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(54) **ANATOMICAL MODELS AND ASSOCIATED METHODS**

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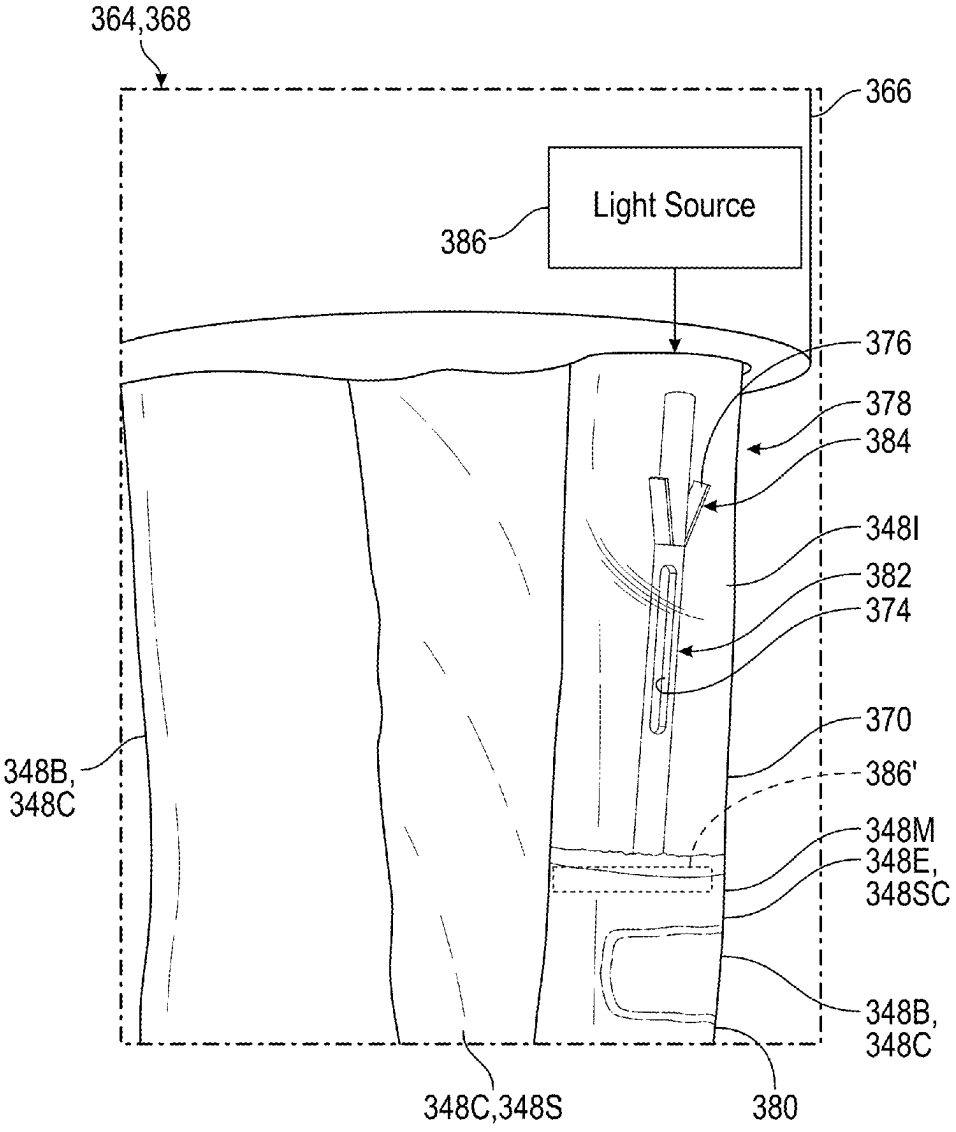
G09B 23/32	(2006.01)

(52) **U.S. Cl.**

CPC ***G09B 23/34*** (2013.01); ***G09B 23/32*** (2013.01); *A61F 2/4684* (2013.01)

(57) **ABSTRACT**

This disclosure relates to surgical systems, devices and methods for planning and implementing surgical procedures. The systems and methods disclosed herein may be utilized to establish physical anatomical models of anatomy. The physical anatomical model may include one or more features for viewing an interior of the model.



