthroscopic surgery because of the extremely small puncture incision that is needed.

The embodiment shown in Figures 12 through 15, is extremely simplified because of the elimination of one of the drill shafts and one of the drill guide members. The ability to advance a single flexible drill shaft through its curved path also reduces the number and complexity of the linkages involved. It will be understood that any drive means such as those shown and described in the previous two embodiments may be utilized, or adapted by one of ordinary skill in the art, to drive the single drill shaft and the double worm drive shafts to be described. The details of such drive mechanism are therefore omitted from the drawings for the sake of simplicity.

Referring to FIG. 12, the drill shaft housing 151 may be a straight tubular section, rectangular in cross-section, and made from rigid material such as stainless steel. The tubular housing 151 will be understood to be connected to a hand-held drive mechanism such as those previously described. The bottom extent of one end wall of the tubular housing 151 is removed as at 152 to permit the approximate 180° rotation of the drill guide. The arcuate drill guide comprises a single channel shaped semi-circular member 153 having one end thereof welded or otherwise rigidly attached to the single radius arm 154. The arm 154 is pivotally attached at one end to the bottom end of the tubular housing 151 by means of the cross-shaft 156. A flexible drill shaft section 157 is located in the housing 151 and includes a coupler section 158. It will be understood that the coupler 158 is a part of the rigid drive shaft and that a tension spring biased slip connection is provided such as previously described relative to Fig. 10. The flexible drill shaft section 157 is spring biased upwardly, as viewed in FIG. 12, and passes through the collar section 159 on the free end of the channel guide member 153. The flexible drill section 157 will be free to rotate within the collar 159 as the channel guide is caused to advance through its arcuate course.

As illustrated in FIG. 13, the channel member 153 is U-shaped in cross-section and each of the sidewalls of the U-shaped section is provided with spaced radial slots 161 around substantially it entire periphery. These slots are designed to mesh with the helical threads 162 on the two helical drive shafts 163 and 164 which extend vertically in the housing 151 parallel with the flexible drill shaft 157. Any conventional means may be utilized to journal mount the drive shafts 163 and 164 and to provide a rotary drive therefore. In order to stabilize the bottom ends of the drive shafts 163 and 164 against reaction forces due to the advancement of the channel member 153, the cross pins 166 and 167 are provided and are vertically spaced, one above the channel member and one below. These cross pins 166 and 167 may be anchored in the sidewalls of the housing 151. With this arrangement, rotation of the helical drive shafts 163 and 164, both of which will be rotated in a direction to advance the channel member, will result in pulling the flexible drill shaft 163 through a curved path into the bone surface. The enlarged cutter tip 168 ensures that the drill shaft and the arcuate guide will be easily passed through the bore formed by the tip. The tip 168 extends beyond the 180° arc of the channel member 153 thus also ensuring that a complete rotation of the channel member through approximately 180°will form a through bore completely into-and-out-of the bone surface.

Since the drilling pressure is applied on only one side of the 180° guide channel, there is a tendency to produce lateral shifting of the drill housing 151 preventing maintenance of accurate location and stability throughout the drilling operation. For this reason, the housing 151 and the drill guide are inserted within a close fitting anchor sleeve 169. The anchor sleeve may be formed by any suitable construction such as that illustrated which provides vertical bores or passages for the insertion of anchoring pins. Such pins are known as Steinman pins and are commonly used to locate jigs or other appliances in preparation for bone drilling. A plurality of vertical passages provide for placement of a plurality of Steinman pins 174 placed at selected locations about the periphery of the anchoring sleeve as will be understood by those familiar with the art. Any suitable means may be utilized to provide for the placement of the pins and anchoring of the sleeve.

In the embodiment of Figures 12 and 13, the sleeve 169 completely encloses the housing 151 and the arcuate guide 153 in its initial or starting position with the guide extending beyond the walls of the housing 151. In this mode of operation, the incision provided to gain access to the bone surface to be drilled must be only large enough to accommodate the shape of the guide channel and anchor sleeve, as shown in FIG. 12.

FIG. 14 illustrates another embodiment wherein the anchoring sleeve 176 is wide enough to accommodate only the housing 151 and is provided with an opening 177 coextensive with the opening 152 of the housing 151. It will be understood that, except for location of the slot 152, the anchoring sleeve 176 is otherwise the same as anchoring sleeve 169 in cross-section to provide for insertion of Steinman pins.

The embodiment of Figures 14 and 15 has special utility in arthroscopic procedures wherein a scope is inserted through a puncture incision in a joint cavity and the anchor sleeve 176 is inserted through a separate puncture incision of a size to accommodate only the shape of the sleeve. The pin locating sleeve is initially inserted into the joint cavity and placed on the bone in the desired position. The Steinman pins are inserted through the sleeve by means of any conventional pin inserting apparatus. The drill guide 153 is then moved to the position where the radius arm 154 is substantially vertical as shown in the dotted line position in FIG. 14. This position allows the housing 151 to be inserted within the anchor sleeve 176. The housing is inserted through the sleeve until the drill guide is in a position to be rotated to the solid line position through the opening in the housing and the opening 177 in the sleeve, shown in FIG. 14, ready for drilling. The drill shaft housing is then seated on the surface of the bone to be drilled. The drilling operation may then be commenced. After the drill guide has been rotated through 180°and the curved bore hole formed, the guide is retracted to the full line position shown in FIG. 14 to remove the drill shaft and cutter means from the bore hole. The drill housing is then raised off the bone and the guide returned to the vertical dotted line position in order to permit removal of the housing from the anchor sleeve. The drill housing 151 is then withdrawn from the anchoring sleeve. The anchoring sleeve 176 may remain in the joint cavity for the purpose of admitting suture passing instruments or to relocate the sleeve to another desired location for further drilling operations.

The means and construction disclosed herein are by way of example and comprise primarily the preferred form of putting the invention into effect. Although the drawings depict a preferred and alternative embodiments of the invention, other embodiments have been described within the preceding text. One skilled in the art will appreciate that the disclosed device may have a wide variety of shapes and configurations. Additionally, persons skilled in the art to which the invention pertains might consider the foregoing teachings in making various modifications, other embodiments, and alternative forms of the invention.

