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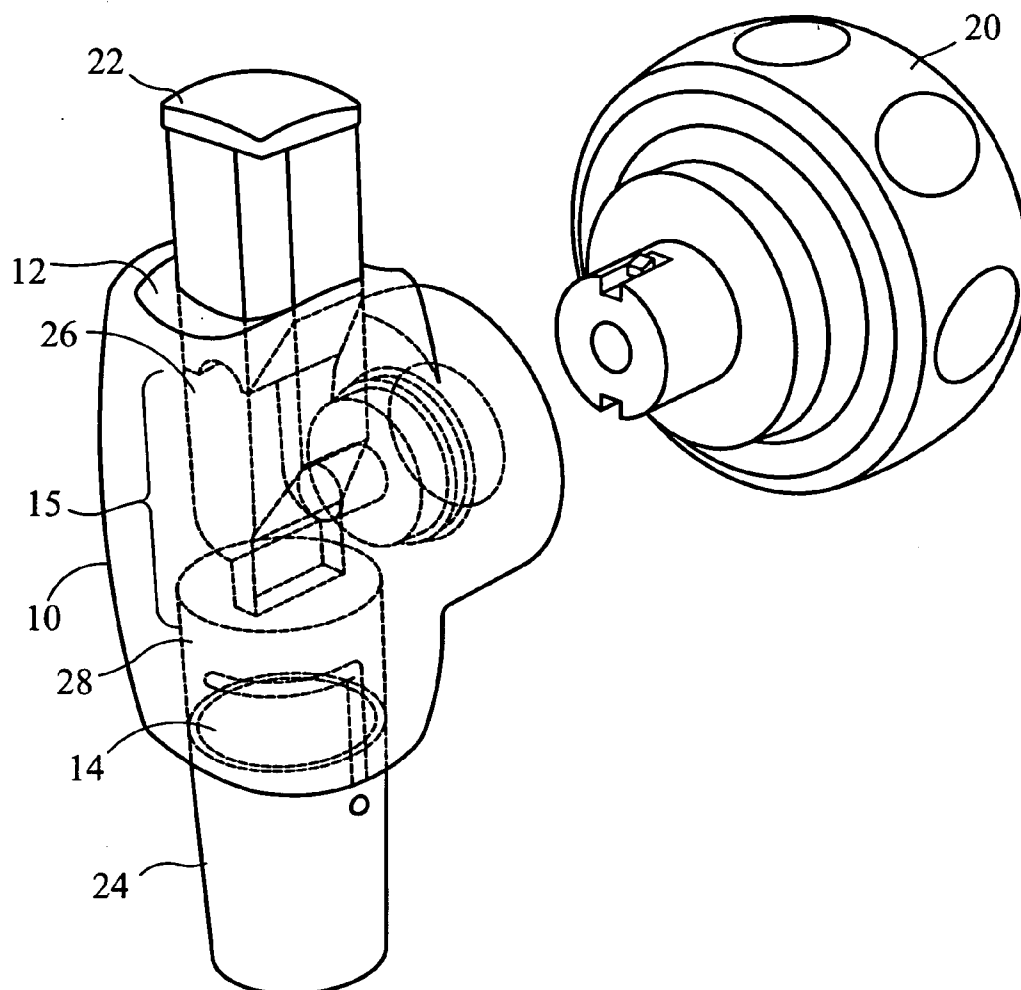
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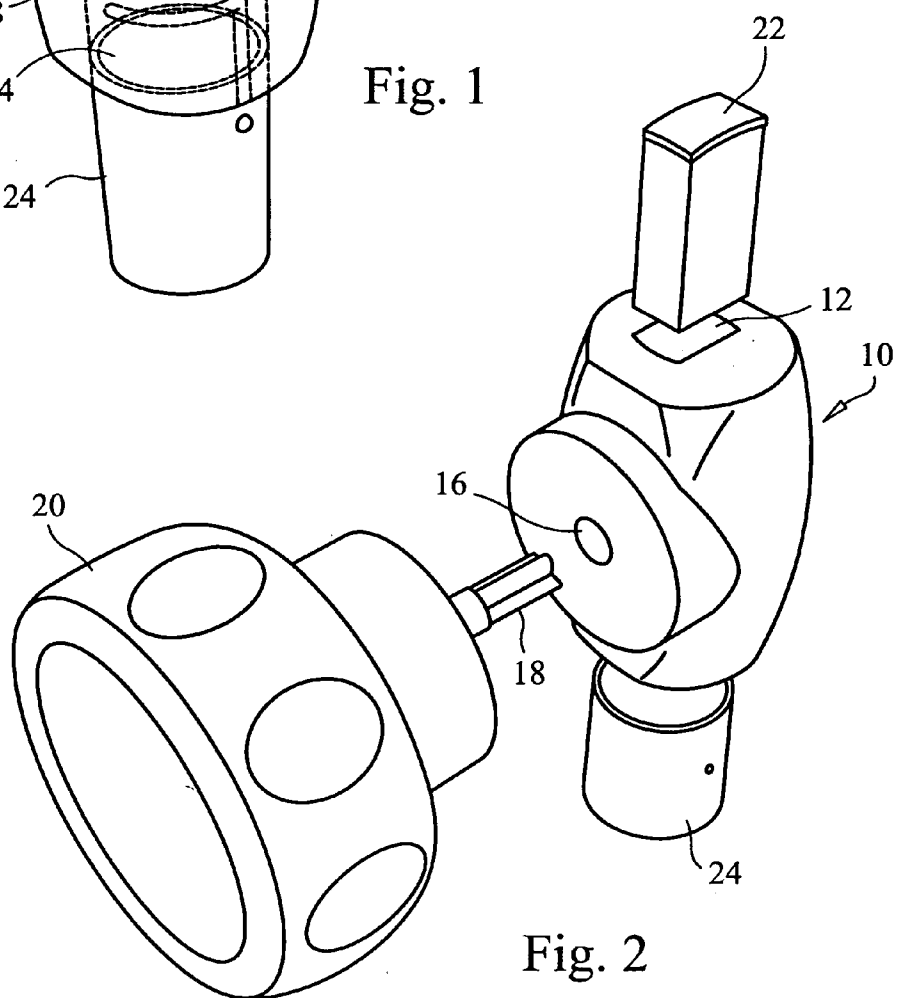
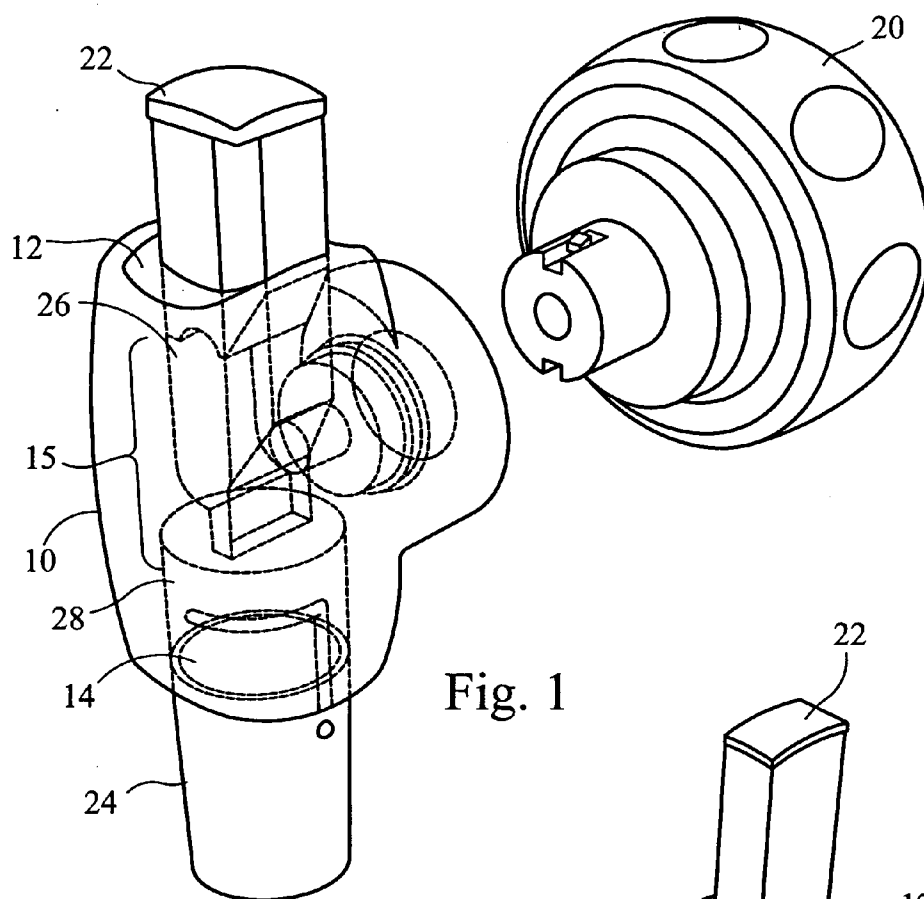
(21) Appl. No.: **11/364,421**(22) Filed: **Feb. 28, 2006****Related U.S. Application Data**

(63) Continuation-in-part of application No. 11/051,882, filed on Feb. 4, 2005.

(57) **ABSTRACT**

An apparatus for bone milling includes a housing defining a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening. The linear passage has a first surface with third opening there through and a second surface transverse to the first surface. A rotatable cutting member is insertable through the third opening to partially block the linear passage. The rotatable cutting member is positioned at a distance from the second surface of the linear passage corresponding to a predetermined bone chip size.





