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(54) **AUTOMATED BONE MILL APPARATUS**

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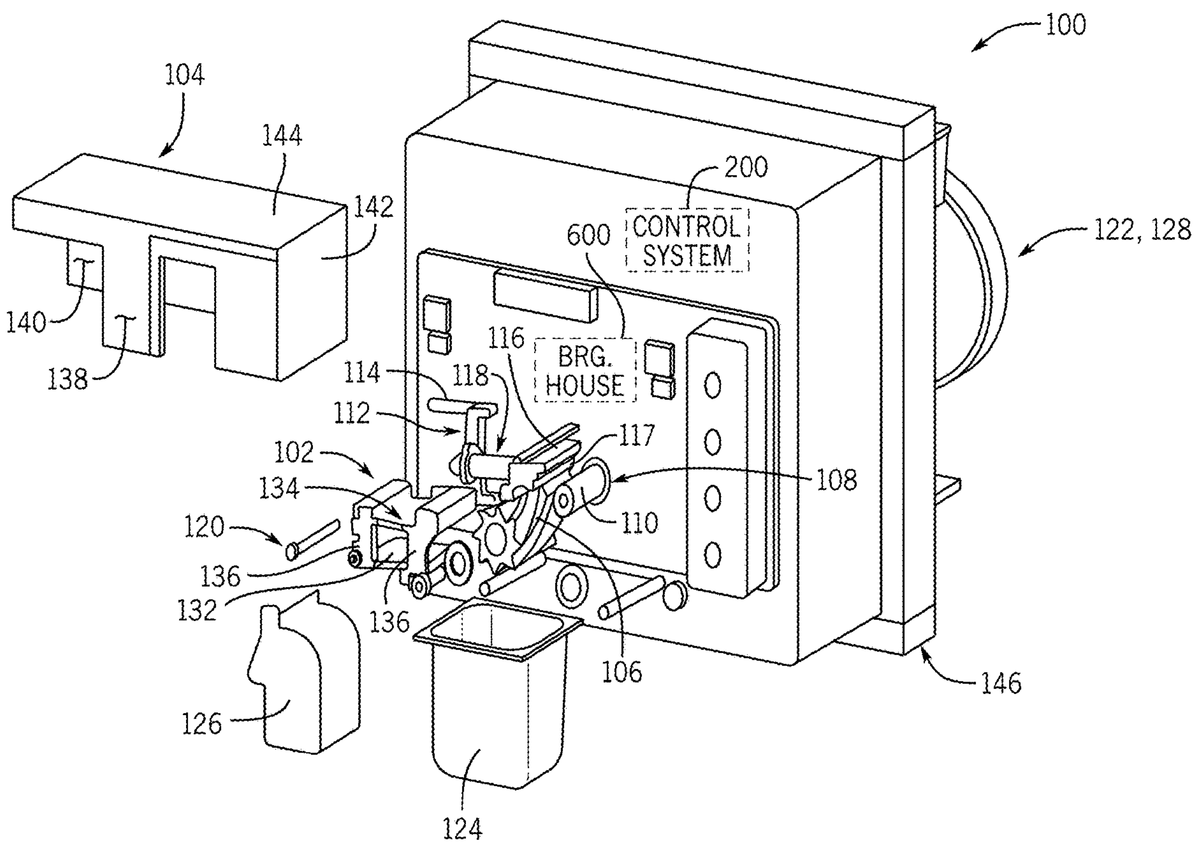
(57) **ABSTRACT**

Present embodiments are directed to facilitating and improving bone mill functionality. For example, present embodiments provide for improving yields in bone fibers produced from a donor sample specimen, while additionally reducing the operating duration used to process the sample. In part, present embodiments provide these improvements by implementing an automated process of the bone mill operation, providing for hands-free operation of the bone mill, and providing for interchangeability and availability of heavy-wear components. In some embodiments, the automated process may adapt and compensate for changes during the milling process, and provide a consistent force biasing a bone sample against a cutter while reducing opportunities for operator accidents.



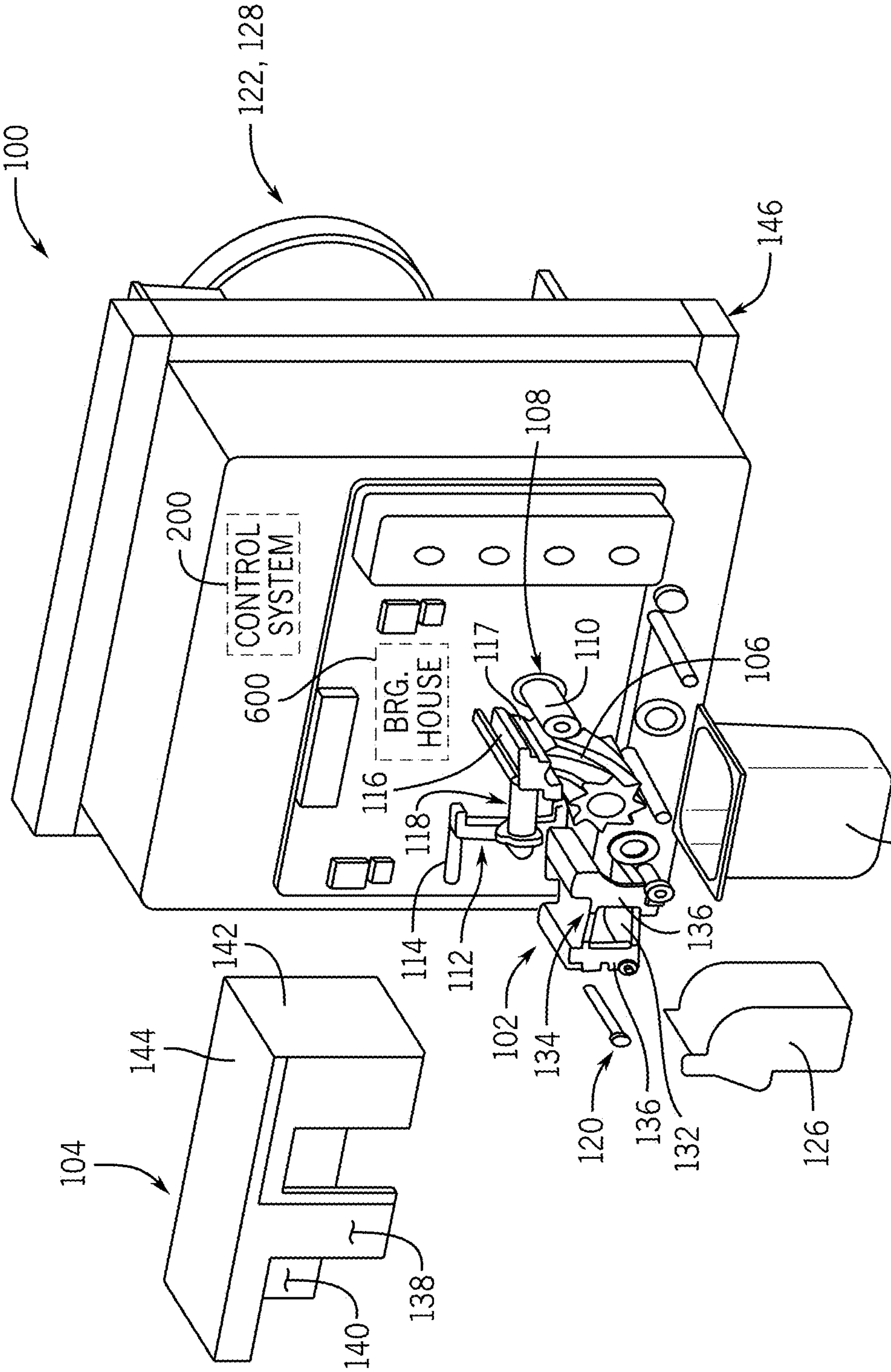

100
122, 128
146
200
CONTROL SYSTEM
600
BRG. HOUSE
108
117
110
106
116
118
114
112
102
134
136
136
132
120
124
126
142
144
104
138
140