It is, therefore, to be understood that the invention is not limited to the particular embodiments or specific features shown herein. To the contrary, the inventor claims the invention in all of its forms, including all alternatives, modifications, equivalents, and alternative embodiments which fall within the legitimate and valid scope of the appended claims, appropriately interpreted under the Doctrine of Equivalents.

INDUSTRIAL APPLICABILITY

The claimed apparatus and methods are of special utility in situations where a curved bore must be drilled. For example, the drill shaft or shafts may be advanced through a first approach path, which may be at right angles to the surface of the material being bored, and then advanced through a curvilinear path without requiring movement or angular displacement of the drilling apparatus. Thus, one or more flexible drill shaft sections may be guided through curvilinear paths to form a semicircular bore or hole through the material. The curved bore permits the attachment of a tying device or the like to the drilled material.

Although the invention has a wide range of applications, the invention has special application in surgical procedures where a ligament or other tissue must be secured to a bone surface. The present device permits such procedures to be accomplished in areas of limited access with minimum damage to bone and to surrounding tissue. A suture or other attaching filament may be easily passed through the curved bore, formed by the present invention, to anchor the tissue or ligament to the bone.

CLAIMS

What is claimed is:

Claim 1. An apparatus for drilling a curved bore within a material comprising:

(a) rotary drive means;

(b) drill shaft means having one end adapted for connection to said rotary drive means, said drill shaft means having a distal flexible end section;

(c) cutting means secured to said flexible end section;

(d) mounting means for directing said drill shaft means along a rectilinear path substantially normal to a surface of said material;

(e) guide means carried by said mounting means to guide said flexible end section and said cutting means from said rectilinear path along a curved path to form said curved bore within said material, said rectilinear path having an angle of approach with respect to a surface of said material; and

(f) means for pivotally moving said guide means along said curved path without requiring an alteration of said angle of approach.

Claim 2. An apparatus for drilling a curved bore within a material comprising:

(a) housing means;

(b) rotary drive means;

(c) drill shaft means having one end adapted for connection to said rotary drive means, said drill shaft means having a distal flexible end section;

(d) cutting tip means secured to said flexible end section;

(e) means mounting said drill shaft means within said housing means for reciprocal movement therein;

(f) curved guide means located within said housing means adjacent to said flexible end section;

(g) means pivotally mounting said curved guide means within said housing for movement of said curved guide means along a curved path; and

(h) means acting between said curved guide means and said flexible end section to guide said flexible end section and said cutting tip means along said curved path when said drill shaft means is reciprocated concurrently with pivoting said curved guide means.

Claim 3. The apparatus of Claim 2, further comprising:

(a) first and second drill shaft means;

(b) first and second curved guide means, said first and said second curved guide means being generally arcuate;

(c) means pivotally mounting said first and said second curved guide means within said housing for pivotal movement of said first and said second curved guide means within a substantially common plane to enable corresponding flexible end sections and said cutting tip means to form said curved bore.

Claim 4. The apparatus of Claim 2, wherein said curved guide means comprises:

(a) a curved channel member having one side open for reception of said flexible end section as said flexible end section advances, said curved channel member having a predetermined curvature of an intended curved bore; and

(b) radius arm means connected at one end thereof to said curved channel member and having another end thereof pivotally connected to said housing means;

(c) wherein another end of said curved channel member comprises engaging means to engage said flexible end section adjacent to said cutting tip means and to retain said cutting tip means therein.

Claim 5. The apparatus of Claim 4, further comprising:

(a) first and second drill shaft means;

(b) first and second curved guide means, said first and said second curved guide means being generally arcuate;

(c) means pivotally mounting said first and said second curved guide means within said housing for pivotal movement of said first and said second curved guide means within a substantially common plane to enable corresponding flexible end sections and said cutting tip means to form said curved bore.

Claim 6. The apparatus of Claim 4, wherein said cutting tip means is generally larger in diameter than said curved channel member,

said engaging means comprising a collar attached to an end of said curved channel member thereby securing said flexible end section to said curved channel member behind said cutting tip means,

whereby said curved bore formed by said cutting tip means is larger in diameter than said curved channel member to permit movement therethrough by said curved channel member as said cutting tip means advances, and

said apparatus further comprising actuation means to advance said drill shaft means and to pivot said curved channel member simultaneously,

whereby said curved channel member guides said advancing flexible end section along said curved path.

Claim 7. The apparatus of Claim 6, wherein said actuation means comprises:

(a) journal housing means for mounting driven ends of said drill shaft means, said journal housing means being mounted for reciprocal movement relative to said drill shaft means for advancing and retracting said drill shaft means;

(b) actuation lever means pivotally connected to said housing means and to said journal housing means for effecting said reciprocal movement;

(c) a push rod located within said housing means, said push rod being pivotally connected to said actuation lever means; and

(d) operating linkage means connecting said push rod to said curved guide means for rotating said curved guide means simultaneously with advancement of said drill shaft means.

Claim 8. The apparatus of Claim 3, further comprising first and second cutting tip means mounted on said corresponding flexible end sections,

said first cutting tip means having a concave forward cutting surface, and

said second cutting tip means having a convex forward cutting surface,

whereby said curved bore is completed upon completion of travel of said cutting tip means.

Claim 9. An apparatus for drilling a curved bore within a material comprising:

(a) an elongated tubular drill shaft housing;

(b) drill shaft drive means;

(c) drill shaft means having a rigid shaft section adapted for connection to said drill shaft drive means at one end thereof and having a distal flexible end section connected to an opposite end thereof, said drill shaft means being contained within said drill shaft housing and guided for reciprocation along a rectilinear path therein;

(d) cutting tip means connected to a distal end of said flexible shaft section;

(e) a generally arcuate curved channel shaped guide member pivotally mounted within said housing adjacent to said cutting tip means for movement along a predetermined arcuate path which is generally tangential to said rectilinear path of said flexible end section, said guide member being in retaining engagement with said flexible end section behind said cutting tip means to guide said cutting tip means and said flexible end section through said arcuate path as said drill shaft means is advanced through said material; and

(f) actuation means carried by said drill shaft housing to simultaneously advance said drill shaft means and said guide member to form said curved bore, said cutting tip means being greater in diameter than said guide member to permit said guide member to move freely within said curved bore.