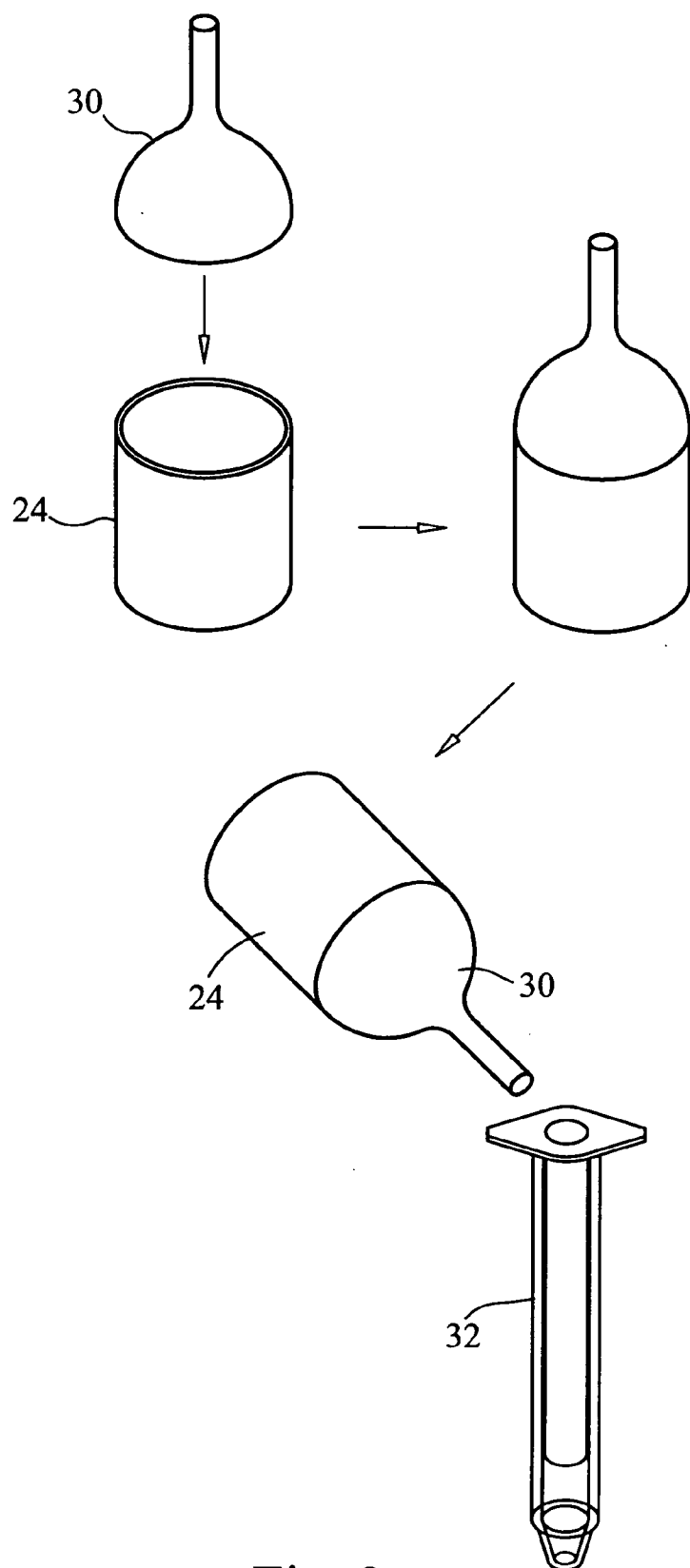


Fig. 3

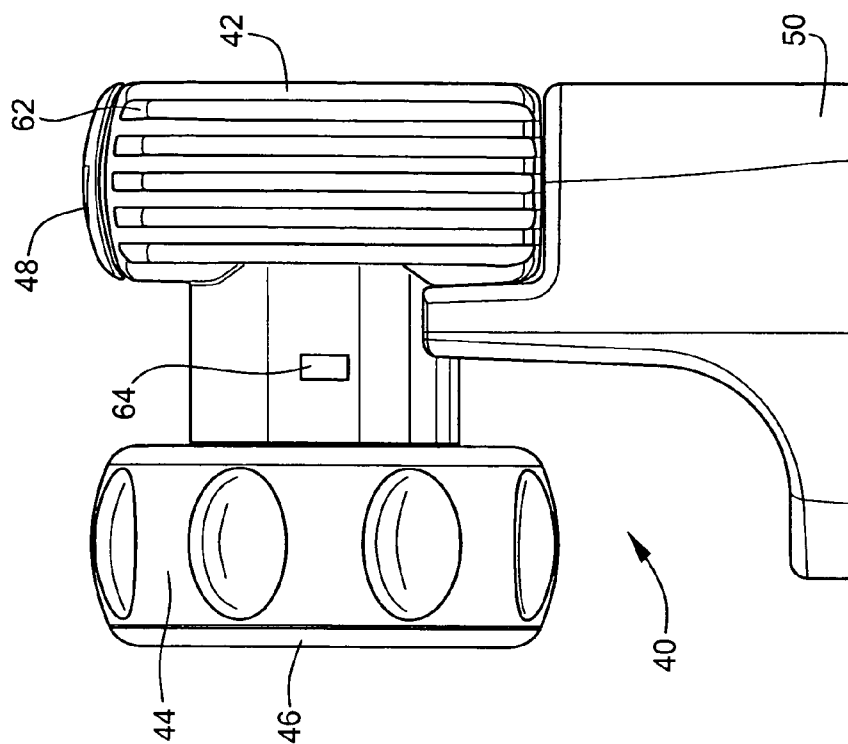


FIG. 5

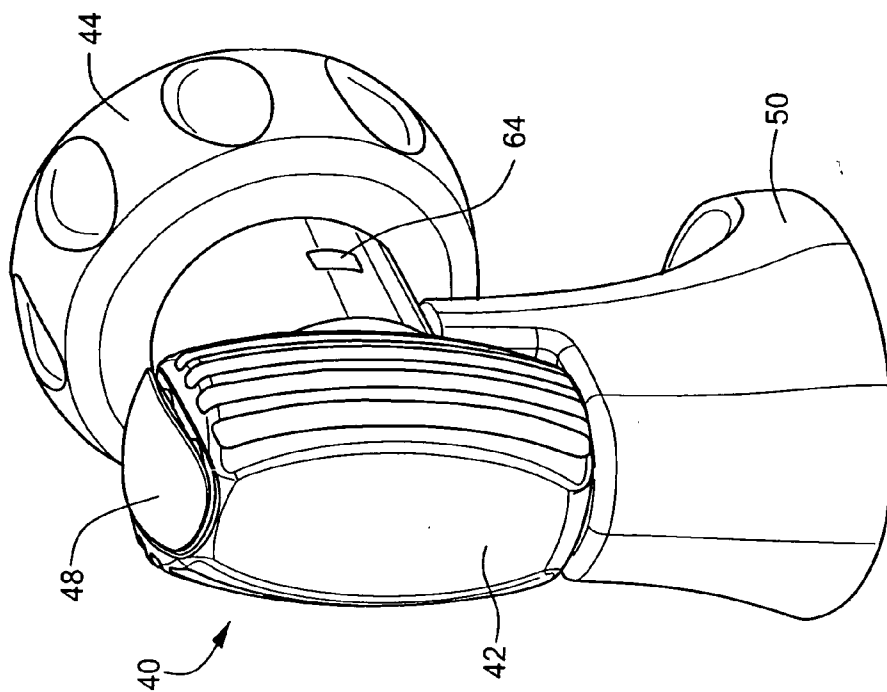


FIG. 4

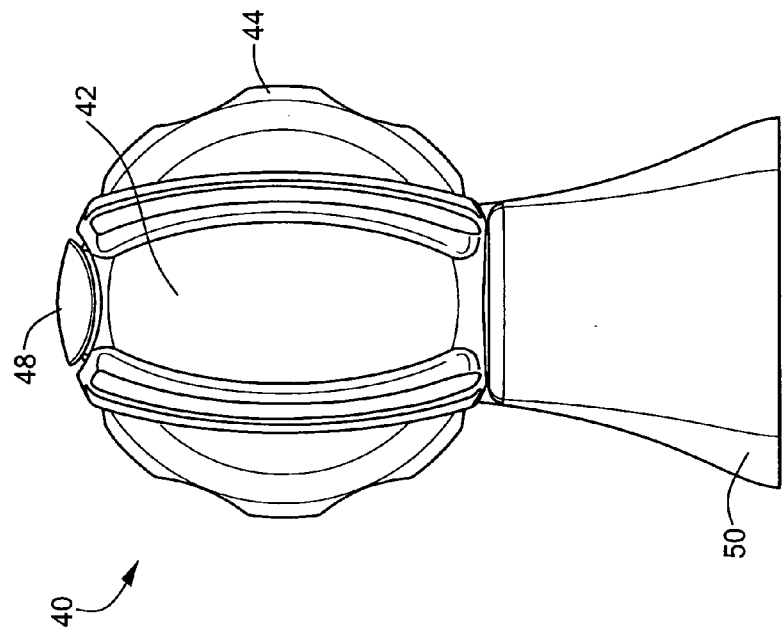


FIG. 6

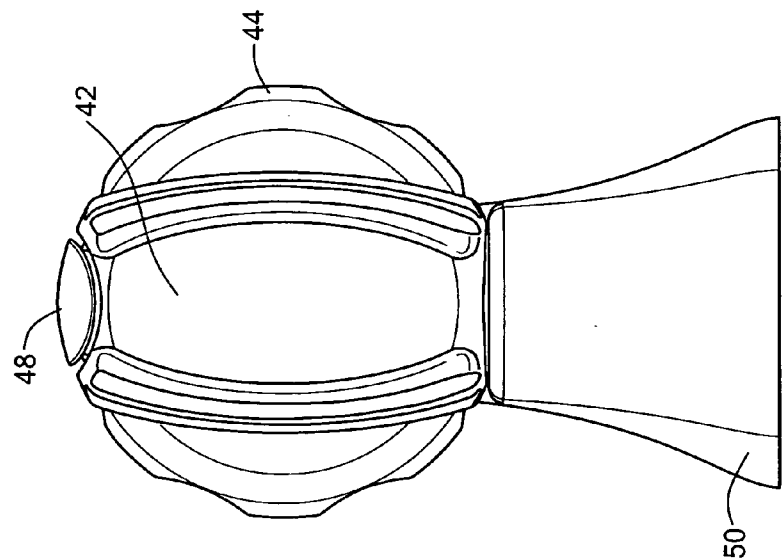


FIG. 7

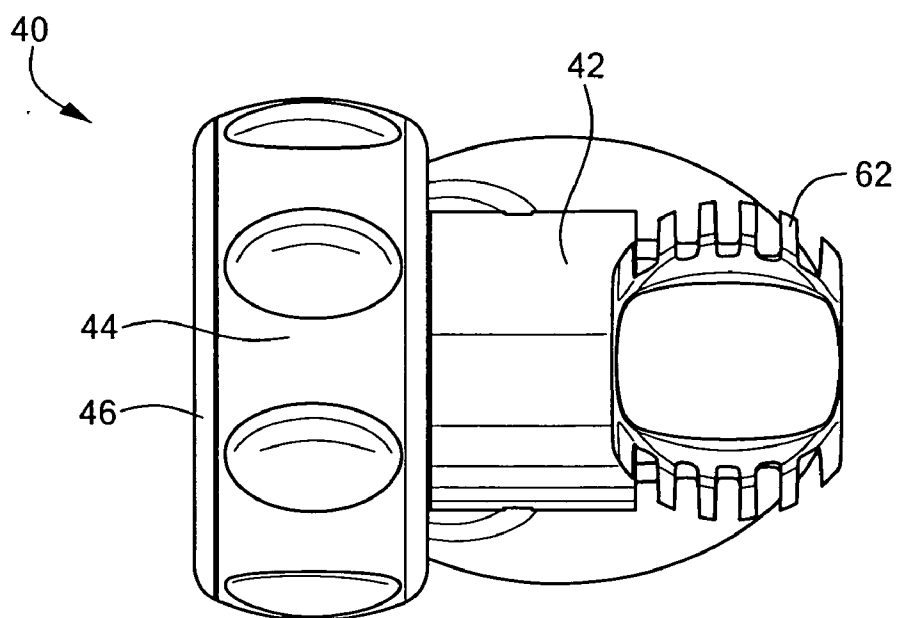


FIG. 8

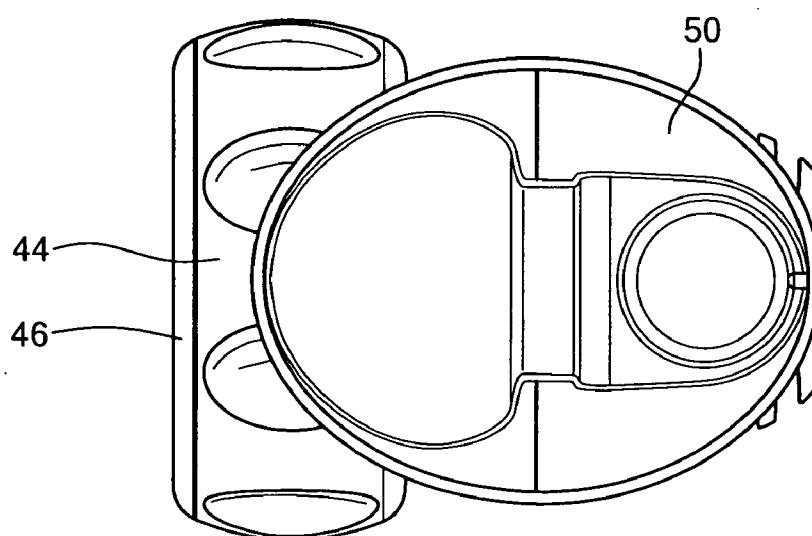


FIG. 9

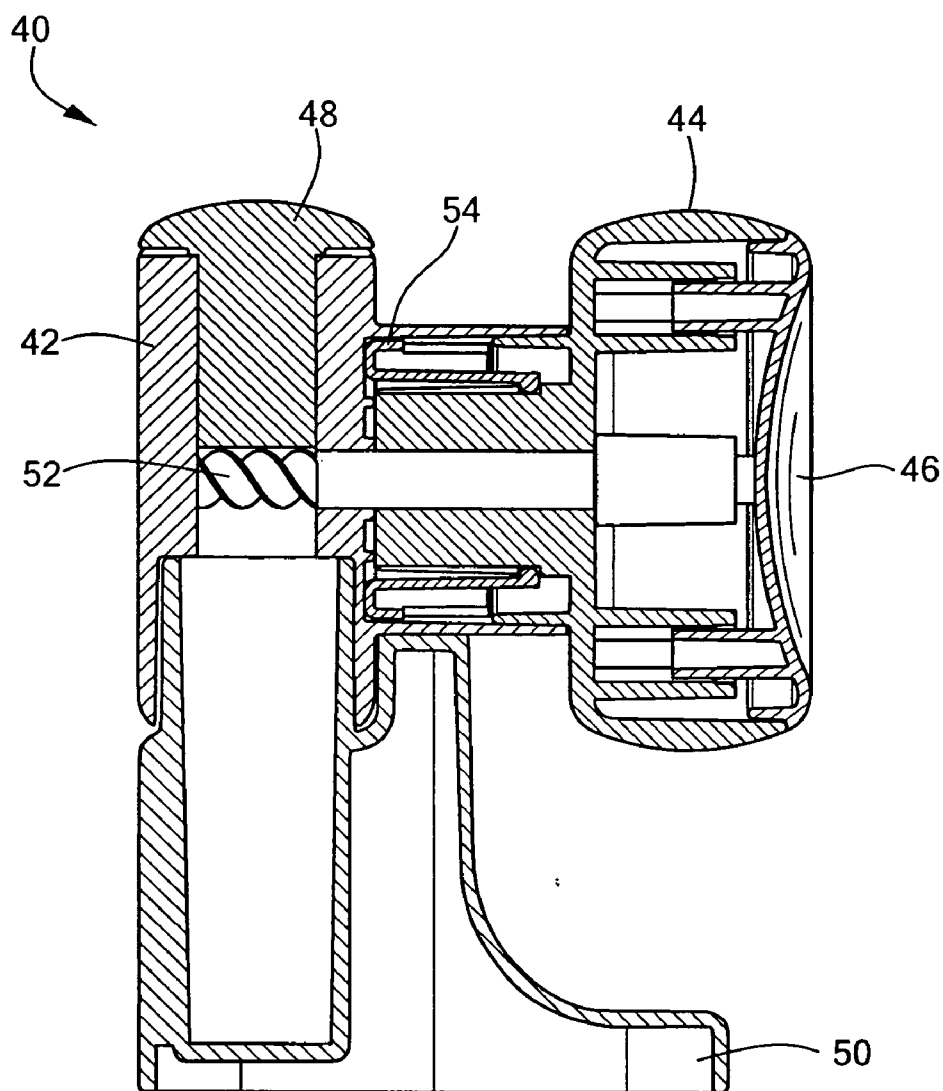


FIG. 10

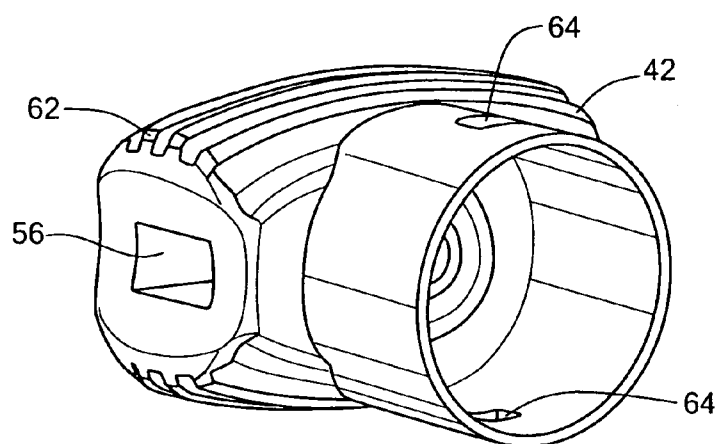


FIG. 11

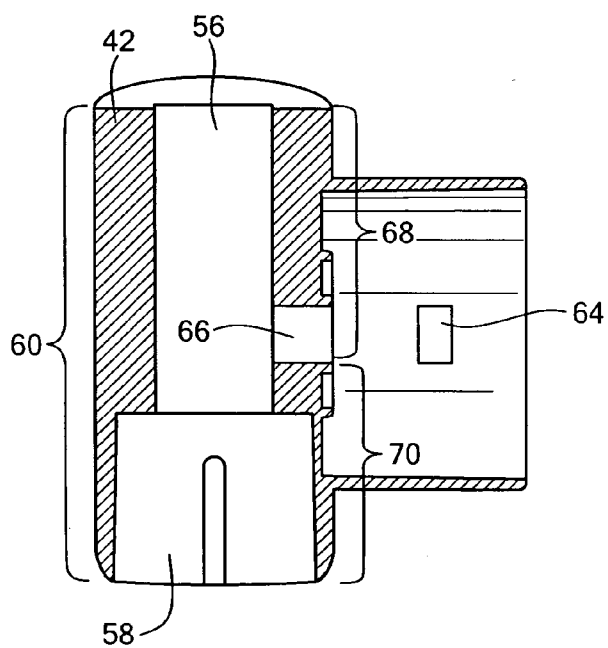


FIG. 13

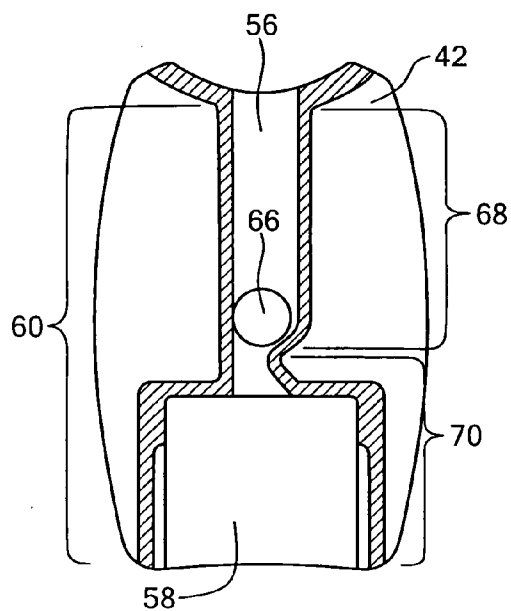


FIG. 12

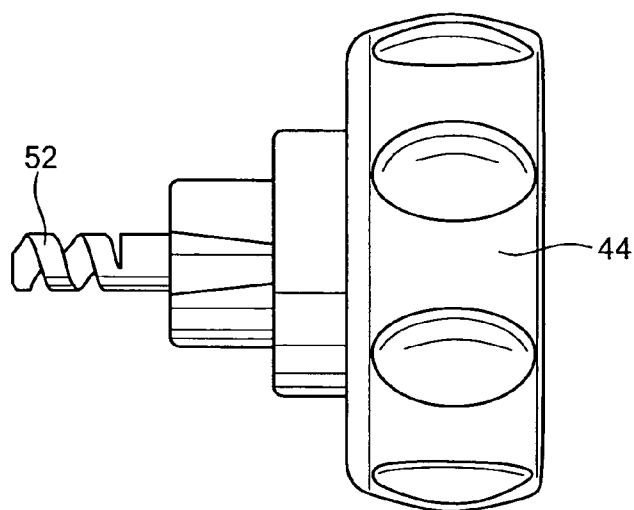


FIG. 14

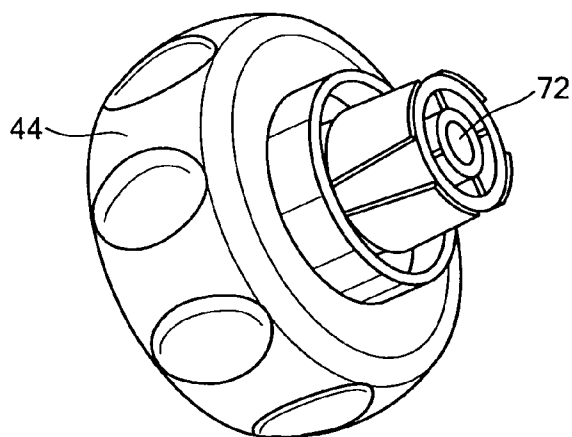


FIG. 15

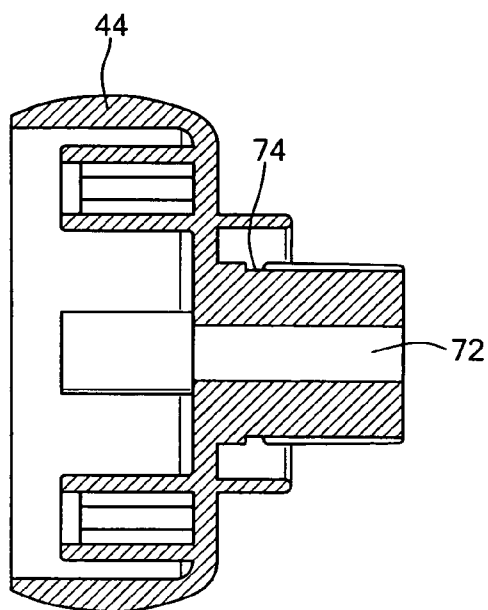


FIG. 16

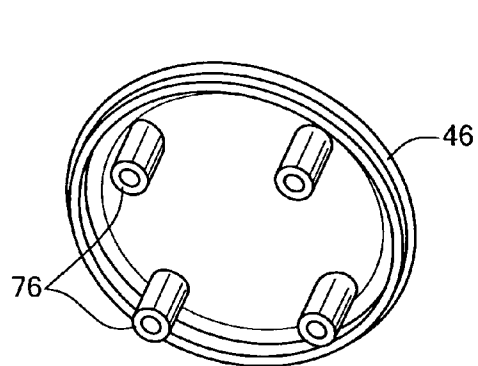


FIG. 17

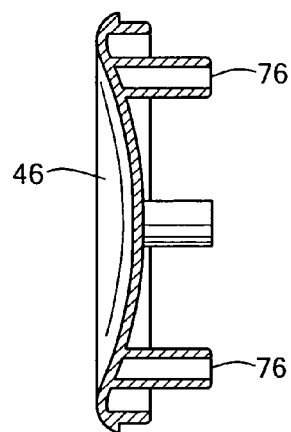


FIG. 18

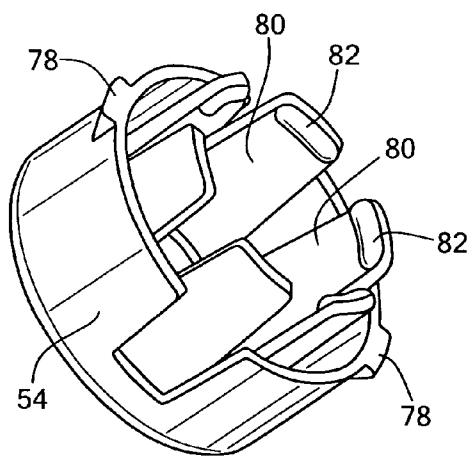


FIG. 19

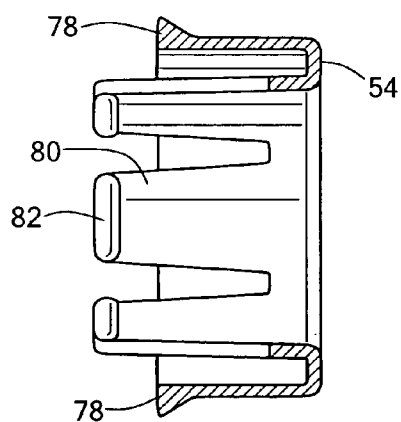


FIG. 20

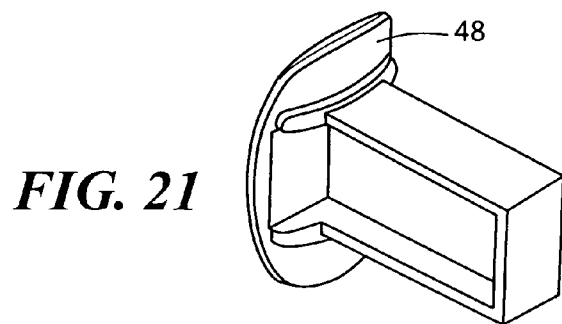


FIG. 21

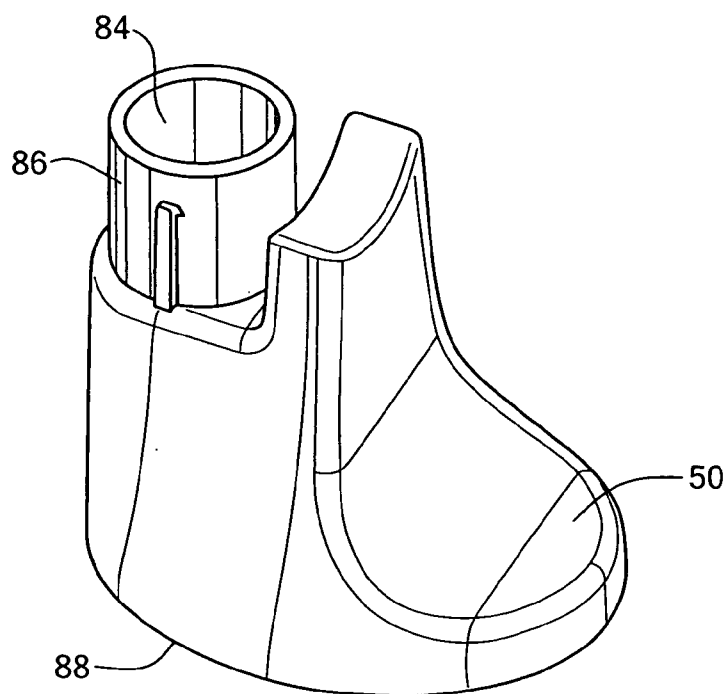


FIG. 22

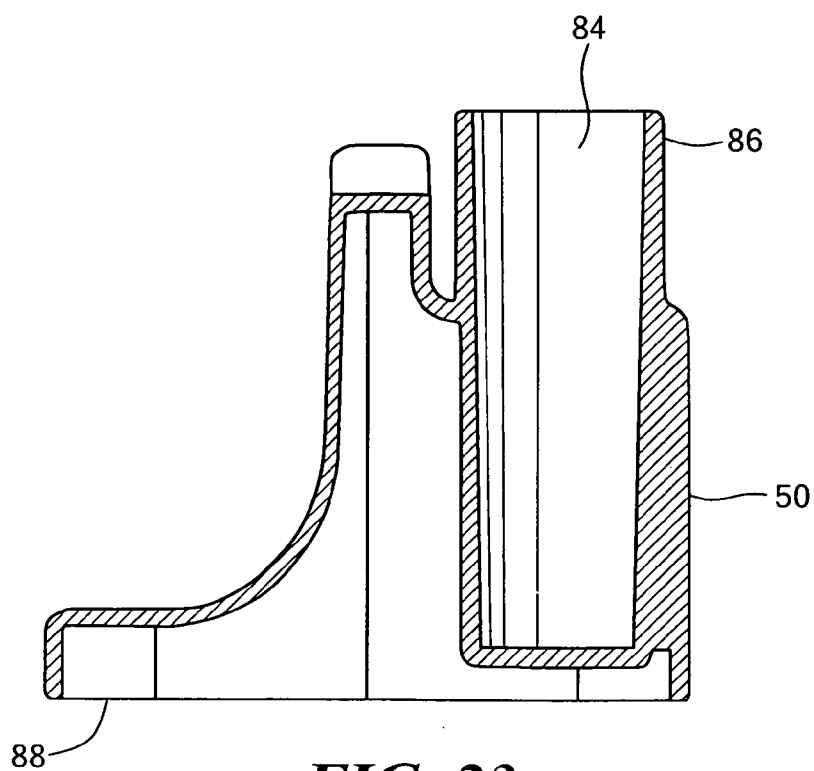


FIG. 23

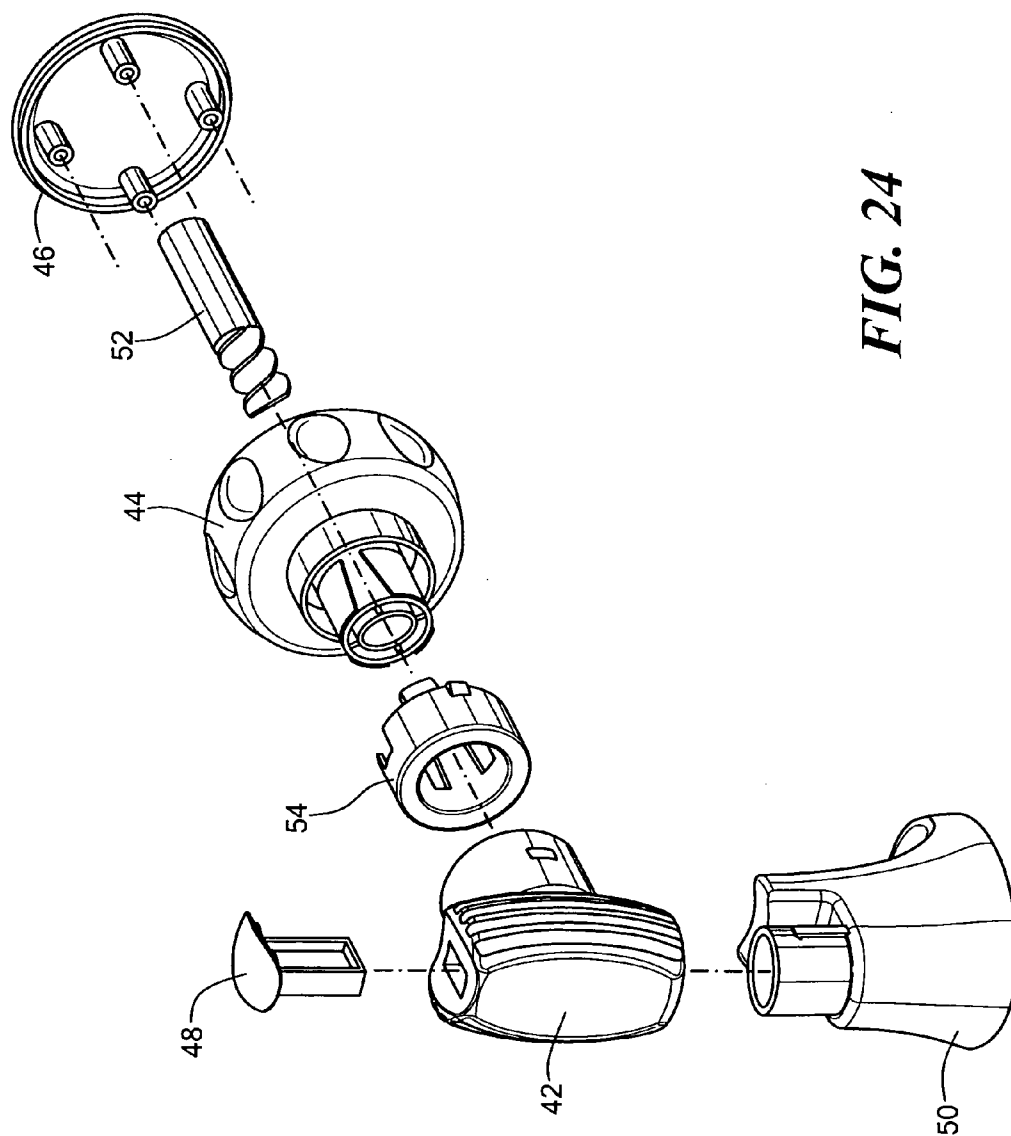


FIG. 24

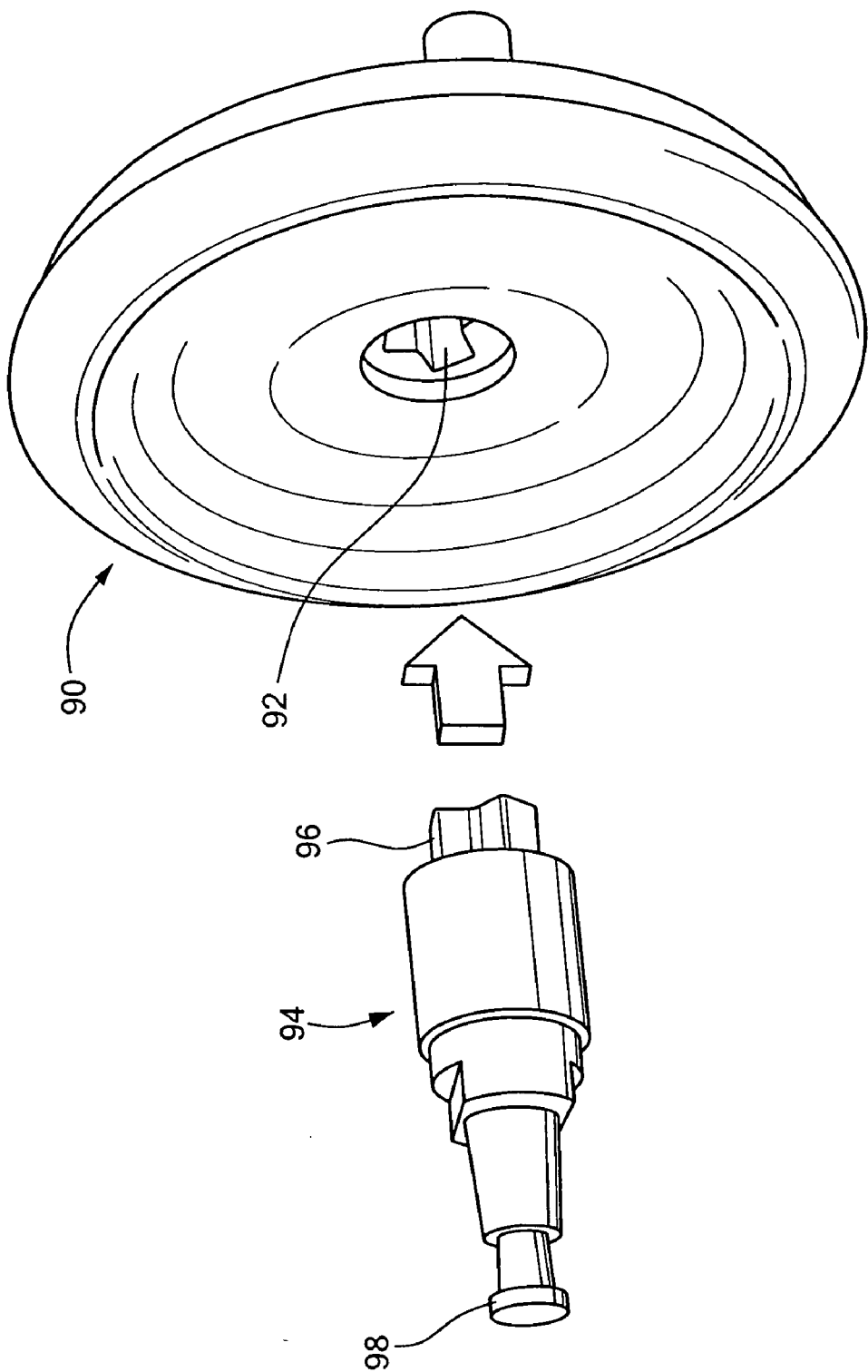


FIG. 25

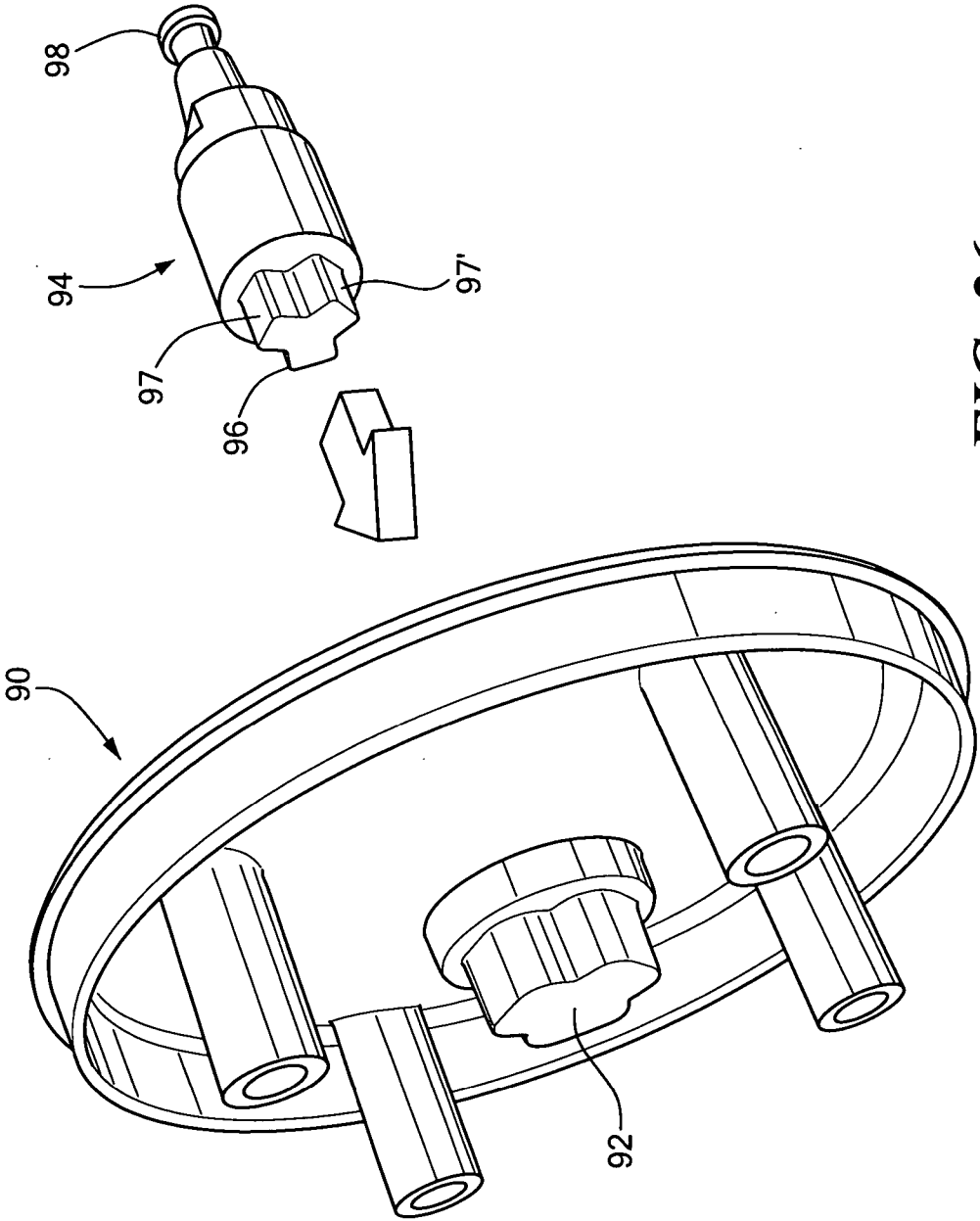


FIG. 26

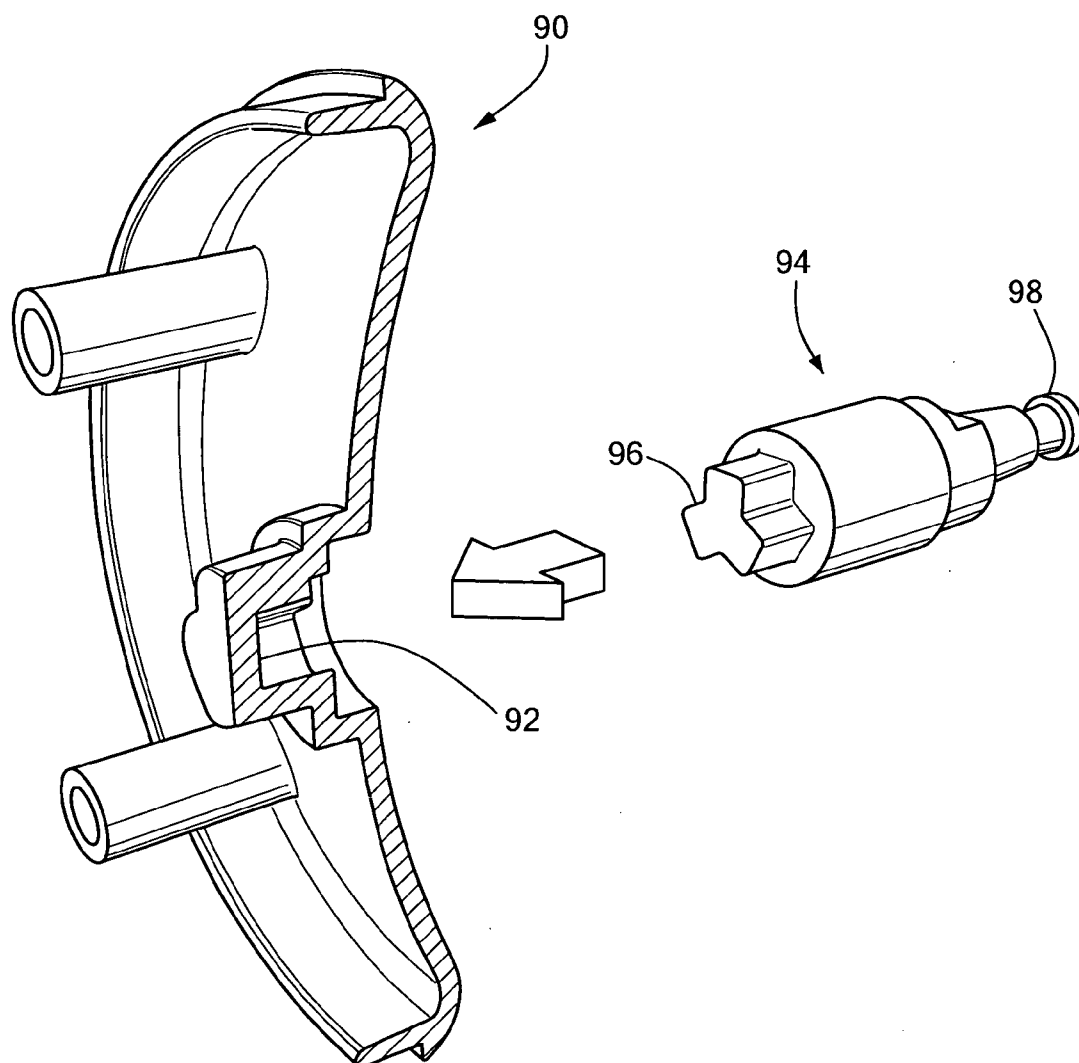


FIG. 27

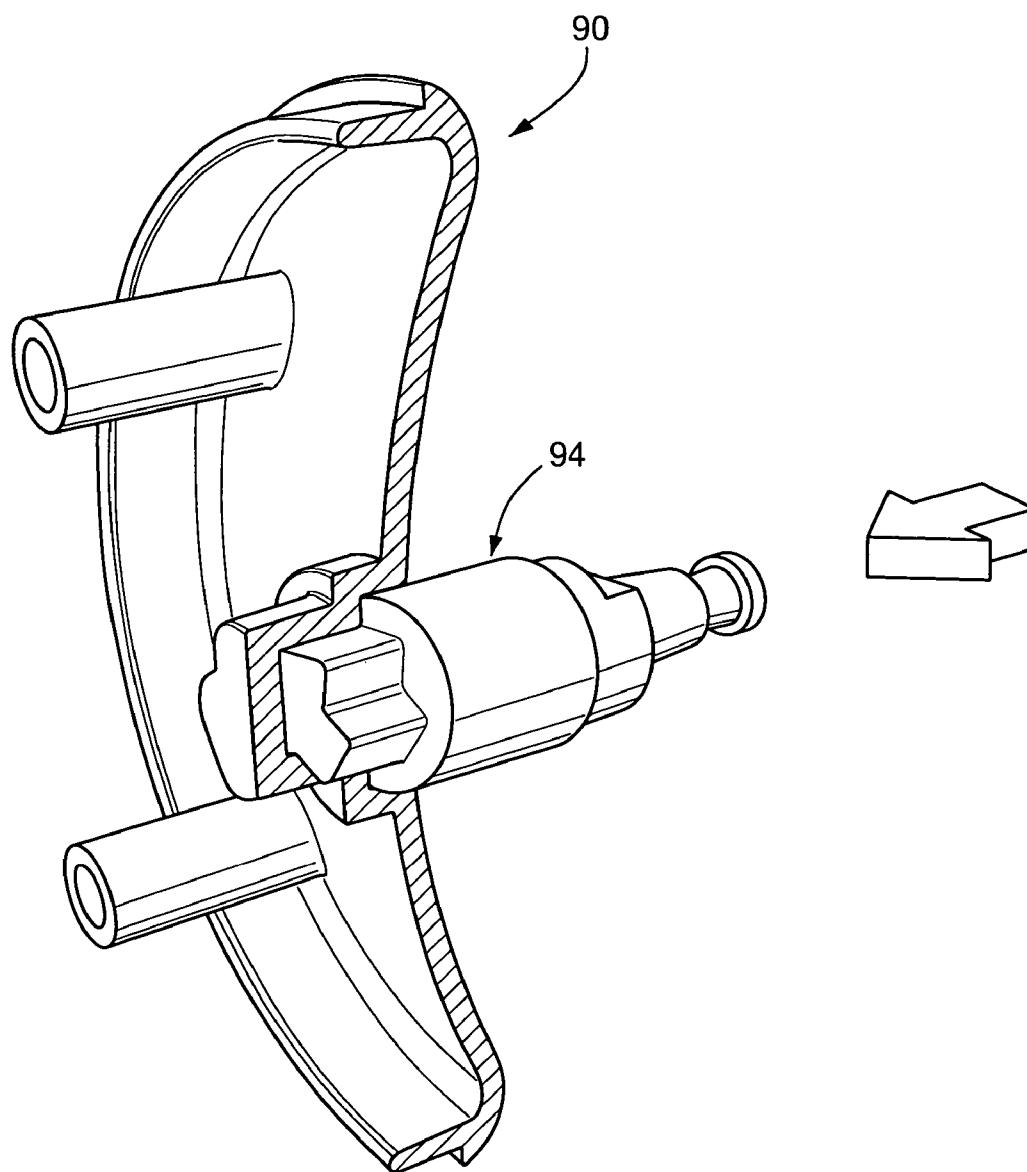


FIG. 28

POWER DRIVEN BONE CRUSHER AND METHOD FOR BONE CRUSHING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a Continuation-in-Part of and claims priority to U.S. Continuation-in-Part Patent Application Ser. No. 11/051,882, filed Feb. 4, 2005, entitled BONE CRUSHER AND METHOD FOR BONE CRUSHING, which Application claims priority from U.S. Utility Patent Application Ser. No. 10/961,573, filed Oct. 08, 2004, entitled BONE CRUSHER AND METHOD FOR BONE CRUSHING, which application is related to and claims priority to U.S. Provisional Patent Application Ser. No. 60/542,209, filed Feb. 05, 2004, entitled BONE CRUSHER AND METHOD THEREFORE, the entirety of all which are incorporated herein by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] n/a

FIELD OF THE INVENTION

[0003] The present invention relates to an orthopedic medical device and method, in particular to a method and device for bone cutting for use during orthopedic surgery.

BACKGROUND OF THE INVENTION