FIG. 1

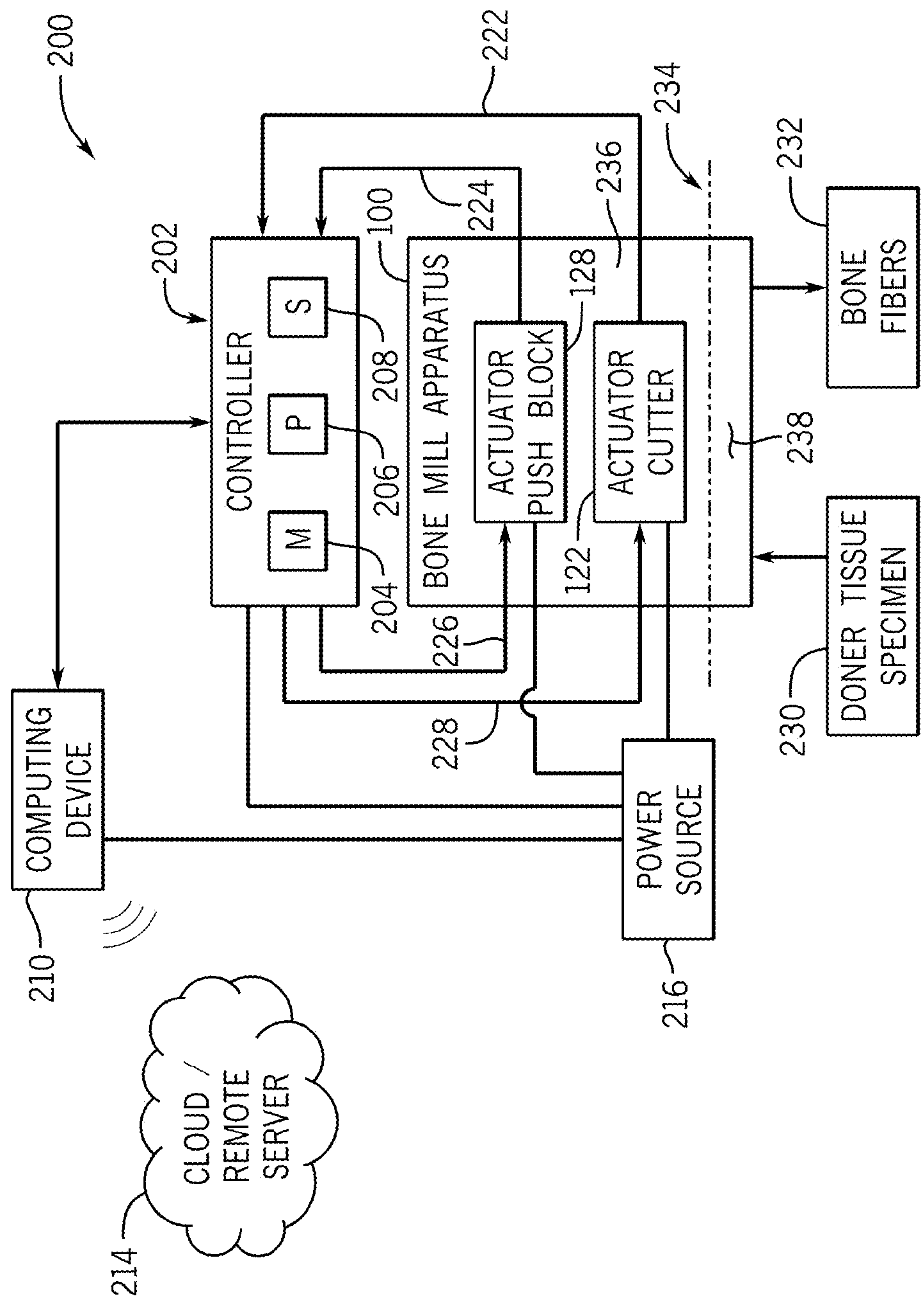

200
202
CONTROLLER
M
P
S
204
206
208
100
BONE MILL APPARATUS
ACTUATOR PUSH BLOCK
ACTUATOR CUTTER
128
122
222
224
226
228
234
236
238
232
BONE FIBERS
230
DONER TISSUE SPECIMEN
COMPUTING DEVICE
210
POWER SOURCE
216
CLOUD / REMOTE SERVER
214

FIG. 2

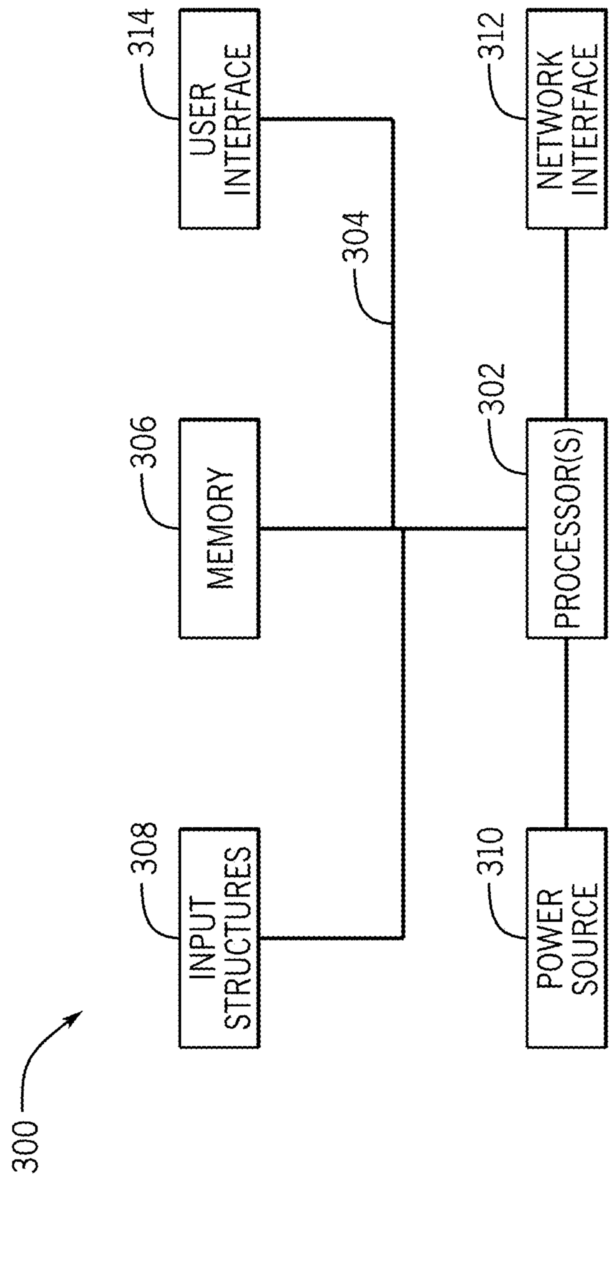

300
308
INPUT STRUCTURES
306
MEMORY
314
USER INTERFACE
304
310
POWER SOURCE
302
PROCESSOR(S)
312
NETWORK INTERFACE

FIG. 3

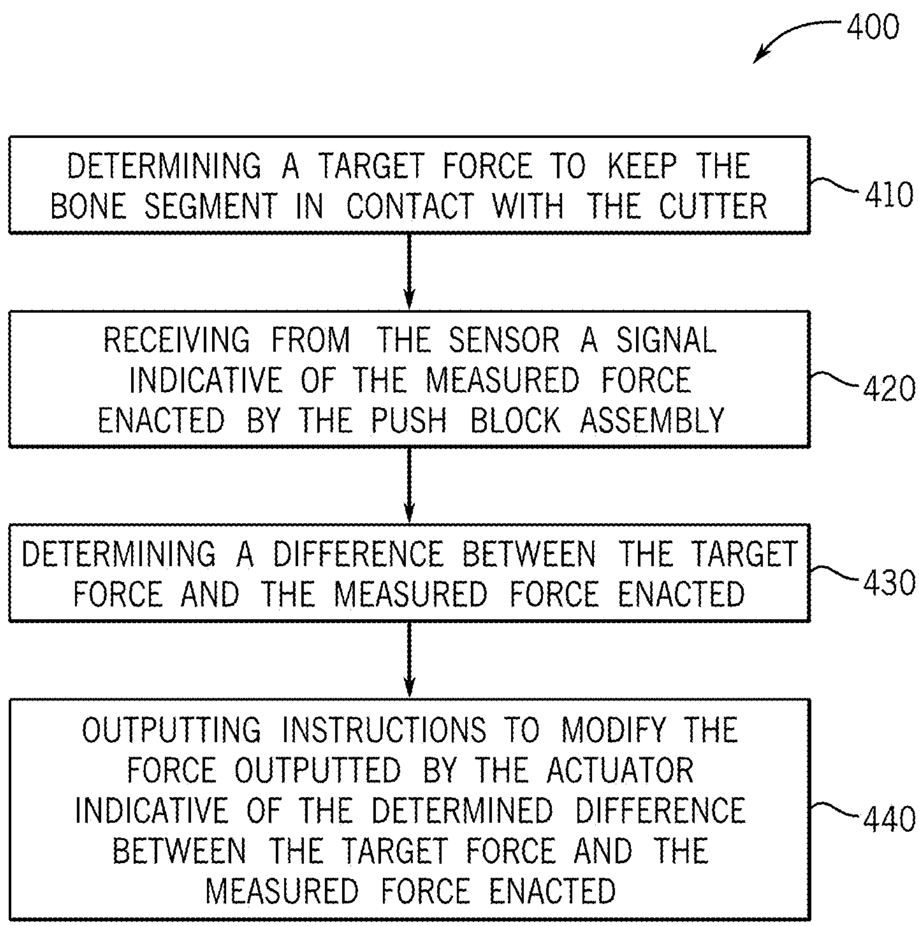

400
DETERMINING A TARGET FORCE TO KEEP THE BONE SEGMENT IN CONTACT WITH THE CUTTER
410
RECEIVING FROM THE SENSOR A SIGNAL INDICATIVE OF THE MEASURED FORCE ENACTED BY THE PUSH BLOCK ASSEMBLY
420
DETERMINING A DIFFERENCE BETWEEN THE TARGET FORCE AND THE MEASURED FORCE ENACTED
430
OUTPUTTING INSTRUCTIONS TO MODIFY THE FORCE OUTPUTTED BY THE ACTUATOR INDICATIVE OF THE DETERMINED DIFFERENCE BETWEEN THE TARGET FORCE AND THE MEASURED FORCE ENACTED
440