Claim 10. The apparatus of Claim 9, wherein said actuation means comprises:

(a) journal housing means for mounting a driven end of said drill shaft means, said journal housing means being mounted on said drill shaft housing for relative reciprocal movement therewith for advancing and retracting said drill shaft means;

(b) actuation lever means pivotally connected to said drill shaft housing and to said journal housing means for effecting said reciprocal movement;

(c) a push rod in said drill shaft housing pivotally connected to said actuation lever means; and

(d) operating linkage means connecting said push rod to said guide member for pivoting said guide member simultaneously with advancement of said drill shaft means.

Claim 11. The apparatus of Claim 10, further comprising:

(a) first and second drill shaft means;

(b) first and second curved guide members, said first and said second guide members being generally arcuate; and

(c) means pivotally mounting said first and said second guide members within said drill shaft housing for pivotal movement of said first and said second guide members within a substantially common plane to enable corresponding distal flexible end sections and said cutting tip means to form said curved bore.

Claim 12. The apparatus of Claim 11, wherein said journal housing means comprises:

(a) gear means connected for simultaneously driving said first and said second drill shaft means; and

(b) input drive shaft means adapted for connection to a power drive motor and to said gear means.

Claim 13. A method for forming a curved bore within a material, comprising the steps of:

(a) directing a drill shaft having a flexible distal end section with cutting means thereon along a rectilinear approach path at a given angle of approach to a surface of said material;

(b) maintaining a portion of said drill shaft within said rectilinear approach path; and

(c) simultaneously guiding said flexible distal end section and said cutting means through a curved path, said cutting means forming a curved bore into said material, said drill shaft being capable of being advanced and retracted to form said curved bore without requiring an alteration of said angle of approach.

Claim 14. The method of Claim 13, further comprising the steps of:

(a) simultaneously directing a second drill shaft having a flexible distal end section with cutting means thereon along a second rectilinear approach path which is generally parallel to said first rectilinear approach path; and

(b) guiding said the flexible distal end sections of said first and said second drill shafts within a common plane until said cutting means approach each other to form a curved bore.

Claim 15. An apparatus for drilling a curved bore within a material comprising:

(a) a rotary drive means;

(b) housing means;

(c) drill shaft means mounted for reciprocation along a rectilinear path within said housing means, said drill shaft means having one end adapted for connection to said rotary drive means, said drill shaft means having a distal flexible end section;

(d) cutting means secured to said flexible end section;

(e) a curved guide member pivotally mounted within said housing means adjacent said cutting means for movement in a predetermined curved path generally tangential to said rectilinear path of said flexible end section, said curved guide member being in retaining engagement with said flexible end section to guide said cutting means and said flexible end section away from said rectilinear path toward said predetermined curved path as said drill shaft means is advanced through said material.

Claim 16. An apparatus for forming a curved bore within a material comprising:

(a) cutting means;

(b) housing means;

(c) bore forming means mounted for reciprocation along a rectilinear path within said housing means, said bore forming means having a distal flexible end section with said cutting means associated therewith;

(d) a generally arcuate curved guide means pivotally mounted within said housing means adjacent to said flexible end section for movement along a predetermined arcuate path generally tangential to said rectilinear path of said bore forming means, said guide means being in retaining engagement with said flexible end section to guide said cutting means and said flexible end section along said predetermined arcuate path as said bore forming means is advanced through said material.

Claim 17. An apparatus for drilling a curved bore within a material comprising:

(a) housing means;

(b) cutting means;

(c) rotary drill shaft means mounted for reciprocation along a rectilinear path within said housing means, said rotary drill shaft means having a distal flexible end section whereupon said cutting means are attached;

(d) a curved guide means pivotally mounted within said housing means adjacent to said cutting means for movement along a predetermined curved path, said predetermined curved path being generally tangential to said rectilinear path of said flexible end section, said guide means being in retaining engagement with said flexible end section to guide said cutting means from said rectilinear path through said predetermined curved path as said rotary drill shaft means is advanced through said material.

Claim 18. A method for forming a curved bore within a material comprising the steps of:

(a) directing a bore forming means having a flexible distal end section with cutting means associated therewith through a rectilinear approach path at a given angle of approach to a surface to be bored;

(b) maintaining a portion of said bore forming means within said rectilinear path; and

(c) simultaneously guiding said flexible distal end section and said cutting means through a curved path, said cutting means forming a curved bore into said material, said bore forming device being capable of being advanced and retracted to form said curved bore without requiring an alteration of said angle of approach.

Claim 19. The method of Claim 18, further comprising the steps of:

(a) simultaneously directing a second bore forming device having a flexible distal end section with cutting means associated therewith along a second rectilinear approach path which is generally parallel to said first rectilinear approach path; and

(b) guiding said the flexible distal end sections in a common plane until said cutting means approach each other to form a curved bore.

Claim 20. An apparatus for drilling a curved bore through a material comprising:

(a) a rotary drive means;

(b) cutting means;

(c) drill shaft means having one end thereof adapted for connection to said rotary drive means, said drill shaft means having a distal flexible end section with said cutting means attached thereon;

(d) mounting means for directing said drill shaft means along an approach path within said mounting means relative to a surface of said material; and

(e) guide means carried by said mounting means to guide said flexible end section and said cutting means from said approach path along a curved path upon entry into said material, said drill shaft means being moved along said approach path with respect to said mounting means.

Claim 21. A method for forming a curved bore within a material, comprising the steps of:

(a) directing a bore forming means having a flexible distal end section with cutting means associated therewith through an approach path relative to a surface to be bored:

(b) maintaining a portion of said bore forming means along said approach path; and

(c) simultaneously guiding said flexible distal end section and said cutting means through a curved path, said cutting means forming a curved bore into said material, said bore forming device being capable of being advanced and retracted to form said curved bore without requiring an alteration of said orientation of said approach path.