[0004] Orthopedic surgery often requires the infusion of a slurry comprised of blood and crushed bone into a surgical site to promote healing and recovery after an injury. The crushed bone in the slurry is ground and pulverized from a larger bone specimen using a bone grinder that reduces the larger specimen into crushed bone particles. Bone mills allow patients to have their own bone particles implanted when there is a preference towards using an autograft to alleviate the possibility of rejection or infection at the surgical site. The surgeon can utilize the bone particles and the resulting slurry to repair bone defects and perform bone augmentation.

[0005] Existing bone mills are large, expensive devices which are cumbersome to use and clean and further require re-sterilization at the end of each procedure. Such re-sterilization takes the form of expensive and time consuming gas sterilization or autoclave sterilization. In the case of gas sterilization, the nature of the sterilization process makes the bone mills available for use only once in a 24-hour period. When using an autoclave sterilization process, the bone mills can be sterilized and available for reuse in less than a 24-hour period, however, the bone mills are not immediately available. The resulting period required to re-sterilize the bone mills nevertheless increases the time which necessarily passes between procedures, thereby decreasing operating room and surgical efficiency. Further, the porous nature of blades commonly found in bone mills facilitates the retention of bone particles. The blade porosity hampers the effectiveness of the cleaning process, which furthers the possibility of contamination during subsequent use of the bone mill.

[0006] Moreover, existing bone mills are typically powered devices that require an external means for driving the mill, such as a pressurized air source or an electrical motor.

Additionally, existing mills may only have the capability to produce a single size of crushed bone particles. As such, a surgical suite needs to have multiple devices to provide crushed bone at different sizes, which greatly increases the cost of having bone-milling capabilities. Otherwise, a surgeon is disadvantageously forced to use crushed bone having a size either too large or too small for a particular surgical procedure, resulting in potential difficulties during an orthopedic procedure.

[0007] It is therefore desirable to have an inexpensive bone mill which is easy to sterilize and can further be adapted to create bone chips of different sizes. It is also desirable to have a bone mill which can be manually operated without the assistance of external power sources.

SUMMARY OF THE INVENTION