FIG. 4

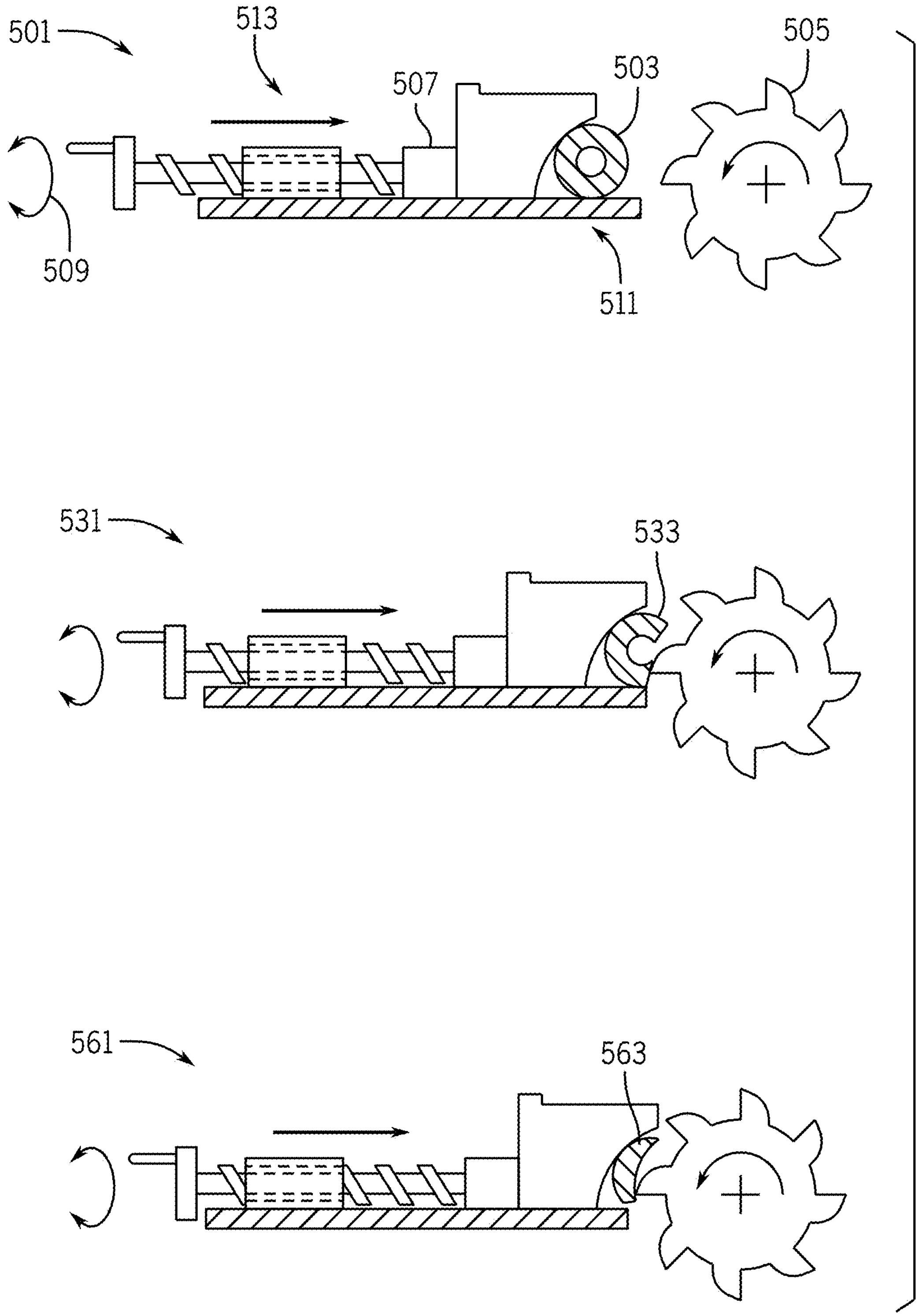


FIG. 5

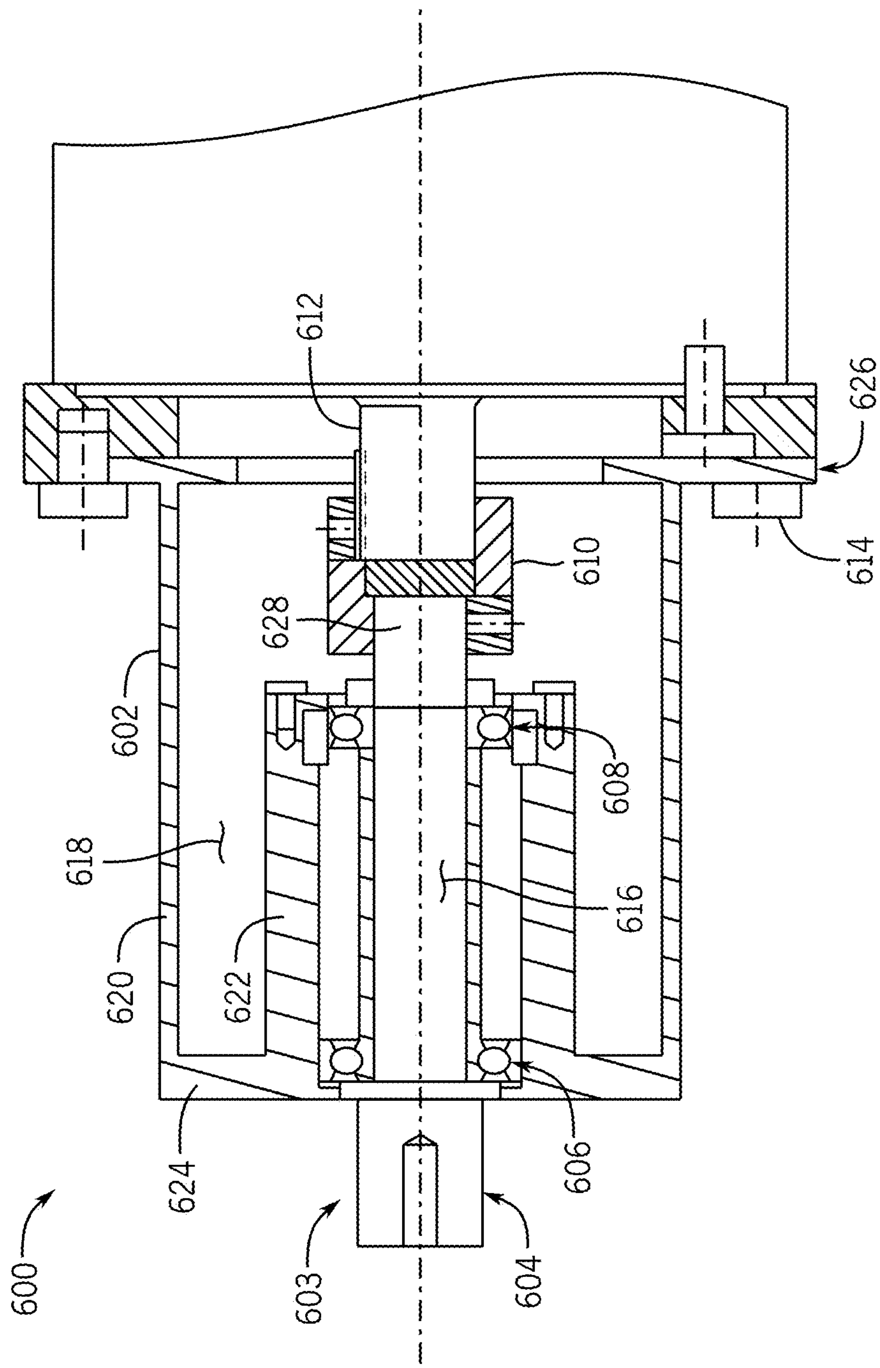


FIG. 6

AUTOMATED BONE MILL APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority and benefit of U.S. Provisional Patent Application No. 63/552,719, entitled "AUTOMATED BONE MILL APPARATUS," filed on Feb. 13, 2024, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This invention relates to an apparatus for cutting bone, and more particularly, to an apparatus for milling bone fragments which may subsequently be demineralized and used to produce shaped materials or used in other contexts where bone matters or fibers are employed.

BACKGROUND

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present techniques, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present techniques. Accordingly, it should be understood that these statements are to be read in this light, and not as admission of prior art.

[0004] The medical industry has various uses for bone fragments, which may be produced by milling or grinding larger pieces of bone to form such fragments. By way of example, bone tissue collected from donor material during a milling or grinding process may help medical personnel treat patients with a variety of skeletal defects, diseases, or injuries. While operating traditionally, a bone mill produces valuable bone fibers that form the foundation of bone grafts that help a recipient re-grow bone material or otherwise receive treatment for a skeletal ailment. However, traditional bone mills produce yields that are variable and irregular, and often lead to generation of unwanted fiber materials that have to be scrapped. Additionally, operating a traditional bone mill is a difficult, typically manual, process that may lead to operator injuries. Accordingly, it is now recognized that new solutions are needed to improve this area of the medical industry.

BRIEF DESCRIPTION

[0005] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0006] Present embodiments are directed to facilitating and improving bone mill functionality. For example, present embodiments provide for improving yields in bone fibers produced from a donor sample specimen, while additionally reducing the operating duration used to process the sample. In part, present embodiments provide these improvements by implementing an automated process of the bone mill operation, providing for hands-free operation of the bone mill, and providing for interchangeability and availability of heavy-wear components. In some embodiments, the automated process may adapt and compensate for changes during the milling process, and provide a consistent force biasing a bone sample against a cutter while reducing opportunities for operator accidents.