Claim 22. An apparatus for drilling a curved bore within a material comprising:

(a) rotary drive means;

(b) cutting tip means;

(c) drill shaft housing means;

(d) drill shaft means adapted for connection at one end thereof to said rotary drive means, said drill shaft means having a distal flexible end section, said cutting tip means being attached to said flexible end section;

(e) means mounting said flexible end section of said drill shaft means within said drill shaft housing means for reciprocal movement therein;

(f) curved guide means located within said drill shaft housing means adjacent to said flexible end section;

(g) means pivotally mounting said curved guide means within said drill shaft housing means for rotation along a curved path;

(h) drive means for rotating said curved guide means; and

(i) engaging means acting between said curved guide means and said flexible end section;

(j) whereby rotation of said curved guide means advances said flexible end section and said cutting tip means along said curved path to form said curved bore.

Claim 23. The apparatus of Claim 2, wherein:

said means acting between said curved guide means and said flexible end section comprises engaging means to advance said flexible end section toward said material upon rotation of said curved guide means;

whereby said flexible end section is pulled and guided through said curved path within said curved bore upon pivotal movement of said curved guide means.

Claim 24. The apparatus of Claim 2, further comprising:

(a) means mounted in said housing means for rotating said curved guide means along said curved path about said pivotal mounting means;

(b) slidable connecting means located within said drill shaft means for permitting reciprocal movement of at least said flexible end section within said housing means during rotation thereof, said means acting between said curved guide means and said flexible end section comprising engaging means for advancing said flexible end section into said material as said curved guide means is rotated in one direction; and

(c) spring biased return means within said slidable connecting means for returning said flexible end section and said cutting tip means to retracted position upon reverse rotation of said curved guide means.

Claim 25. The apparatus of Claim 23, further comprising:

(a) a hand held drive unit connected to said housing means, said hand held drive unit being adapted to mount rotary drive means thereto for rotation of said drill shaft means,

(b) wherein said means for rotating said curved guide means comprises drive gear means mounted within said hand held unit drive unit, said drive gear means being activated by a trigger, said drive shaft means being drivingly connected to said drive gear means for rotating said curved guide means;

(c) means to connect said drive shaft means to said drive gear means, said drive gear means being depressible in one direction to rotate said curved guide means within said curved bore; and

(d) spring return means for returning said trigger to activate said gear means to drive said curved guide means in an opposite direction.

Claim 26. The apparatus of Claim 25, wherein said curved guide means comprises:

(a) a curved channel member having one side thereof open for reception of said flexible end section as said flexible end section advances;

(b) said curved channel member having a predetermined curvature of said curved bore; and

(c) said engaging means having a collar surrounding said flexible end section adjacent said cutting tip to retain said flexible end section within said curved channel member and to push said cutting tip means through said curved path to form said curved bore.

Claim 27. The apparatus of Claim 24, further comprising:

(a) first and second drill shaft means; and

(b) first and second curved guide means, said first and said second curved guide means being generally arcuate, said means pivotally mounting said first and said second curved guide means within said housing for pivotal movement of said curved guide means within a substantially common plane to enable corresponding flexible end sections and said cutting tip means to travel along said curved path to form said curved bore.

Claim 28. The apparatus of Claim 24, wherein said curved guide means is generally arcuate, and

wherein said means for rotating said curved guide means is adapted to rotate said curved guide means to form said curved bore within said material.

Claim 29. The apparatus of Claim 25, wherein said curved guide means is generally arcuate, and

wherein said means for rotating said curved guide means is adapted to rotate said curved guide means to form said curved bore within said material.

Claim 30. The apparatus of Claim 29, wherein said curved guide means comprises a radius arm connected at one end thereof to one end of said curved guide means and having another end thereof pivoted to one side of said housing means,

slot means in one side of said housing means adjacent to said means for pivotally mounting said radius arm,

said radius arm extending substantially a full width of said housing means and movable through approximately 180° between a first position extending through said slot means and outside said housing means and a second position normal to a longitudinal arm of said housing means within said housing means,

whereby rotation of said radius arm from said first position to said second position rotates said curved guide means through approximately 180° to form said curved bore.

Claim 31. The apparatus of Claim 30, further comprising:

an anchor sleeve surrounding said housing means, said radius arm, and said curved guide means when in said first position; and

means for temporarily pinning said anchor sleeve to said surface of said material in a desired location,

whereby lateral displacement of said drill shaft housing means may be prevented during a drilling operation.

Claim 32. The apparatus of Claim 30, further comprising:

an anchor sleeve surrounding said housing means, and

means for temporarily pinning said anchor sleeve to said surface of said material to be drilled in a desired location,

said anchor sleeve having vertical slot means in register with a slot in said housing means, said slot in said anchor sleeve being at least twice a length of said radius arm, whereby said anchor sleeve may be affixed to said surface to be drilled, said housing means being inserted therein with said radius arm located between said first position and said second position, said arm rotating toward said first position through said slot and said housing means then being seated upon said surface of said material to be drilled.

Claim 33. The apparatus of Claim 1, wherein said drill shaft means is mounted for reciprocating movement within said mounting means and relative thereto,

said guide means being carried by said mounting means for movement relative thereto for guiding said flexible end section and said cutting means from said rectilinear path along said curved path.

Claim 34. The apparatus of Claim 20, wherein said guide means is carried by said mounting means for movement relative thereto for guiding said flexible end section and said cutting means from said approach path through said curved path.

Claim 35. A method for forming a curved bore with a drilling apparatus having a drill shaft means mounted therein with one end thereof adapted for connection to rotary drive means, said drill shaft means having a distal flexible end section with cutting means thereon, said method comprising the steps of:

(a) directing said drill shaft means along an approach path within said drilling apparatus, said approach path and drilling apparatus having a specific orientation relative to a surface to be drilled, and

(b) guiding said flexible end section and said cutting means from said approach path along a curved path,

(c) whereby said drill shaft means may be advanced and retracted to form said curved bore without altering said orientation of said drilling apparatus and said approach path.