[0008] The present invention advantageously provides a method and system for a bone mill that is easy to sterilize, adapted to create bone chips of different sizes, and operated manually without the need for external power sources. As such, the present invention reduces the overall cost of orthopedic procedures requiring a crushed bone slurry, does not adversely impact the surgical suite turn-over time and provides a high yield of usable bone particles having relatively uniform dimensions.

[0009] In accordance with the present invention, an aspect provides an apparatus for bone milling in which a housing defines a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening. The linear passage has a first surface with third opening there through and a second surface transverse to the first surface. A rotatable cutting member is insertable through the third opening to partially block the linear passage. The rotatable cutting member is positioned at a distance from the second surface of the linear passage corresponding to a predetermined bone chip size.

[0010] In accordance with another aspect, the present invention provide an apparatus for bone milling in which a housing defines a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening. A rotatable cutting member traverses at least a portion of the linear passage. An actuator element defines a first end, a second end opposite the first end and a channel extending from the first end to the second end. The channel is adapted to contain at least a portion of the rotatable cutting member therein. The first end is removably coupled to the housing and the rotatable cutting member is removable from the channel through the second end of the actuator element while the actuator element remains coupled to the housing.

[0011] According to still another aspect a method for milling bone is provided in which bone to be milled is inserted into a bone milling apparatus. The apparatus has a housing defining a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening, the linear passage having a first surface with third opening there through and a second surface transverse to the first surface. The apparatus also has a rotatable cutting member insertable through the third opening to partially block the linear passage. The rotatable cutting member is positioned at a distance from the second surface of the linear passage corresponding to a predeter-