[0007] In a non-limiting embodiment, a system includes a bone mill configured to mill bone fibers from a bone segment during use, such that the bone mill includes a cutter and a push block assembly. Additionally, the system includes an actuator configured to receive a force input specifying a target force to keep the bone segment in contact with the cutter during operation, and in response to receiving the force input, outputting an output force based on the target force, and a sensor configured to detect a measured force enacted by the push block assembly onto the bone segment. Also, the system includes a control system that includes processing circuitry and a memory, accessible by the processing circuitry, and storing instructions that, when executed by the processing circuitry, cause the processing circuitry to perform actions including determining the target force to keep the bone segment in contact with the cutter, receiving from the sensor a signal corresponding to the measured force enacted by the push block assembly, determining a difference between the target force and the measured force enacted, and outputting instructions directly or indirectly to the actuator to adjust operation of the push block assembly based on the determined difference.

[0008] In a non-limiting embodiment, a bone fiber is cut from a bone segment, such that the bone fiber is cut by a process including determining a target force to keep the bone segment in contact with a cutter, receiving from a sensor a signal corresponding to a measured force enacted by a push block assembly, and determining a difference between the target force and the measured force enacted. The process also includes determining a target rotational output to turn the cutter through the bone segment, receiving from an additional sensor an additional signal corresponding to a measured rotational output enacted by the cutter, and determining an additional difference between the target rotational output and the measured rotational output enacted. The process also includes outputting instructions directly or indirectly to an actuator to adjust operation of the push block assembly based on the difference and outputting additional instructions directly or indirectly to an additional actuator to adjust operation of the cutter based on the additional difference.

[0009] In a non-limiting embodiment, a method includes determining a target force to keep a bone segment in contact with a cutter, receiving from a sensor a signal corresponding to a measured force enacted by a push block assembly, determining a difference between the target force and the measured force enacted, and outputting instructions directly or indirectly to an actuator to adjust operation of the push block assembly based on the determined difference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0011] FIG. **1** is an exploded view of a bone milling apparatus, in accordance with aspects of the present techniques;

[0012] FIG. **2** is a schematic view of an embodiment of a processor-based control system for an automated bone milling apparatus, in accordance with aspects of the present techniques;

[0013] FIG. **3** is a block diagram of example components that may be used in the control system of FIG. **2**, in accordance with aspects of the present techniques;

[0014] FIG. **4** is a flowchart of an embodiment of a feedback-based method for controlling a bone billing apparatus used to harvest bone tissue fibers from a sample specimen, in accordance with aspects of the present techniques;

[0015] FIG. **5** is a front view of an embodiment of the bone milling apparatus in various stages of operation, in accordance with aspects of the present techniques; and

[0016] FIG. **6** is a section view of an embodiment of a bearing housing assembly utilized in an embodiment of the bone milling apparatus, in accordance with aspects of the present techniques.

DETAILED DESCRIPTION

[0017] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0018] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0019] Present embodiments are directed to facilitating and improving bone mill functionality. For example, present embodiments provide for improving yields in bone fibers produced from a donor sample specimen, while additionally reducing the operating duration used to process the sample. In part, present embodiments provide these improvements by implementing an automated process of the bone mill operation that utilizes force feedback control. Further, the force feedback control can adapt and compensate for changes during the milling process, including but not limited to automatically adjusting a feed rate or a spindle speed of the mill in response to readings from a force sensor. By utilizing aspects of the present techniques, yields of bone fiber that can be produced from donor tissue may increase, while reducing the operating duration.

[0020] Also, present embodiments provide for hands-free operation of the bone mill, introducing automatic actuation of the cutting mechanism and/or the feed portion of the mill. In part, the hands-free operation is achieved through the previously discussed implementation of force feedback control. While prior approaches to operating a bone mill required an operator to mechanically actuate a crank to spin a cutter or advance a push block to position a piece of donor tissue against the cutting mechanism, present embodiments eliminate this requirement, and as a result, reduces opportunities for accidents or injuries. Further, the automatic actuation enables the bone mill to control various components during operation to provide a consistent force biasing a bone sample against a cutter.

[0021] Additionally or alternatively, present embodiments provide for improvements to the interchangeability and availability of heavy wear and expendable items. For example, the bone mill is designed to accept cutting mechanisms that are readily available, while still maintaining the capability to accept a custom-manufactured cutting mechanism. In one embodiment, the cutting mechanism is configured in a manner such that the blades are oriented in a helical geometry, enabling the cutting mechanism to cut fibers from the donor tissue while avoiding premature breakage or snapping of the bone fibers. Further, the cutting mechanism can be indexed and positioned in a plurality of angles and configurations to accommodate for varying parameters for fiber length, geometry, thickness, and other suitable output variables.

[0022] Also, certain embodiments may be configured to operate in a cleanroom environment, and adhere to guidelines in place that govern ISO 5/Class **100** work environments. For example, the bone mill may be configured to extend through a dividing wall such that a portion of the bone mill that includes cutting mechanism and bone specimen extends into the cleanroom environment, and another portion that includes actuators and working parts of the bone mill may operate outside the cleanroom environment. Further, individual components of the bone mill are configured to be removed and cleaned separately from the bone mill and each component may be sterilized individually.

[0023] Turning to the drawings, FIG. **1** is an exploded view of the bone milling apparatus **100** according to an embodiment of the present technique. The bone milling apparatus may include a housing **102**, a cover **104**, a cutter **106**, a push block assembly **110**, a drive motor **122**, a push block motor **128**, a control system **200**, a bearing support assembly **148** and a fiber pan **124**. The housing **102** may be configured to provide a support structure for the cutter **106** and the push block assembly **110**. In certain embodiments, the housing **102** includes a base portion **132** disposed in a horizontal orientation, and a top portion **134** similarly disposed in a horizontal orientation, vertically offset above the base portion **132** by a specified distance. In other embodiments, the base portion **132** and the top portion **134** may be parallel with respect to each other, and the specified distance may create a cavity suitable to at least partially house the push block assembly **110**, the cutter **106**, or both. The housing **102** may also include a plurality of support braces **136** configured to fix the top portion **134** in a position sufficiently apart from the base portion **132** such that the aforementioned cavity may be created. Additionally or alternatively, the support braces **136** may be configured to provide rigidity to the housing **102** and positioned to counteract any reaction forces experienced by the housing **102** during the bone milling operation. The housing **102**, base portion, **132**, top portion, **134**, and support braces **136** may be made from any suitable material, such as but not limited to metal, metal alloy, ceramics, carbon fiber compositions, polymeric compositions (e.g., plastic), wood, or any other suitable material or combinations thereof.

[0024] In certain embodiments, the bone milling apparatus **100** may include a cover **104**. The cover **104** is configured to be positioned around the housing **102**, cutter **106**, and push block assembly **110** such that the internal moving components are protected from any elements in a cutting room environment. Additionally or alternatively, the cover **104** is configured to act as a barrier during milling operation to prevent shavings from a donor sample or other by-products of the milling process to enter the environment. In a non-limiting embodiment, the cover **104** includes a front panel **138**, a back panel **140**, at least one side panel **142**, and a top panel **144**. In other embodiments, the front panel is configured to have a plurality of cutouts positioned appropriately such that an operator may add or remove a bone segment, or otherwise access input areas of the bone milling apparatus. The cover **104** and its associated panels **138**, **140**, **142**, **144** may be made from any suitable material, such as but not limited to metal, metal alloy, ceramics, carbon fiber compositions, polymeric compositions (e.g., plastic), wood, or any suitable material or combinations thereof. The cover **104** may be configured to removably couple to the bone milling apparatus, enabling removal when maintenance or other procedures require more comprehensive access to the internal components.

[0025] In a non-limiting embodiment, the bone milling apparatus includes a cutter **106** disposed on a cutter shaft **108**. The cutter **106** may be coupled with or integrally attached to the cutter shaft **108**, such that the cutter rotates with, and is rotatable along the axis of, the cutter shaft at a desired rotational speed. The cutter shaft **108** may protrude from an aperture in a barrier wall **146** such that the cutter shaft extends a specified distance into the cutting room environment, enabling the cutter **106** to rotate and apply a cutting force to a bone segment. The cutter shaft **108** may be configured to accept cutters **106** that are readily available as a standard option (i.e. standard size in a catalog, available online as a default size, etc.) or may accept cutters **106** that include customized specifications that are detailed for a specific embodiment. In some embodiments, the cutter **106** may be decoupled from the cutter shaft **108** so that the cutter may be cleaned separately. The cutter **106** may be made from any suitable material, such as but not limited to metal, metal alloy, or any combination thereof.

[0026] The cutter **106** may be any suitable length and diameter. In one non-limiting embodiment, the cutter **106** may be a length that is equal to or greater than the length of the bone segments for which the bone milling apparatus **100** is designed to receive for milling. For example, in one embodiment, the cutter **106** may have a length, along its axis of rotation, of between three and one half (3½) to four (4) inches. Additionally or alternatively, the cutter **106** may have any suitable diameter. In a non-limiting embodiment, the cutter may have a diameter of between two and one half (2½) to three (3) inches. However, any suitable length or diameter of cutter **106** is considered within the scope of the various embodiments of the present techniques.