Claim 36. An apparatus for drilling a curved bore within a material, comprising:

(a) rotary drive means;

(b) cutting means;

(c) drill shaft means having one end adapted for connection to said rotary drive means, said drill shaft means having a distal flexible end section with said cutting means attached thereto;

(d) mounting means for directing said drill shaft means along a rectilinear path which is substantially normal to a surface of said material, and

(e) guide means carried by said mounting means to guide said flexible end section and said cutting means from said rectilinear path along said curved path upon entry into the surface of the material to be drilled, said mounting means maintaining the remainder of the drill shaft in the rectilinear path throughout the drilling operation.

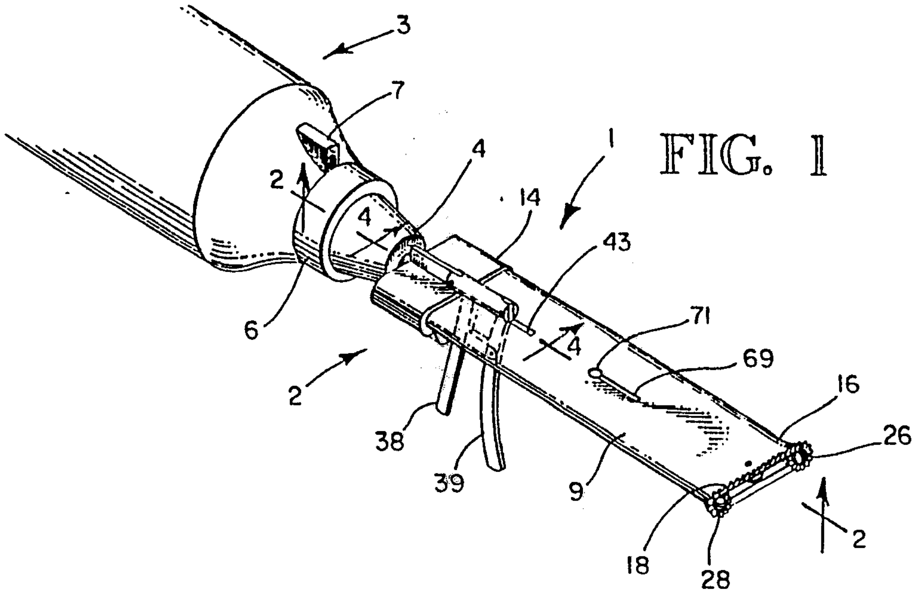


FIG. 1

FIG. 2

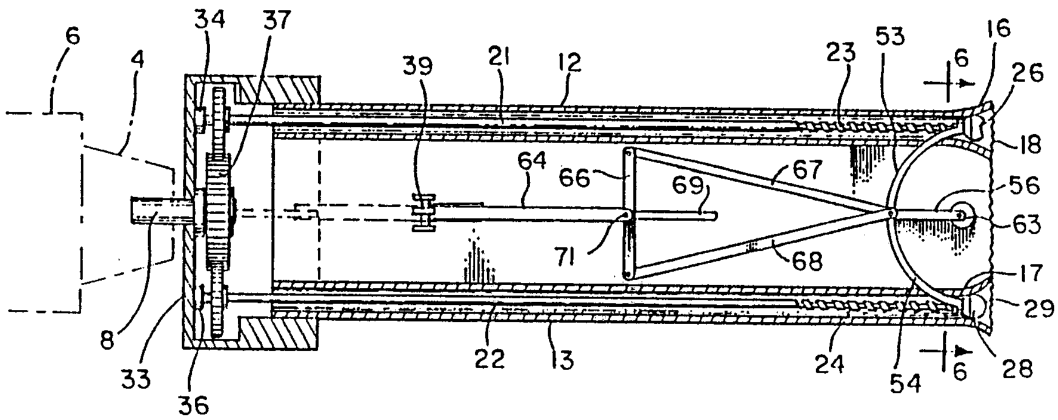
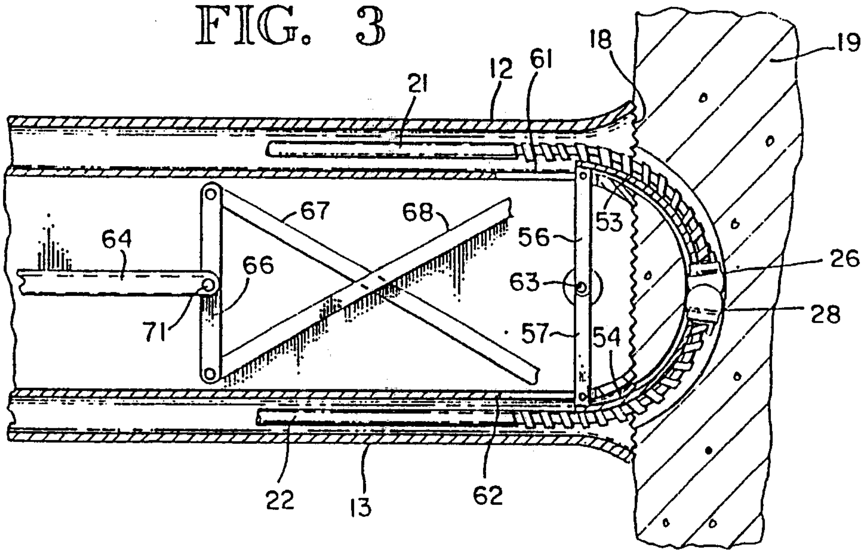