mined bone chip size. The apparatus further includes a plunger and a milled material receptacle removably coupled to the second opening. The plunger is placed in the first opening of the apparatus to force the bone towards the rotatable cutting member. The actuator element is operated to rotate the rotatable cutting member, thereby milling the bone. The milled material is collected in the milled material receptacle. In addition, the present invention provides for a bone mill which can be coupled to a powered device through an intermediary adapter to eliminate the need to actuate the bone mill manually.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more complete understanding of the present invention, and the attendant advantages and features thereof, will be more readily understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

[0013] **FIG. 1** illustrates the internal and external features of a bone mill in accordance with the present invention;

[0014] **FIG. 2** depicts an exploded view of a bone mill in accordance with the present invention;

[0015] **FIG. 3** shows added features of a bone mill in accordance with the present invention;

[0016] **FIG. 4** shows a perspective view of an alternative embodiment of a bone mill in accordance with the present invention;

[0017] **FIG. 5** illustrates a side view of an alternative embodiment of a bone mill in accordance with the present invention;

[0018] **FIG. 6** depicts a rear view of an alternative embodiment of a bone mill in accordance with the present invention;

[0019] **FIG. 7** shows a front view of an alternative embodiment of a bone mill in accordance with the present invention;

[0020] **FIG. 8** illustrates a top view of an alternative embodiment of a bone mill in accordance with the present invention;

[0021] **FIG. 9** depicts a bottom view of an alternative embodiment of a bone mill in accordance with the present invention;

[0022] **FIG. 10** shows a cross-sectional view of an alternative embodiment of a bone mill in accordance with the present invention;

[0023] **FIG. 11** depicts a perspective view of a mill body of an alternative embodiment of a bone mill in accordance with the present invention;

[0024] **FIG. 12** illustrates a cross-sectional view of a mill body of an alternative embodiment of a bone mill in accordance with the present invention;

[0025] **FIG. 13** shows an additional cross-sectional view of a mill body of an alternative embodiment of a bone mill in accordance with the present invention;

[0026] **FIG. 14** illustrates a perspective view of an actuator element of an alternative embodiment of a bone mill in accordance with the present invention;

[0027] **FIG. 15** depicts a cross sectional view of an actuator element of an alternative embodiment of a bone mill in accordance with the present invention;

[0028] **FIG. 16** shows a side view of an actuator element of an alternative embodiment of a bone mill in accordance with the present invention;