[0027] Further, the cutter **106** may have any suitable number of teeth or bladed edges. In some embodiments, the cutter **106** may have between two (2) and ten (10) teeth or bladed edges. However, a single tooth or bladed edge as well as greater than ten (10) teeth or bladed edges are considered within the scope of the various embodiments of the present techniques. In a non-limiting embodiment, the cutter includes eight (8) teeth or bladed edges. Also, the teeth or bladed edges may be configured in a suitable arrangement along the axis of rotation. In certain embodiments, the teeth or bladed edges of the cutter **106** may be configured in a helical pattern around the cutter **106**. In certain embodiments, the helical pattern of the teeth or bladed edges may traverse the length of the cutter **106** at a helix angle of thirty degrees (30°). However, helix angles above and below thirty degrees (30°) are considered within the scope of the various embodiments of the present techniques. The teeth or bladed edges of the cutter **106** may be configured depending on a desired specification of the fibers that result from the milling process. For example, the helix angle of the teeth or bladed edges may be one factor in determining a thickness of the fibers for a given cutter rotational speed.

[0028] In certain embodiments, the cutter shaft may be connected to a drive motor **122**, such as a variable speed drive motor. In other embodiments, the cutter shaft may be configured to be actuated manually with a crank, or other suitable mechanism. The drive motor **122** may be operated manually, electrically, or by a computing device. In a non-limiting embodiment, the drive motor **122** may be isolated from the cutting room environment such as in an isolation chamber or adjacent room, so that any contaminants (e.g. dust, grease, shavings, or fumes) created by the drive motor **122** may be kept away from the cutting room environment, which may be a clean room or sterile environment.

[0029] The bone milling apparatus **100** includes a push block assembly **110** configured to hold or push the bone segment against the cutter **106** during operation of the bone mill. The push block assembly includes a crank arm **112**, a crank handle **114**, a push block **116**, and a drive screw **118**. In certain embodiments, the crank arm **112** is coupled to the crank handle **114** in a perpendicular orientation and in a position such that the crank handle **114** is positioned at an end of the crank arm **112**. In other embodiments, the crank handle **114** is positioned in other suitable positions along the length of the crank arm **112**, as long as a force applied along the length of the crank handle **114** transfers a tangential force causing the crank arm **112** to rotate around an end opposite to the end where the crank handle **114** mounts.

[0030] As a result of the application of the tangential force, the crank arm **112** introduces a rotational motion to the drive screw **118**. At a first end, the drive screw **118** is removably coupled to the end of the crank arm **112** opposite to the crank handle **114**, and at a second end, the drive screw **118** is removably coupled to the push block **116**. In certain embodiments, the drive screw **118** is configured to transfer rotational motion into an axial force. For example, as a result of the crank arm **112** introducing a rotational motion to the first end of the drive screw **118**, the drive screw **118** in turn transfers an axial force to the push block **116**. In other embodiments, the drive screw may be dimensioned in such a manner such that the geometry of the screw may sufficiently counteract any forces that may propagate from the cutter **106** through the push block **116**.

[0031] The push block assembly **110** includes the push block **116** that may be configured to engage the bone segment and hold the sample against the cutter **106**. Additionally or alternatively, the push block **116** includes an interface surface **117** configured to include one or more engaging features that assist in maintaining the sample against the cutter **106**. In certain embodiments, the engaging features include serrations, spikes, nodules, one or more textured surfaces, knurling, or the like, or any combinations thereof. The engaging features of the interface surface **117** may be integral to the push block **116**, or may removably attach to the push block. The engaging features of the interface surface may be made of similar or different material than the push block **116**. Further, the geometry of the push block **116** may be configured such that the profile of the push block matches or is complementary to the diameter of the cutter **106**. For example, the profile geometry of the interface surface **117** may be defined in part by a radius characteristic or parameter that matches or approximates (i.e., matches within a tolerance such as a manufacturing tolerance) the diameter of the cutter **106**, such that when the drive screw **118** extends the push block **116** to a maximum length, the interface surface **117** may closely fit around a portion of the cutter **106**, enabling the bone segment to be nearly completely be milled with little or no residual bone material being unprocessed.

[0032] In certain embodiments, the push block assembly **110** may be connected to a push block motor **128**, such as a variable speed drive motor. As described above, similar to the drive motor **122**, the push block motor **128** may be operated manually, electrically, or by an electromechanical controller or computing device. In a non-limiting embodiment, the push block motor **128** may be isolated from the cutting room environment such as in an isolation chamber or adjacent room, so that any contaminants (e.g. dust, grease, shavings, fumes, etc.) created by the push block motor **128** may be kept away from the cutting room environment.

[0033] The bone milling apparatus **100** may include a feed chute **126**. Generally, the feed chute **126** may be include an opening, bore, or aperture positioned proximate to the housing **102**. In a non-limiting embodiment, the feed chute **126** may be configured to receive a bone segment having a length corresponding approximately to the length of the cutter **106** (or shorter), and to present the sample in an orientation such that the length of the sample is substantially parallel to the rotational axis of the cutter **106** during operation. In certain embodiments, the bone segment is a portion of a bone, and the results from the milling operation produces fibers of a specified length and thickness. As the fibers are produced, they are collected in a fiber pan **124** disposed in a suitable position proximate to the cutter **106** and bone segment such that the fiber pan catches the fibers produced from the operation. After the fibers from the sample are produced, they are transferred in the fiber pan **124** to a processing area so that they may be utilized, such as in the production of shaped osteogenic materials.

[0034] In the illustrated embodiment, a bearing support assembly **148** is included in the bone milling apparatus **100**. As will be discussed in further detail below, the bearing support housing **14** includes a plurality of bearings configured to provide support to the cutter shaft **108** during operation of the bone mill. Also, a control system **200** is included in the bone milling apparatus **100**. As will be discussed in further detail below, the control system **200** includes a controller, which in some embodiments includes a processor and a memory configured to provide instructions to various components of the bone milling apparatus **100**. In other embodiments, the control system may utilize a specialized integrated circuit (e.g., an application specific integrated circuit (ASIC)) designed to generate a control signal in response to a feedback signal as opposed to or in addition to a processor. In certain embodiments, the control system **200** may output instructions to the drive motor **122** and/or the push block motor **128** that controls the electrical power (i.e., a current, a voltage) transmitted to the actuating components of the bone milling apparatus **100**. The control system **200** may include a plurality of controllers, such that a controller is configured to output instructions to an individual actuator. In other embodiments, a single controller is configured to output instructions to the various actuating components of the bone milling apparatus.

[0035] FIG. **2** is a schematic view of the elements of the control system **200** in accordance with aspects of the present techniques. In the illustrated embodiment, the control system **200** for the bone milling apparatus **100** is depicted. The control system **200** includes a controller **202** that is communicatively or electrically coupled to the drive motor **122** that actuates the cutter **106**, and communicatively or electrically coupled to the push block motor **128** that actuates the push block assembly **110**. As discussed in more detail below, the controller **202** may be configured to output instructions to the motors in the form of control signals along control paths **226**, **228**, and may be configured to receive feedback along communication paths **222**, **224** that are indicative of operating conditions while the bone milling apparatus **100** is in operation. The controller **202** includes a processor **206**, a memory **204**, and a sensor **208** that are configured to work together to provide instructions to the various components of the bone milling apparatus **100**. For example, the controller **202** may be programmed (e.g., via computer readable code or instructions stored on the memory **204**, such as a non-transitory computer readable medium, and executable by the processor **206** and/or by circuit design of an ASIC) to provide signals for controlling the motors **122**, **128**. In certain embodiments, the controller **202** may be programmed according to a specific configuration desired for a particular application. Additionally or alternatively, the sensor **208** may be configured to detect external inputs, reference signals, or other suitable signals that are indicative of the performance of the bone milling apparatus **100**. In a non-limiting embodiment, the controller **202** may be configured to respond to external inputs and reference signals detected by the sensor **208**, and the controller may be configured to respond in a programmed or pre-determined manner according to a set of operating parameters. For example, the operating parameters may determine the speed or torque of the motors **122**, **128** or may determine how the controller **202** responds to various external inputs detected by the sensor **208**. With feedback data from the sensor **208**, the control system **200** may keep detailed track of the various conditions under which the bone milling apparatus **100** is operating. For example, the feedback data may include conditions such as actual motor speed, voltage, frequency, power quality, alarm conditions, etc. In some embodiments, the feedback data may be communicated back to one or more computing devices **210** for additional analysis.

[0036] The computing device **210** may be communicatively coupled to the controller **202** via a wired or wireless connection. The computing device **210** may receive inputs from a user defining a bone milling operation using a native application running on the computing device **210** or using a website accessible via a browser application, a software application, or the like. The user may define a series of steps and processes that define the bone milling operation by writing code, interacting with a visual programming interface, inputting or selecting values via a graphical user interface, or providing some other inputs. The user may use software and/or software services to create, analyze, and otherwise develop the operation. The computing device **210** may send a set of operating parameters to the controller **202** for execution. Execution of the operation causes the controller **202** to control the actuating components (i.e. the drive motor **122** and the push block motor **128**) through performance of one or more tasks and/or processes. The controller **202**, via the sensor **208**, may collect feedback data during execution of the operation, and the feedback data may be provided back to the computing device **210** for analysis. In certain embodiments, the feedback data may include one or more execution times, one or more alerts, one or more error messages, one or more alarm conditions, one or more motor speeds, one or more voltages, one or more frequencies, and so forth.