FIG. 3



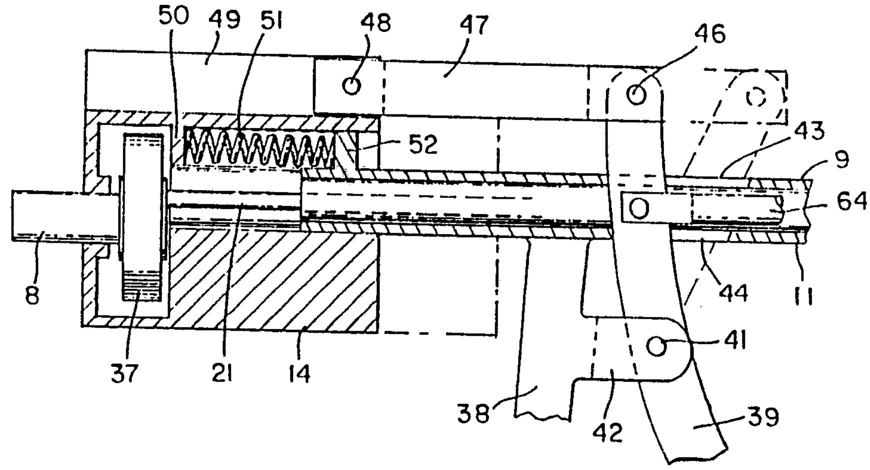


FIG. 4

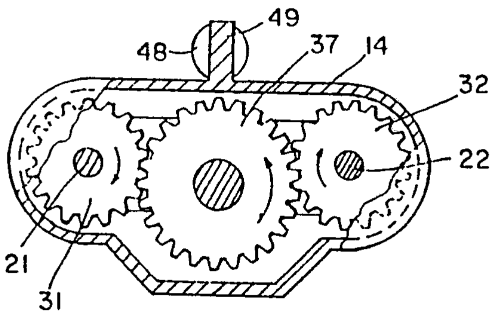


FIG. 5

FIG. 6

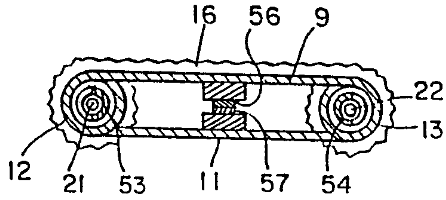


FIG. 7

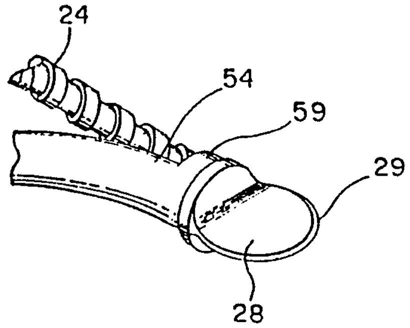
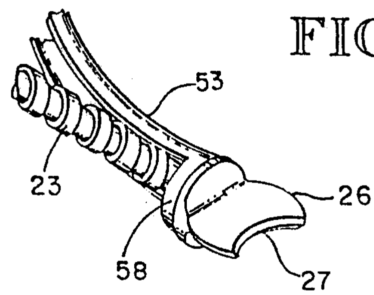


FIG. 8



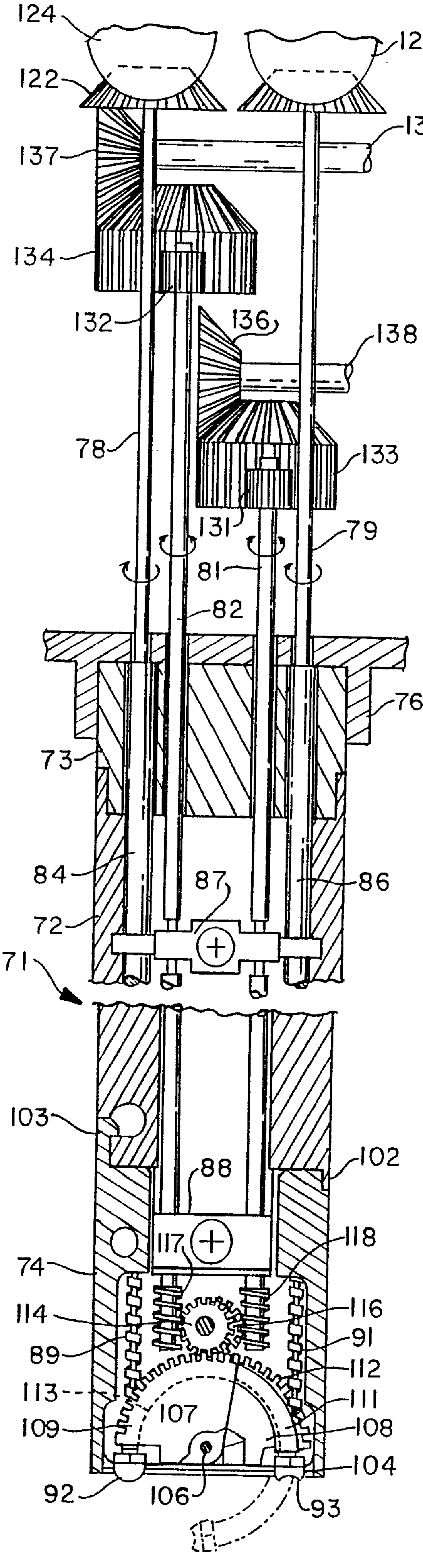

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FIG. 9

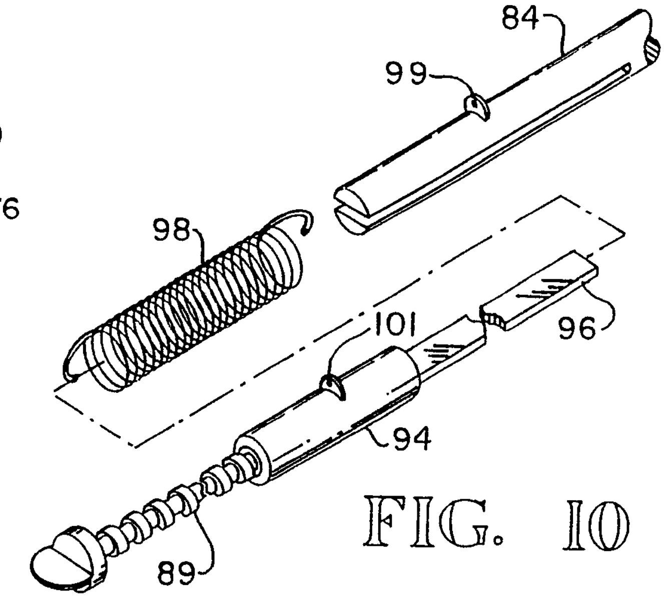
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FIG. 10