[0029] **FIG. 17** shows an actuator cap of an alternative embodiment of a bone mill in accordance with the present invention;

[0030] **FIG. 18** illustrates a cross-sectional view of an actuator cap of an alternative embodiment of a bone mill in accordance with the present invention;

[0031] **FIG. 19** illustrates a perspective view of a coupling element of an alternative embodiment of a bone mill in accordance with the present invention;

[0032] **FIG. 20** depicts a cross-sectional view of a coupling element of an alternative embodiment of a bone mill in accordance with the present invention;

[0033] **FIG. 21** shows a plunger of an alternative embodiment of a bone mill in accordance with the present invention;

[0034] **FIG. 22** depicts a receptacle of an alternative embodiment of a bone mill in accordance with the present invention;

[0035] **FIG. 23** illustrates a cross-sectional view of a receptacle of an alternative embodiment of a bone mill in accordance with the present invention;

[0036] **FIG. 24** shows an expanded view of an assembly of a bone mill in accordance with the present invention;

[0037] **FIG. 25** depicts a modified actuator cap and an adapter of an alternative embodiment of a bone mill in accordance with the present invention;

[0038] **FIG. 26** shows an additional view of the modified actuator cap and adapter of **FIG. 25** in accordance with the present invention;

[0039] **FIG. 27** illustrates a cross-sectional view of the modified actuator cap of **FIG. 25** in accordance with the present invention; and

[0040] **FIG. 28** shows a cross-sectional view of the modified actuator cap coupled with the adapter of **FIG. 25** in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0041] The present invention provides a disposable, hand-operated bone mill that accommodates cutting plates to produce bone chips of a selected size based on a blade installed in the mill body 10. Referring now to **FIG. 1**, an exemplary embodiment of the present invention includes a bone mill having a mill body 10 that defines a first opening 12, a second opening 14, and a linear passage 15 that extends from the first opening 12 to the second opening 14. The mill body 10 further includes a rotatable cutting member 18 coupled to an actuator element 20, as shown in **FIG. 2**. Further, the mill body 10 can include a third opening 16 through which the rotatable cutting member 18 couples to the actuator element 20. The first opening 12 can be adapted

to receive a plunger 22, and a receptacle 24 can be removably coupled to the second opening 14.