[0037] The computing device **210** may be communicatively coupled to a cloud server **214** or remote server via the internet, or some other network. In one embodiment, the cloud server **214** may be operated by the manufacturer of the controller **202**, a software provider, a seller of the controller **202**, a service provider, an operator of the controller **202**, owner of the controller **202**, etc. The cloud server may be used to help users create and modify different operating programs or control feedback "recipes" to be utilized by the bone milling apparatus **100**, to help troubleshoot any problems that arise with the controller, develop policies, or to provide other services. The remote/cloud server **214** may be one or more servers operated by the manufacturer, software provider, seller, service provider, operator, or owner of the controller **202**. The remote/cloud server **214** may be disposed at a facility owned and/or operated by the manufacturer, software provider, seller, service provider, operator, or owner of the controller **202**. In other embodiments, the remote/cloud server **214** may be disposed in a datacenter in which the manufacturer, software provider, seller, service provider, operator, or owner of the controller **202** owns or rents server space. In further embodiments, the remote/cloud server **214** may include multiple servers operating in one or more data center to provide a cloud computing environment.

[0038] The control system **200** includes a power source **216**, which is configured to provide electrical power to various components of the control system **200**. The power source **216** may include a generator, an external power grid, a battery, or some other source of power. In certain embodiments, the power source **216** may be electrically coupled to the controller **202**, the drive motor **122** for the cutter **106**, the push block motor **128**, and any other suitable electrical component that requires a power source. In some embodiments, the power source **216**, similar to the motors **122**, **128** may be disposed in a power room environment **236** separate from the cutting environment **238**.

[0039] In the illustrated embodiment, the controller **202** is communicatively coupled to the drive motor **122**. A first communication path **222** is configured to connect the drive motor **122** to the controller **202** such that the sensor **208** receives an input signal indicative of current operating conditions experienced by the drive motor **122**. For example, the drive motor **122** may experience a condition where the cutter **106** requires an additional amount of power to cut through a particular cross section of a bone segment. In some embodiments, the controller **202** receives the signal from the sensor **208**, accesses programmed control recipes stored in the memory **204** via the processor **206**, and determines an appropriate control signal to output along a first control path **228** to the drive motor **122**. The signal received from the sensor may use a detected voltage and/or current from the drive motor **122**, and the controller **202** may determine a requisite power output that would be suitable. In other embodiments, the controller **202** may continuously receive input signals via the first communication path **222** and continuously output control signals along the first control path **228** to enable the drive motor **122** to cut bone fibers that are consistent in thickness, length, and quality.

[0040] In the illustrated embodiment, the controller **202** is communicatively coupled to the push block motor **128**. A second communication path **224** is configured to connect the push block motor **128** to the controller **202** such that the sensor **208** receives an input signal indicative of current operating conditions experienced by the push block motor **128**. For example, the push block motor **128** may experience a condition where the push block assembly **110** requires an additional amount of power to keep the bone segment in contact with the cutter **106**. In some embodiments, the controller **202** receives the signal from the sensor **208**, accesses programmed control recipes stored in the memory **204** via the processor **206**, and determines an appropriate control signal to output along a second control path **226** to the push block motor **128**. The signal received from the sensor may use a detected voltage and/or current from the push block motor **128**, and the controller **202** may determine a requisite power output that would be suitable. In other embodiments, the controller **202** may continuously receive input signals via the second communication path **224** and continuously output control signals along the second control path **228** to enable the push block motor **128** to keep the bone segment in a position such that the cutter **106** may cut bone fibers that are consistent in thickness, length, and quality.

[0041] In the illustrated embodiment, a barrier **234**, **146** is configured to divide the bone milling apparatus **100** into two or more environments. In a first environment, a cutting room environment **238** includes the cutter **106**, housing **102**, cover **104**, push block assembly **110**, feed chute **126** and fiber pan **124** as discussed previously in FIG. **1**. The cutting room environment **238** is an enclosed work area, and it is envisioned and within the scope of the present techniques that the enclosed work area could be as large as a room, and the cutter **106** may extend into the cutting room environment **238** from one or more of the other environments. Additionally or alternatively, the bone segment **230** and cutter **106** are advantageously situated within the cutting room environment **238**, isolated from other environments and potential contaminants, so as to reduce the opportunity for degradation or contamination of the bone segment **230** or completed bone fibers **232**. In other embodiments, the cutting room environment **238** would meet the requirements for an ISO 5 cleanroom designation. In a second environment, a power room environment **236** includes the drive motor **122**, the push block motor **128**, the control system **200**, the computing device **210** and the power source **216**.

[0042] FIG. **3** illustrates a block diagram of example components of a computing device **300** that could be used as the computing device **210**, the cloud/remote server **214**, the controller **202**, or some other device provided by the present techniques. As used herein, the computing device **300** may be implemented as one or more computing systems, including a laptop, notebook, desktop, tablet, HMI, or workstation computer, as well as server type devices (e.g., on-prem servers, remote servers, cloud servers) or portable, communication type devices, such as cellular telephones and/or suitable computing devices.

[0043] As illustrated, the computing device **300** may include various hardware components, such as one or more processors **302**, one or more busses **304**, memory **306**, input structures **308**, a power source **310**, a network interface **312**, a user interface **314**, and/or other computer components useful in performing the functions described herein. The one or more processors **302** may include, in certain implementations, microprocessors configured to execute instructions stored in the memory **306** or other accessible locations. Alternatively, the one or more processors **302** may be implemented as application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), and/or devices designed to perform functions discussed herein in a dedicated manner. As will be appreciated, multiple processors **302** or processing components may be used to perform functions discussed herein in a distributed or parallel manner.

[0044] The memory **306** may encompass any tangible, non-transitory medium for storing data or executable routines. Although shown for convenience as a single block in FIG. **2**, the memory **306** may encompass various discrete media in the same or different physical locations. The one or more processors **302** may access data in the memory **306** via one or more busses **304**.

[0045] The input structures **308** may allow a user to input data and/or commands to the device **300** and may include mice, touchpads, touchscreens, keyboards, controllers, and so forth. The power source **310** can be any suitable source for providing power to the various components of the computing device **300**, including line and battery power. In the depicted example, the device **300** includes a network interface **312**. Such a network interface may allow communication with other devices on a network using one or more communication protocols. In the depicted example, the device **300** includes a user interface **314**, such as a display that may display images or data provided by the one or more processors **302**. The user interface **314** may include, for example, a monitor, a display, and so forth. As will be appreciated, in a real-world context a processor-based system, such as a computing device **300** of FIG. **3**, may be employed to implement some or all of the present approach, such as performing the functions of the controller **202**, the computing device **210**, and or the cloud/remote server **214** shown in FIG. **2**, as well as other memory-containing devices.

[0046] FIG. **4** depicts a flowchart of an embodiment of a method **400** for automatically controlling a bone milling apparatus during a milling operation of a bone sample. First in block **410** of the method **400**, a bone milling apparatus includes a controller configured to determine a target force to keep a bone segment in contact with a cutter. In other embodiments, the controller may be configured to determine a cutting force that may be targeted to be outputted by a cutter in order to mill appropriately sized bone fibers. In certain embodiments, the controller may determine the target forces by accessing stored programming that may include "recipes" (i.e., preset or preconfigured operational setting and/or parameters) and/or predefined actions to take when the controller experiences a particular condition, as may be determined from a feedback or other sensor signal in some embodiments. In other embodiments, a computing device may input a desired length, thickness, or other controllable quality of a finished bone fiber, and the controller may receive the input and determine the target force output to maintain the bone segment in a position that enables the bone milling apparatus to output appropriately sized fibers. Additionally or alternatively, the recipes or predefined actions may include instructions for milling a bone segment with a specified length, thickness, and cross-sectional geometry, and based on historical data, determine a recipe for modifying the forces outputted by the push block motor and the cutting motor as the bone segment is milled.

[0047] At **420**, the controller receives from a sensor a signal indicative of the measured force enacted by a push block assembly against the bone sample. The signal that the sensor receives may be in the form of a voltage, current, or otherwise appropriate means that may be used as a corollary to the measured force enacted to hold the bone sample against the cutter. In certain embodiments, the controller continuously receives signals indicative of the force enacted by the push block assembly. Due to the cross section of the bone sample varying during different stages of operation, the force enacted by the push block assembly may vary in a similar manner during the duration of the milling operation. At **430**, the controller determines a difference between the target force to hold the bone sample against the cutter and the force currently being enacted. In some embodiments, the target force may be greater than the measured force enacted upon the push block assembly, the target force may be less than the measured force enacted upon the push block assembly, or the target force may be substantially equal to the measured force enacted upon the push block assembly. For example, while milling the bone segment, the cross-sectional area of the sample being milled may vary during the operation, and during portions of the duration where the cross-sectional area being milled is at a maximum, the power drawn from the push block motor and cutting motor to generate the target forces may be at a maximum. Additionally or alternatively, while the cross-sectional area of the sample being milled is at a minimum, the power drawn from the push block motor and cutting motor to generate the target forces may be at a minimum.