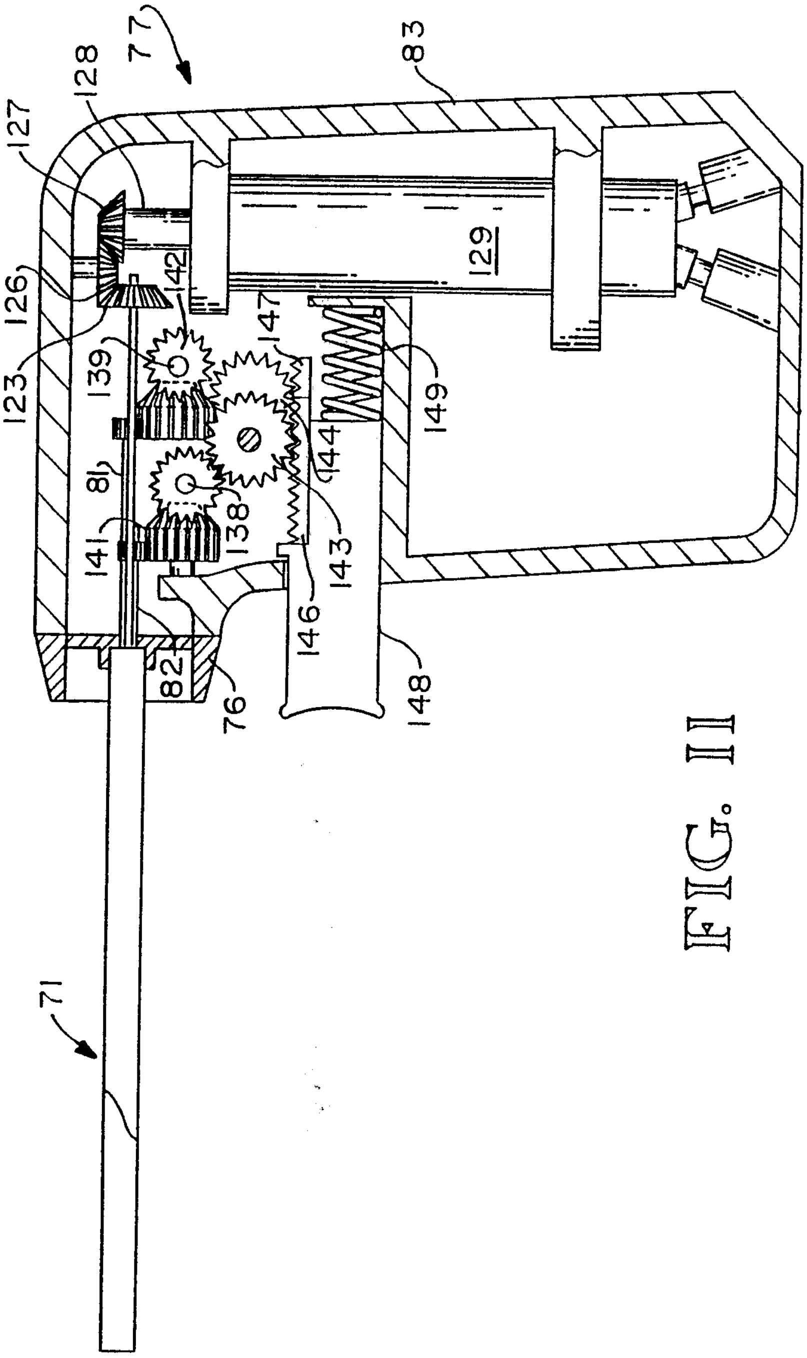
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FIG. 11