[0042] The first opening 12 provides an access area into which a suitably sized bone portion can be inserted for milling. First opening 12 can be of any shape, whether having a circular or rectangular cross-section, so long as a bone specimen of a particular dimension can pass through first opening 12 and into the mill body 10 for subsequent milling. First opening 12 can be adapted to receive the plunger 22, which is used to aid in forcing a bone specimen further into the linear passage 15 towards the rotatable cutting member 18. The plunger 22 can be of any shape or orientation, so long as it is capable of being inserted into the first opening 12, and includes at least one depressing surface for contacting a bone specimen in the mill body 10 and forcing it further into the linear passage 15.

[0043] The second opening 14 provides an exit area from which milled bone particles may be dispensed. Second opening 14 can be of any shape, whether having a circular or rectangular cross-section, so long as it is of sufficient width to allow milled bone particles to descend out of the opening and into the receptacle 24. Receptacle 24 can be removably coupled to the second opening 14 through any suitable affixation means, including affixation through the use of a threaded interlocking surface, a snap-on mechanism, or the like. Additionally, receptacle 24 may be affixed either to an exterior surface or interior surface of the mill body 10 in the vicinity of the second opening 14 in order to capture the dispensed milled bone material. The receptacle 24 generally defines an interior cavity accessible by a single opening to receive dispensed milled material, and may be of any suitable shape as to be removably coupled to the second opening 24 of the mill body 10.

[0044] The rotatable cutting member 18 preferably includes a cylindrical, rod-shaped element having a substantially solid cross-section, and further has at least one cutting element or cutting groove disposed on its outer periphery. Additionally, the rotatable cutting element 18 has a diameter that is less than one-half of an inch, and is positioned in the mill body 10 such that the rotatable cutting member substantially fills or occludes a portion of the linear passage 15. By occluding or filling a portion of the linear passage 15, a bone specimen inserted in the bone mill is ensured direct contact with the rotatable cutting member 18 to further guarantee that only bone chips of a particular dimension proceed further down the linear passageway 15, where they eventually descend into the receptacle 24. An example of a suitable embodiment of the rotatable cutting member 18 is a precision milling bit (for instance, part #233049 from CONTROX®). The rotatable cutting member is preferably constructed from a highly durable steel or metal material that will not dull easily during repeated uses of the bone mill. Rotatable cutting member 18 can include a spiral-oriented plurality of grooves which present multiple cutting edges for reducing a bone specimen into bone chips or particles. The cutting edges of the cutting member can be positioned to cut into a bone specimen at approximately a 45-degree angle when the bone mill is in use, which provides a maximized mechanical advantage, reduces the amount of torque necessary to effectively mill a bone specimen, and eases the overall use of the bone mill. Moreover, the cutting edges of the cutting member may include jagged or saw-tooth edges which perforate or otherwise cut into the bone on a micro

level, delivering particles of the desired size and resulting in a more efficient milling process.

[0045] While an exemplary size of the bone particles produced by the rotatable cutting member 18 ranges from one-eighth ($1/8$) of an inch to approximately three-sixteenths ($3/16$) of an inch, the measurements and dimensions of the cutting grooves located on the rotatable cutting member may be modified or characterized in order to produce bone chips of an alternatively predetermined size.

[0046] Rotatable cutting member 18 is coupled to an actuator element 20 by any suitable means of affixation including a bolt, screw, lock ring, or the like. Actuator element 20 provides the mechanical driving means to rotate the rotatable cutting member 18. The bone mill is preferably manually driven, only requiring the hand strength of a single individual. To ease the use of the bone mill, the actuator element 20 can be in the form of a knob or handle having a diameter or width that is significantly larger than the diameter or width of the rotatable cutting member 18. The size ratio between the actuator element 20 and the rotatable cutting member 18 provides a mechanical advantage for the user and decreases the force that needs to be applied to the actuator element 20 in order to create sufficient force in the rotatable cutting member 18 to successfully reduce a bone specimen into particles of a desired size.

[0047] The linear passage 15 provides a direct pathway in which a bone specimen can descend directly through the first opening 12, through the rotatable cutting member 18, and outward from the second opening 14. The linear passage 15 can have any virtually any shape or orientation, whether being a circular or rectangular cross-section, so long as the width is sufficient to receive a bone specimen and allow the specimen to descend through the mill body 10. The linear passage 15 can further include a first region 26 having a first width and a second region 28 having a second width. The first width of the first region 26 can be larger than the second width of the second region 28 so as to accommodate a larger bone specimen, while the second region need only be of sufficient width to allow the milled particles to descend downward to the receptacle 24. The rotatable cutting member 18 can be positioned such that at least a portion of the rotatable cutting member 18 intersects at least a portion of the first region 26 and at least a portion of the second region 28. Placing the rotatable cutting member 18 in such a position can ensure that only milled bone particles of a particular size can pass through to the second region 28 of the linear passage 15, while maintaining location of the larger bone specimen within the first region 26. Alternatively to having a first and second region, the linear passage can have a single, uniform width, or a plurality of widths, so long as a bone specimen to be milled comes into contact with the rotatable cutting member prior to exiting the mill body 10.

[0048] As shown in FIG. 3, the bone mill can further include a funnel 30 and syringe 32. The funnel 30 can be removably coupled to the receptacle 24 when a desired amount of milled bone has been collected. The receptacle 24 is uncoupled from the mill body 10, and is then coupled to the funnel 30 through a mechanism similar to that which coupled the receptacle 24 to the mill body 10, whether by the use of a threaded interlocking surface, a snap-on mechanism, or the like. Upon coupling the receptacle 24 to the funnel 30, the milled contents in the receptacle can be

transferred into the syringe 32 for direct insertion to a surgical site. By coupling the funnel 30 directly to the receptacle 24, a user can ensure that no milled contents are wasted or lost when transferring the milled bone from the bone mill to the eventual surgical site.

[0049] In an exemplary use prior to a medical procedure, a bone specimen to be milled is inserted into the first opening 12 of the mill body 10. The plunger 22 is then placed into contact with the bone specimen as it resides in the first region 26 of the linear passage 15 in the area above the rotatable cutting member 18. The actuator element 20 is then manually turned, which, in turn, rotates the rotatable cutting member 18. While turning the actuator element 20, the user can depress the plunger, thereby forcing the bone specimen towards and into contact with the rotatable cutting member. As the user continues to depress the plunger and turn the actuator element, the bone specimen will be reduced to bone particles of a desired size, which then descend through the second region 28 of the linear passage 15 and into the receptacle 24 that is removably coupled to the second opening 14 of the mill body.

[0050] In an alternative exemplary embodiment, as shown in FIGS. 4 through 24, a bone mill 40 includes a mill body 42, an actuator element 44, an actuator cap 46, a plunger 48, and a receptacle 50. In addition, as illustrated by FIG. 10, the bone mill 40 also includes a rotatable cutting member 52 and a coupling element 54.

[0051] Now referring to FIGS. 11 through 13, the mill body 42 defines a first opening 56, a second opening 58, and a linear passage 60 that extends from the first opening 56 to the second opening 58. The first opening 56 can be adapted to receive the plunger 48, and the receptacle 50 can be removably coupled to the second opening 58. The mill body 42 may also include a plurality of ridges 62 distributed about a portion of an exterior surface of the mill body 42, as well as one or more coupling slots 64. The ridges 62 increase the ability of the mill body 42 to be gripped when the bone mill 40 is in use, while the coupling slots 64 provide for subsequent assembly of the bone mill 40.

[0052] The mill body 42 further includes a third opening 66 through which the rotatable cutting member 52 may pass through as to partially fill or occlude a portion of the linear passage 60. The linear passage 60 includes a first region 68 descending from the first opening 56 towards an area where the linear passage 60 intersects with the third opening 66, and thus, where the rotatable cutting member 52 would be located within the linear passage 60. Further, the linear passage 60 includes a second region 70 descending from the first region 68 towards the second opening 58.

[0053] As shown in FIG. 14, the rotatable cutting member 52 is preferably a rod-like element having grooves or cutting projections 78 disposed about an outer surface of the cutting member. Rotatable cutting member 52 can include a spiral-oriented plurality of grooves which present multiple cutting edges for reducing a bone specimen into bone chips or particles. The rotatable cutting member 52 may be removably coupled to the actuator element 44, where the actuator element 44 provides the mechanical driving means to rotate the rotatable cutting member 52.

[0054] Now referring to FIGS. 15 and 16, the actuator element 44 may be in the form of a handle or knob having

a diameter significantly larger than the diameter of the rotatable cutting member 52 in order to provide a mechanical advantage which reduces the amount of force necessary in order to mill bone material. The actuator element 44 can have a cutting member channel 72 extending through the actuator element 44 which allows the rotatable cutting member 52 to be inserted, and thus coupled, to the actuator element 44. The channel 72 extends through the entire width of the actuator element 44, although the circumference of the channel 72 may vary in order to mechanically engage the rotatable cutting member 52. In addition, the actuator element 44 can have a mating groove 74 extending around a circumference of a surface of the actuator element 44.

[0055] The bone mill 40 can also include the actuator cap 46, as shown in FIGS. 17 and 18. The actuator cap 46 has a generally disc-like shape and may further include a plurality of protrusions 76 adapted to removably couple to the actuator.

[0056] As shown in FIGS. 19 and 20, the bone mill 40 may include the coupling element 54. The coupling element 54 is an essentially ring-like structure that can include first and second projections 78 disposed about an outer surface. Additionally, the coupling element 54 includes one or more prongs 80 extending from the body of the coupling element 54, where the prongs 80 have a raised shoulder 82 at a single end of the prong.

[0057] The plunger 48 is provided as illustrated in FIG. 21. The plunger 48 can be adapted to any shape which allows for insertion of the plunger 48 into the first opening 56 of the mill body 42 to aid in forcing a bone specimen into the linear passage 60 and towards the rotatable cutting member 52.

[0058] Now referring to FIGS. 22 and 23, the receptacle 50 defines a cavity 84 for receiving milled bone material when coupled to the mill body 42. In addition to capturing dispensed bone material, the receptacle 50 may also provide a support function for stabilizing the bone mill 40 when the mill is placed on a surface for subsequent use. For example, the receptacle 50 can include a first end 86 which couples to the mill body 42, where the first end 86 includes an opening into the cavity 84 for deposit of milled bone material. The receptacle 50 also includes a second end 88, opposite the first end 86, which has a larger width than the first end 86, thereby increasing a surface area of the receptacle 50 and increasing the stability of the bone mill 40 when placed on a surface. The receptacle 50 may include an alignment feature, in the form of a groove or raised projection to aid in ensuring the proper alignment of the cavity 84 and the second opening 58 in the mill body 42 when the receptacle 50 is coupled to the mill body 42.