[0048] At **440**, the controller may output instructions to modify the force outputted by the motor that is indicative of the determined difference between the target force and the measured force enacted. In certain embodiments, if the target force is greater than the measured force enacted upon the push block assembly, the controller may output a recipe including instructions that include increasing the power outputted by a push block motor. The increase in the power outputted may take the form of an increased torque, increase in speed or RPM of the motor, or otherwise appropriate means for increasing the power output. In other embodiments, if the target force is less than the measured force enacted upon the push block assembly, the controller may output a recipe including instructions that include decreasing the power outputted by the push block motor. The decrease in the power outputted may take the form of a decreased torque, decrease in speed or RPM of the motor, or otherwise appropriate means for decreasing the output. In a non-limiting embodiment, if the target force is substantially equal to the measured force enacted, and the controller may output a recipe including instructions to keep the power output of the motor at current levels.

[0049] FIG. **5** is a front view of a simplified bone milling apparatus **100** in various stages of operation. In block **501**, a full bone segment **503** is shown on top of the bottom plate **511** and is in a state prior to the milling process beginning. The full bone segment **503** is placed against the push block assembly **507** which is configured to translate horizontally along the bottom plate **511**. In block **501**, the push block assembly **507** is positioned away from the cutter **505**, which is disposed to the right of the bottom plate **511**. The push block assembly **507**, as described previously, is configured to translate horizontally and apply an axial force **513** on the full bone segment **503**, as the crank handle **509** is rotated. In certain embodiments, a drive motor may be coupled to the crank handle **509** or an otherwise appropriate member to electrically drive the rotation of the crank handle **509**, thereby electrically applying the axial force **513**.

[0050] In block **531**, a partially cut bone segment **533** is shown on top of the bottom plate **511** and is in a state during the milling process. The partially cut bone segment **533** is kept in place against the cutter **505** by the push block assembly **507** as the crank handle **509** rotates. In certain embodiments, the cutter **505** is configured to rotate such that the partially cut bone segment **533** is able to produce bone fibers that have a consistent length, shape, thickness and quality. In block **561**, a cut bone segment **563** is shown on top of the bottom plate **511** and is in a state nearing the end of the milling process. The cut bone segment **563** is kept in place against the cutter **505** by the push block assembly **507** as the crank handle **509** rotates. In a non-limiting embodiment, the cutter is configured to rotate such that the blade matches a profile of the push block of the push block assembly **507**. In other embodiments, the push block profile may be configured to prevent the bone segment **503**, **533**, **563** from rotating while it is being cut, contributing to the consistency of the bone fibers produced from the bone milling apparatus.

[0051] FIG. **6** is a schematic view of an embodiment of a bearing housing assembly **600** that is included as a part of the bone milling apparatus **100**. The bearing housing assembly may include a support housing **602**, a cutter shaft **603**, **108**, a first bearing **606**, a second bearing **608**, a coupling **610**, and a plurality of fasteners **614**. The support housing **602** is configured to provide rigidity and support for the cutter shaft **603**, **108** and provide support for the first bearing **606** and second bearing **608**. Additionally or alternatively, the support housing **602** is configured to provide cover for the cutter shaft **603**, **108** such that contaminants (dust, grease, shavings, or fumes, etc.) do not come into contact with the cutter shaft as it rotates. In a non-limiting embodiment, the support housing **602** has an outer cylindrical shell **620** and an inner cylindrical annular portion **622** connected by a radial end plate **624**. Further, the outer cylindrical shell **620** may additionally be fixed to a flange **626** on an end opposite from the radial end plate **624**. In other embodiments, the support housing **602** and associated components **620**, **622**, **624**, **626** may be made from any suitable material, such as but not limited to cast iron, steel, metal, metal alloy, or any combination thereof. In a non-limiting embodiment, the radial end plate **624** may make up at least a portion of the barrier wall between the cutting room environment and the power room environment. Additionally or alternatively, the radial flange **626** may couple with a mounting plate of a motor, and the plurality of fasteners **614** may assemble through associated thru holes in the radial flange **626** and assemble into the mounting plate.

[0052] The inner cylindrical annular portion **622** may include a plurality of bearing housing locations configured to accept the first bearing **606** and the second bearing **608**. In certain embodiments, the first bearing **606** and the second bearing **608** may be a cylindrical roller bearing, a single row tapered roller bearing, a spherical bearing, or any otherwise suitable bearing design. The first bearing **606** and second bearing **608** may be of similar configurations and diameters, or may have different configurations and different diameters. In other embodiments, the first bearing **606** and second bearing may both be cylindrical roller bearings. In yet other embodiments, the first bearing **606** may be a single-row tapered roller bearing and the second bearing **608** may be a spherical roller bearing. By utilizing the support housing **602** with the inner cylindrical annular portion **622**, present embodiments enable a larger distance between the first bearing **606** and second bearing **608**, and eliminate the requirement for additional wear bushings, and corresponding bushing housings that require additional maintenance.

[0053] In some embodiments, the cutter shaft **603**, **108** includes a plurality of portions, with each portion configured to provide different functionalities. Taken together, the cutter shaft **603**, **108** may be configured to transfer a rotational output from a motor shaft **612** to and output a cutting force via the cutter **106**, as shown previously in FIG. **1**. In certain embodiments, the cutter shaft **603**, **108** includes a coupling portion **628**, a middle portion **616**, and a cutter head portion **604**. In other embodiments, the cutter shaft **603**, **108** may include additional portions configured to perform other various suitable operations related to bone milling. The coupling portion **628** may be configured to couple to the motor shaft **612** and may have a specified diameter. In the illustrated embodiment, the coupling portion **628** has a substantially similar diameter as the motor shaft **612**, and this similarity enables the coupling portion **628** and motor shaft **612** to be attached via a coupling **610**. The diameter of the coupling portion **628** may be different than the diameters of the middle portion **616** and the cutter head portion **604**. For example, in one embodiment, the coupling portion **628** may have a smaller diameter than the middle portion **616** and the cutter head portion **604**. As a result of the coupling portion **628** having a smaller diameter than the middle portion **616**, this enables the first bearing **606** and second bearing **608** to assemble onto the middle portion **616** by sliding over the coupling portion **628**.

[0054] As stated above, the middle portion **616** of the cutter shaft **603** may be configured to interface with the first bearing **606** and second bearing **608**. In the illustrated embodiment, the middle portion **616** has a substantially similar diameter along the length of the middle portion. In certain embodiments, the middle portion **616** may have a smaller diameter than the cutter head portion **604** of the cutter shaft **603**. The cutter head portion **604** is configured to accept a cutter. In other embodiments, the cutter head portion **604** may be configured to have a diameter specified to be larger than an interfacing inner diameter of the cutter, thereby introducing an interference fit between the cutter head portion **604** and the cutter. In a non-limiting embodiment, the diameter of the cutter head portion **604** may be specified to be smaller than the interfacing inner diameter of the cutter, and provide for an otherwise appropriate means for attaching the cutter to the cutter shaft **603**. In a non-limiting embodiment, the cutter shaft **603** may be made of any suitable material, including but not limited to metal, steel, metal alloy, or any combination thereof.

[0055] The subject matter described in detail above may be defined by one or more clauses, as set forth below.

[0056] Clause 1: A system comprises a bone mill configured to mill bone fibers from a bone segment during use, wherein the bone mill comprises a cutter and a push block assembly. Additionally, the system comprises an actuator configured to receive a force input specifying a target force to keep the bone segment in contact with the cutter during operation, and in response to receiving the force input, outputting an output force based on the target force, and a sensor configured to detect a measured force enacted by the push block assembly onto the bone segment. Also, the system comprises a control system that comprises processing circuitry and a memory, accessible by the processing circuitry, and storing instructions that, when executed by the processing circuitry, cause the processing circuitry to perform actions including determining the target force to keep the bone segment in contact with the cutter, receiving from the sensor a signal corresponding to the measured force enacted by the push block assembly, determining a difference between the target force and the measured force enacted, and outputting instructions directly or indirectly to the actuator to adjust operation of the push block assembly based on the determined difference.

[0057] Clause 2: The system of clause 1, wherein the sensor continuously detects the measured force enacted by the push block assembly onto the bone segment.

[0058] Clause 3: The system of clause 1 or 2, wherein the processing circuitry of the control system performs actions including adjusting operation of the actuator by continuously receiving from the sensor the signal corresponding to the measured force enacted by the push block assembly, continuously determining the difference between the target force and the measured force; and outputting instructions directly or indirectly to the actuator that adjust the target force based on changes in the difference.

[0059] Clause 4: The system of clause 1, 2, or 3 further including an additional actuator, wherein the additional actuator is coupled to the cutter, and an additional sensor configured to detect a measured rotational output enacted by the cutter onto the bone segment.

[0060] Clause 5: The system of clause 1, 2, 3, or 4, wherein the processing circuitry of the control system performs actions including determining a target rotational output to turn the cutter through the bone segment, receiving from the additional sensor an additional signal corresponding to the measured rotational output enacted by the cutter, determining an additional difference between the target rotational output and the measured rotational output enacted; and outputting instructions directly or indirectly to the additional actuator to adjust operation of the cutter based on the determined additional difference.

[0061] Clause 6: The system of clause 1, 2, 3, 4, or 5, wherein the additional sensor continuously detects the measured rotational output enacted by the cutter onto the bone segment.