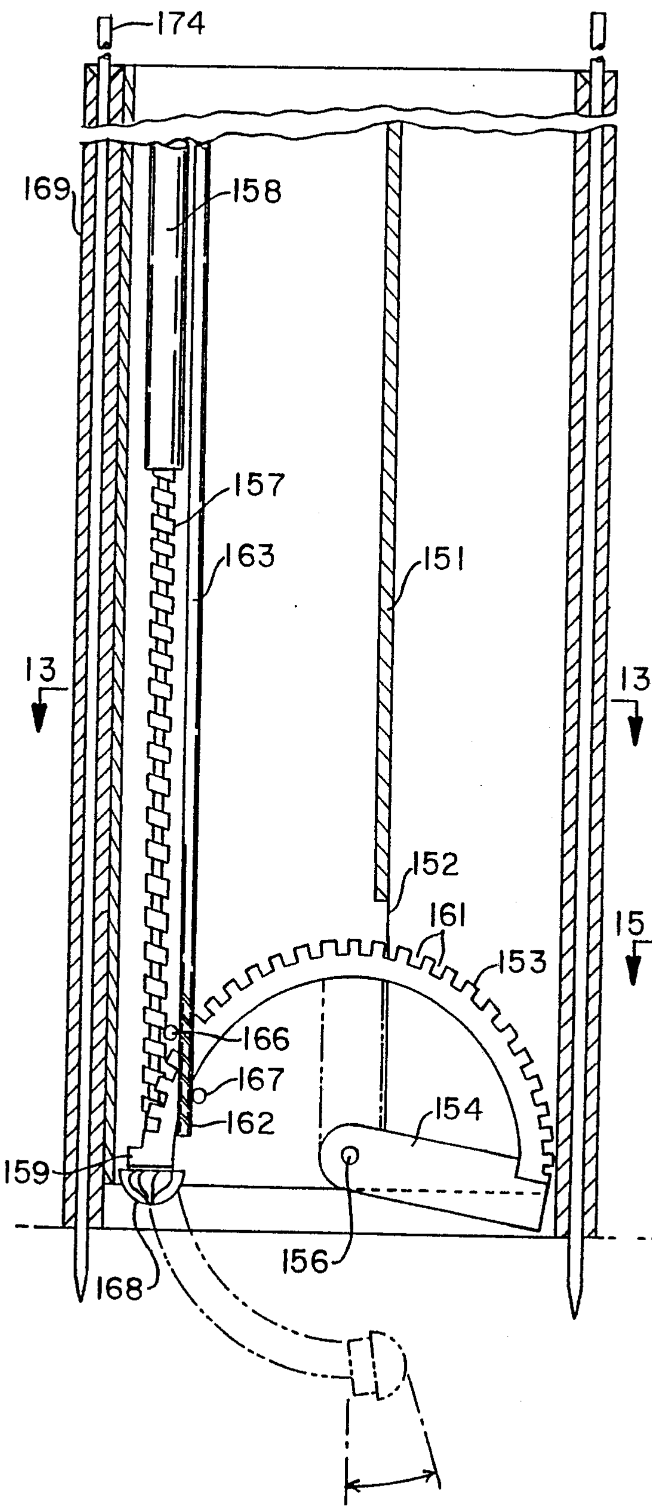
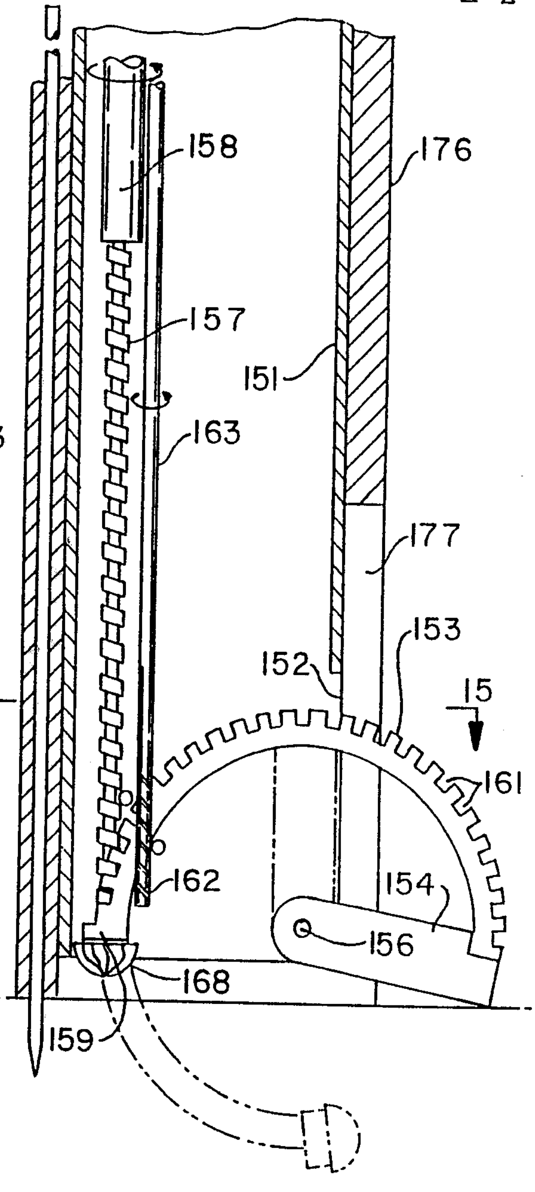


FIG. 12

FIG. 14



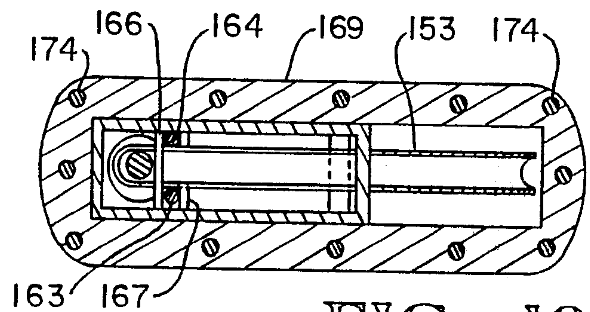
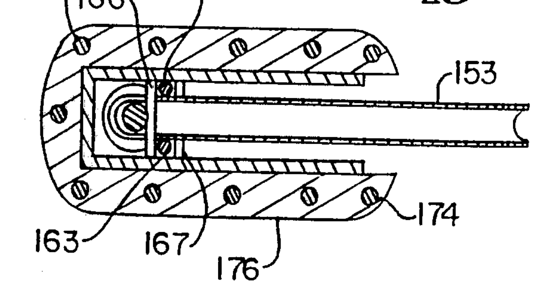


FIG. 13

FIG. 15



INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/00771

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5) A61B 17/16

U.S.CL. 606/80,408/127

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
	606/79,80,82,83,84,170,171,176,177,178,179,180 408/127,146,187

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X Y	US, A, 4,751,922 (DIPIETROPOLO) 21 June 1988 See the entire document.	1 1-36
X Y	US, A, 4,541,423 (BARBER) 17 September 1985 See the entire document.	1 1-36
X Y	US, A, 3,640,280 (SLANKER) 08 February 1972 See the entire document.	1 1-36
X	US, A, 4,589,414 (YOSHIDA) 20 May 1986 See the entire document.	1
X	US, A, 3,554,192 (ISBERNER) 12 January 1971 See the entire document.	1
Y	US, A, 2,455,655 (CARROLL) 07 December 1948 See the entire document.	1-3
X Y	US, A, 4,895,146 (DRAENERT) 23 January 1990 See the entire document.	1 1-36
X Y	US, A, 4,586,497 (DAPRA) 06 May 1986 See the entire document.	1 1-36

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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)

"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

"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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"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.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
26 JULY 1990	05 FEB 1991
International Searching Authority	**Signature of Authorized Officer**
ISA/US	MICHAEL A. BROWN

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ **OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE** [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

3. ☐ Claim numbers ________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ **OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING** [2]

This International Searching Authority found multiple inventions in this international application as follows:

I. Claims 1-12,15-17,20,22-34 and 36 drawn to an apparatus for drilling a curved bore.

II. Claims 13-14,18-19,21 and 35 drawn to a method for forming a curved bore within a material.

1. ☒ As all required additional search fees ~~were timely paid~~ will be paid by check by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.