[0059] As shown in FIG. 24, in an exemplary assembly and use of the bone mill 40 of the present invention, the mill body 42 is mated with the coupling element 54. The first and second projections 78 of the coupling element 54 are inserted into the coupling slots 64 of the mill body 42, as to secure the coupling element 54 to the mill body 42. Subsequently, the actuator element 44 is mated with the coupling element 54, and thus, to the mill body 42. The shoulders 82 extending from the prongs 80 of the coupling element 54 engage the mating groove 74 of the actuator element 44 in such a way that the actuator element 44 is firmly coupled to the coupling element 54 and the mill body 42, yet retains the ability to rotate in place.

[0060] Upon coupling the actuator element 44 to the mill body 42, the rotatable cutting element is inserted through the actuator element 44 and into the cutting member channel 72. Once the rotatable cutting member 52 is placed in the channel 72, a portion of the rotatable cutting member 52 will protrude out of the actuator element 44, through the third opening 66 of the mill body 42, and into a portion of the linear passage 60.

[0061] To prevent the rotatable cutting member 52 from displacing during use of the bone mill 40, the actuator cap 46 is then coupled to the actuator, thus enclosing the exposed interior of the actuator element 44, and preventing the rotatable cutting element from falling out. Because of the removable nature of the actuator cap 46 and the rotatable cutting member 52, cutting members having different dimensions or features may be interchanged without disassembling the entire bone mill 40, allowing bone chips of varying, predetermined sizes to be created rather quickly and effortlessly. The assembled bone mill 40, actuator element 44, rotatable cutting member 52, and actuator cap 46 may then be coupled to the receptacle 50 and placed on a surface, employing the increased surface area, and thus stability, of the receptacle 50. The desired material to be milled is then placed in the first opening 56 of the mill body 42, and forced down the linear passage 60 towards the rotatable cutting member 52 by the plunger 48.

[0062] While the measurements and dimensions of the cutting grooves located on the rotatable cutting member 52 may be modified or characterized in order to produce bone chips of an alternatively predetermined size, characteristics of bone chips created by the bone mill 40 may further be manipulated by modifying the spacing between an outer edge of the rotatable cutting member 52 and a surface of the linear passage 60. As a result, the spacing between the rotatable cutting member 52 and a surface of the linear passage 60 define a single-stage milling assembly capable of producing bone chips of a desired size without the need for additional cutting members to produce intermediate-sized bone chips for subsequent milling.

[0063] For example, as may be readily observed in FIG. 12, in the mill body 42, if the first region 68 of the linear passage 60 has a first width, and the rotatable cutting member 52 has a first diameter that is smaller than the first width, then there would be a space between a surface of the linear passage 60 and the rotatable cutting member 52 equal to the difference between the first width 54 and the first diameter 56. Thus, the spacing between the rotatable cutting member 52 and a surface of the linear passage 60 would physically prevent any bone chips having a size greater than that spacing from passing about the rotatable cutting element and descending through the linear passage 60. As a result, by modifying the spacing between the rotatable cutting member 52 and a surface of the linear passage 60, for example by interchanging rotatable cutting members having different diameters, bone chips of a predetermined size may be created.

[0064] In an alternative embodiment, the bone mill of the present invention can be coupled to a powered tool or drive source element to facilitate the milling process rather than operating the bone mill manually. Now referring to FIGS. 25 through 28, the bone mill may further include an actuator cap 90 adapted to removably couple to the actuator element

20. The actuator cap 90 has a generally disc-like shape as described previously, however, for the alternative power-driven embodiment of the bone mill, the actuator cap further defines an adaptor receiving impression 92 on a surface of the cap. The adapter receiving impression 92 provides an indented surface shaped to receive and couple to an adapter 94.

[0065] The adapter 94 is an intermediary element which serves to couple the actuator cap 90 and thus the bone mill, to a drive source element (not shown), such as a power drill, rotary tool, or other powered device having a tool-receiving portion for engaging drill bits or other elements. The adapter 94 defines a first end 96 coupleable with the adapter receiving impression 92 of the actuator cap 90, and a second end 98 which can be engaged by the particular drive source element. Both the first and second ends of the adapter 94 can include a myriad of shapes or characteristics to effectively implement the drive source element and thus power the bone mill. As merely an illustrative example, the first end 96 of the adapter 94 may define a protruding element having a plurality of surfaces 97, 97' angled sharply from one another in order to securely frictionally engage the actuator cap. The surfaces 97, 97' provide a large area for contacting the walls of the adapter receiving impression 92 of the actuator cap 90 as to reduce the likelihood that the adapter 94 rotates within the actuator cap 90, thereby preventing the walls of the cap becoming stripped or worn down. The second end 98 of the adapter may define a plurality of protrusions having varying diameters or widths as to conform to the tool-receiving portion of the drive source element.

[0066] In an exemplary use of the features described above, the actuator cap 90 having the adapter receiving impression is coupled to the actuator 20 of the bone mill. The adapter 94 is engaged with the drive source element by coupling the second end 98 of the adapter with the tool-receiving portion of the drive source element. The drive source element and the adapter 94 are then positioned proximate the bone mill as to engage the first end 96 of the adapter with adapter receiving impression 92 of the actuator cap 90. Once the adapter 94 is suitably coupled with the actuator cap 90, the drive source element can be turned on or triggered to provide the turning force required to operate the bone mill and thus process milled bone material as discussed above.

[0067] Through the use of the adapter 94 and modified actuator cap 90, the bone mill can be integrated with automated power tools that are already present in the operating room. As such, there is no need to provide an additional tool or element to power the bone mill, and the bone mill can further retain its compact size and portability as there is no integral motor or bulky accessories needed to implement the bone mill as a powered device.

[0068] While it has been described that the actuator cap includes the adapter receiving impression in order to couple the bone mill to a powered drive source, such coupling could also be achieved by directly including a feature similar to the receiving impression in the actuator itself. Subsequently, a suitable adapter could be coupled directly to the actuator in order to engage a powered drive source.

[0069] It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described herein above. In addition,

unless mention was made above to the contrary, it should be noted that all of the accompanying drawings are not to scale. A variety of modifications and variations are possible in light of the above teachings without departing from the scope and spirit of the invention, which is limited only by the following claims.

What is claimed is:

1. An apparatus for bone milling, comprising:
 - a housing defining a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening, the linear passage having a first surface with third opening therethrough and a second surface transverse to the first surface;
 - a rotatable cutting member insertable through the third opening to partially block the linear passage, the rotatable cutting member being positioned at a distance from the second surface of the linear passage, the distance defining a predetermined bone chip size;
 - an actuator element having a first end and a second end opposite the first end, wherein the first end is removably coupled to the housing; and
 - an actuator cap removably coupleable with the second end of the actuator element, the actuator cap defining an adapter receiving impression.
2. The apparatus according to claim 1, further comprising an adapter including a first end and a second end, wherein the first end of the adapter is positionable within the adapter receiving impression of the actuator cap.
3. The apparatus according to claim 2, wherein the first end of the adapter defines a plurality of surfaces substantially angled from one another to securely engage the actuator cap.
4. The apparatus according to claim 1, wherein the actuator element defines a channel adapted to contain at least a portion of the rotatable cutting member therein.
5. The apparatus according to claim 4, where the channel extends substantially from the first end to the second end.
6. The apparatus according to claim 5, wherein the rotatable cutting member is removable from the channel and the linear passage of the housing while the actuator remains coupled to the housing.
7. The apparatus according to claim 1, further comprising a receptacle removably coupled to the second opening.
8. The apparatus according to claim 7, wherein the receptacle has a first end and a second end opposite the first end, the second end having a substantially larger surface area than the first end.
9. The apparatus according to claim 8, wherein the receptacle further includes an alignment element for engagement with a corresponding element on the housing.
10. The apparatus according to claim 9, wherein the alignment element on the receptacle is one of a groove and a raised projection.
11. The apparatus according to claim 1, wherein the rotatable cutting member includes at least one spiral-oriented groove that provides a cutting edge.
12. The apparatus according to claim 1, further including a plunger dimensioned to be removably insertable into the first opening of the housing.
13. The apparatus according to claim 1, wherein the apparatus further comprises a coupling element engageable

with the housing and the actuator element to keep the actuator element coupled to the housing during operation.

14. The apparatus according to claim 13, wherein the housing further includes at least one slot, and wherein the coupling element has:

- at least one projection engageable with a corresponding at least one slot to removeably couple the coupling element with the housing; and

- at least one shoulder to engage the actuator element.

15. An apparatus for bone milling engageable with a drive source having a tool-receiving portion, comprising:

- a housing defining a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening;

- a single-stage milling assembly consisting of a rotatable cutting member traversing at least a portion of the linear passage;

- an actuator element defining a first end, a second end opposite the first end and a channel extending from the first end to the second end;

- an actuator cap removably coupleable with the second end of the actuator element, the actuator cap defining an adapter receiving impression; and

- an adapter defining a first end and a second end, wherein the first end is positionable in the adapter receiving impression of the actuator cap and the second end is engageable with the tool-receiving portion of a drive source.

16. The apparatus according to claim 15, wherein the rotatable cutting member includes a spiral-oriented plurality of grooves that provide a respective plurality of cutting edges.

17. The apparatus according to claim 15, wherein the rotatable cutting member is positioned at a distance from a portion of the linear passage, the distance defining a predetermined bone chip size.

18. The apparatus according to claim 15, wherein the first end of the adapter defines a plurality of surfaces substantially angled from one another to securely engage the actuator cap.

19. A method for milling bone, comprising the steps of:

- inserting bone to be milled into a bone milling apparatus, the apparatus being comprised of:

- a housing defining a first opening, a second opening opposite the first opening, and a linear passage from the first opening to the second opening, the linear passage having a first surface with third opening there through and a second surface transverse to the first surface; and

- a rotatable cutting member defining a cutting edge, the rotatable cutting member being insertable through the third opening to partially block the linear passage, the rotatable cutting member further being positioned at a distance from the second surface of the linear passage corresponding to a predetermined bone chip size;

- an actuator element defining a first end, a second end opposite the first end and a channel extending from the first end to the second end;

an actuator cap removably coupleable with the second end of the actuator element, the actuator cap defining an adapter receiving impression; and

an adapter defining a first end and a second end, wherein the first end is positionable in the adapter receiving impression of the actuator cap;

a plunger; and

a milled material receptacle removably coupled to the second opening;

engaging the second end of the adapter with a drive source;

placing the plunger in the first opening of the apparatus to force the bone towards the rotatable cutting member,

operating the drive source to rotate the rotatable cutting member, thereby milling the bone, and

collecting the milled material in the milled material receptacle.

20. The method according to claim 19, wherein the cutting edge of the rotatable cutting member is positioned to contact the bone at approximately a forty-five degree angle.

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