[0062] Clause 7: The system of clause 1, 2, 3, 4, 5, or 6, wherein the processing circuitry of the control system performs actions including adjusting operation of the additional actuator by continuously receiving from the additional sensor the additional signal corresponding to the measured rotational output enacted by the cutter, continuously determining the additional difference between the target rotational output and the measured rotational output; and outputting instructions directly or indirectly to the additional actuator that adjust the target rotational output based on changes in the difference.

[0063] Clause 8: The system of clause 1, 2, 3, 4, 5, 6, or 7, including a controller, wherein the controller is programmed via the instructions stored on the memory to provide signals for controlling the actuator and the additional actuator.

[0064] Clause 9: The system of clause 1, 2, 3, 4, 5, 6, 7, or 8, including a computing device, wherein the computing device is communicatively coupled to the controller.

[0065] Clause 10: The system of clause 1, 2, 3, 4, 5, 6, 7, 8, or 9, including a cloud server, wherein the cloud server is communicatively coupled to the computing device, wherein the computing device and the cloud server communicate through a network interface.

[0066] Clause 11: The system of clause 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10, wherein a user defines a bone milling operation on the computing device by using a native application, a website accessible via a browser application, a software application, or a combination thereof.

[0067] Clause 12: A bone fiber is cut from a bone segment, wherein the bone fiber is cut by a process including determining a target force to keep the bone segment in contact with a cutter, receiving from a sensor a signal corresponding to a measured force enacted by a push block assembly, and determining a difference between the target force and the measured force enacted. The process also comprises determining a target rotational output to turn the cutter through the bone segment, receiving from an additional sensor an additional signal corresponding to a measured rotational output enacted by the cutter, and determining an additional difference between the target rotational output and the measured rotational output enacted. The process also comprises outputting instructions directly or indirectly to an actuator to adjust operation of the push block assembly based on the difference and outputting additional instructions directly or indirectly to an additional actuator to adjust operation of the cutter based on the additional difference.

[0068] Clause 13: The bone fiber of clause 12, wherein the bone fiber is cut to a consistent thickness, a consistent length, and a consistent quality.

[0069] Clause 14: A method comprises determining a target force to keep a bone segment in contact with a cutter, receiving from a sensor a signal corresponding to a measured force enacted by a push block assembly, determining a difference between the target force and the measured force enacted; and outputting instructions directly or indirectly to an actuator to adjust operation of the push block assembly based on the determined difference.

[0070] Clause 15: The method of clause 14, wherein the sensor continuously detects the measured force enacted by the push block assembly onto the bone segment.

[0071] Clause 16: The method of clause 14 or 15, including determining a target rotational output to turn the cutter, wherein the target rotational output corresponds to a cutting force suitable to mill fibers from the bone segment.

[0072] Clause 17: The method of clause 14, 15, or 16, wherein outputting instructions directly or indirectly to the actuator comprises increasing power outputted by the actuator, wherein the power outputted comprises at least one of actuator RPM, actuator torque, or a combination thereof.

[0073] Clause 18: The method of clause 14, 15, 16, or 17, wherein outputting instructions directly or indirectly to the actuator comprises decreasing power outputted by the actuator, wherein the power outputted comprises at least one of actuator RPM, actuator torque, or a combination thereof.

[0074] Clause 19: The method of clause 14, 15, 16, 17, or 18, wherein the act of determining the target force to keep the bone segment in contact with the cutter is performed by a controller that accesses a data store of pre-defined operational parameters or characteristics and selects one or more of the pre-defined operational parameters or characteristics based on the signal from the sensor.

[0075] Clause 20: The method of clause 14, 15, 16, 17, 18, or 19, wherein the act of determining the target rotational output to turn the cutter is performed by the controller that accesses the data store of pre-defined operational parameters or characteristics and selects one or more of the pre-defined operational parameters or characteristics based on an additional signal from an additional sensor corresponding to a measured rotational output enacted by the cutter.

[0076] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

[0077] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for (perform)ing (a function) . . . " or "step for (perform)ing (a function) . . . ", it is intended that such elements are to be interpreted under 35 U.S.C. 112 (f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112 (f).

1. A system, comprising:

a bone mill configured to mill bone fibers from a bone segment during use, wherein the bone mill comprises a cutter and a push block assembly;

an actuator configured to receive a force input specifying a target force to keep the bone segment in contact with the cutter during operation, and in response to receiving the force input, outputting an output force based on the target force;

a sensor configured to detect a measured force enacted by the push block assembly onto the bone segment; and

a control system comprising processing circuitry and a memory, accessible by the processing circuitry, and storing instructions that, when executed by the processing circuitry, cause the processing circuitry to perform actions comprising:

determining the target force to keep the bone segment in contact with the cutter;

receiving from the sensor a signal corresponding to the measured force enacted by the push block assembly;

determining a difference between the target force and the measured force enacted; and

outputting instructions directly or indirectly to the actuator to adjust operation of the push block assembly based on the determined difference.

2. The system of claim **1**, wherein the sensor continuously detects the measured force enacted by the push block assembly onto the bone segment.

3. The system of claim **2**, wherein the processing circuitry of the control system performs actions comprising adjusting operation of the actuator by:

continuously receiving from the sensor the signal corresponding to the measured force enacted by the push block assembly;

continuously determining the difference between the target force and the measured force; and

outputting instructions directly or indirectly to the actuator that adjust the target force based on changes in the difference.

4. The system of claim **1**, comprising:

an additional actuator, wherein the additional actuator is coupled to the cutter; and

an additional sensor configured to detect a measured rotational output enacted by the cutter onto the bone segment.

5. The system of claim **4**, wherein the processing circuitry of the control system performs actions comprising:

determining a target rotational output to turn the cutter through the bone segment;

receiving from the additional sensor an additional signal corresponding to the measured rotational output enacted by the cutter;

determining an additional difference between the target rotational output and the measured rotational output enacted; and

outputting instructions directly or indirectly to the additional actuator to adjust operation of the cutter based on the determined additional difference.

6. The system of claim **5**, wherein the additional sensor continuously detects the measured rotational output enacted by the cutter onto the bone segment.

7. The system of claim **6**, wherein the processing circuitry of the control system performs actions comprising adjusting operation of the additional actuator by:

continuously receiving from the additional sensor the additional signal corresponding to the measured rotational output enacted by the cutter;

continuously determining the additional difference between the target rotational output and the measured rotational output; and

outputting instructions directly or indirectly to the additional actuator that adjusts the target rotational output based on changes in the additional difference.

8. The system of claim **4**, comprising a controller, wherein the controller is programmed via the instructions stored on the memory to provide signals for controlling the actuator and the additional actuator.

9. The system of claim **8**, comprising a computing device, wherein the computing device is communicatively coupled to the controller.

10. The system of claim **9**, comprising a cloud server, wherein the cloud server is communicatively coupled to the computing device, wherein the computing device and the cloud server communicate through a network interface.

11. The system of claim **9**, wherein a user defines a bone milling operation on the computing device by using a native application, a website accessible via a browser application, a software application, or a combination thereof.

12. A bone fiber cut from a bone segment, wherein the bone fiber is cut by a process comprising:

determining a target force to keep the bone segment in contact with a cutter;

receiving from a sensor a signal corresponding to a measured force enacted by a push block assembly;

determining a difference between the target force and the measured force enacted;

determining a target rotational output to turn the cutter through the bone segment;

receiving from an additional sensor an additional signal corresponding to a measured rotational output enacted by the cutter;

determining an additional difference between the target rotational output and the measured rotational output enacted;

outputting instructions directly or indirectly to an actuator to adjust operation of the push block assembly based on the difference; and

outputting additional instructions directly or indirectly to an additional actuator to adjust operation of the cutter based on the additional difference.

13. The bone fiber of claim **12**, wherein the bone fiber is cut to a consistent thickness, a consistent length, and a consistent quality.

14. A method, comprising:

determining a target force to keep a bone segment in contact with a cutter;

receiving from a sensor a signal corresponding to a measured force enacted by a push block assembly;

determining a difference between the target force and the measured force enacted; and

outputting instructions directly or indirectly to an actuator to adjust operation of the push block assembly based on the determined difference.

15. The method of claim **14**, wherein the sensor continuously detects the measured force enacted by the push block assembly onto the bone segment.

16. The method of claim **14**, comprising determining a target rotational output to turn the cutter, wherein the target rotational output corresponds to a cutting force suitable to mill fibers from the bone segment.

17. The method of claim **14**, wherein outputting instructions directly or indirectly to the actuator comprises increasing power outputted by the actuator, wherein the power outputted comprises at least one of:

actuator RPM;

actuator torque; or

a combination thereof.

18. The method of claim **14**, wherein outputting instructions directly or indirectly to the actuator comprises decreasing power outputted by the actuator, wherein the power outputted comprises at least one of:

actuator RPM;

actuator torque; or

a combination thereof.

19. The method of claim **16**, wherein the act of determining the target force to keep the bone segment in contact with the cutter is performed by a controller that accesses a data store of pre-defined operational parameters or characteristics and selects one or more of the pre-defined operational parameters or characteristics based on the signal from the sensor.

20. The method of claim **19**, wherein the act of determining the target rotational output to turn the cutter is performed by the controller that accesses the data store of pre-defined operational parameters or characteristics and selects one or more of the pre-defined operational parameters or characteristics based on an additional signal from an additional sensor corresponding to a measured rotational output enacted by the cutter.

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