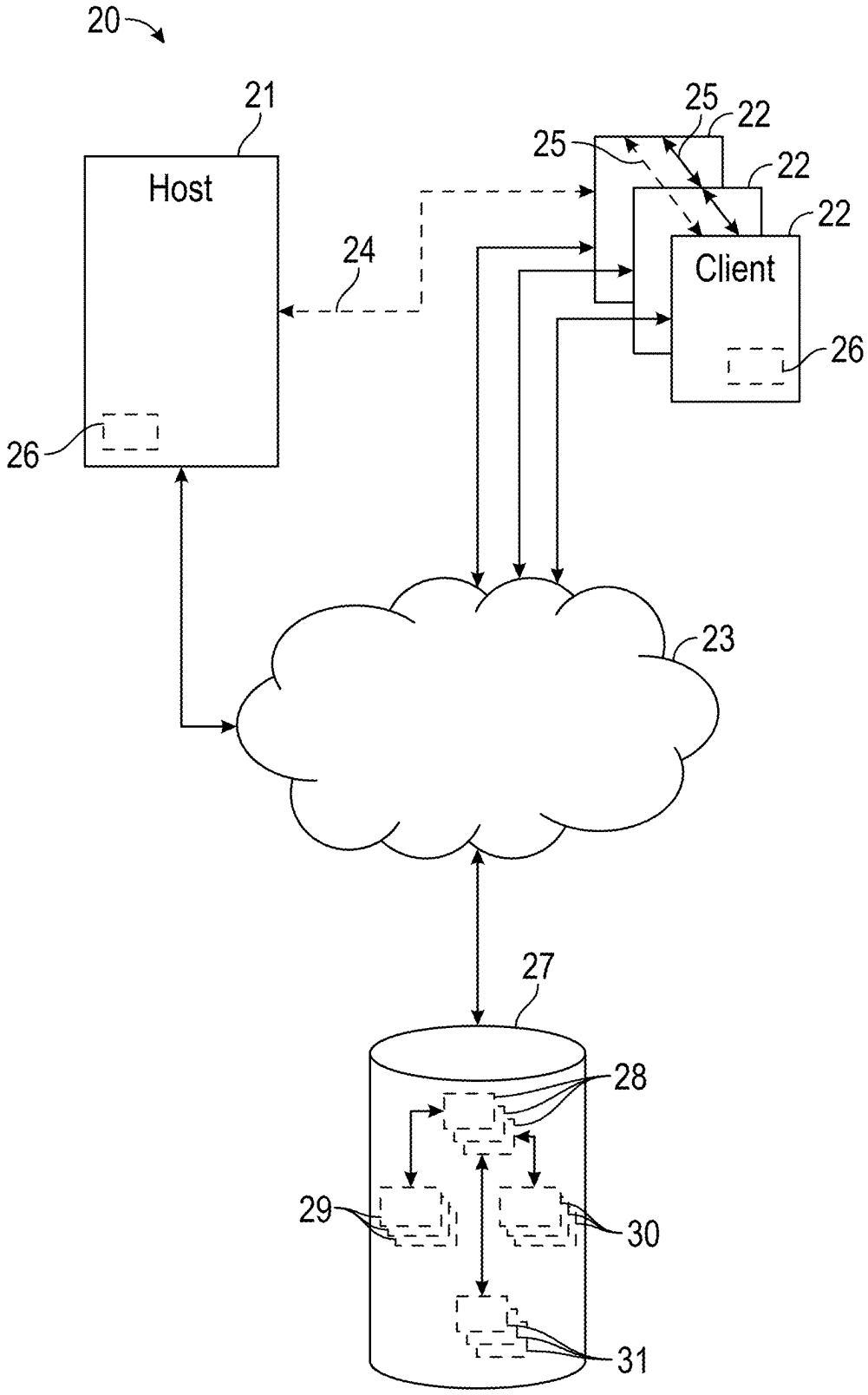


FIG. 1

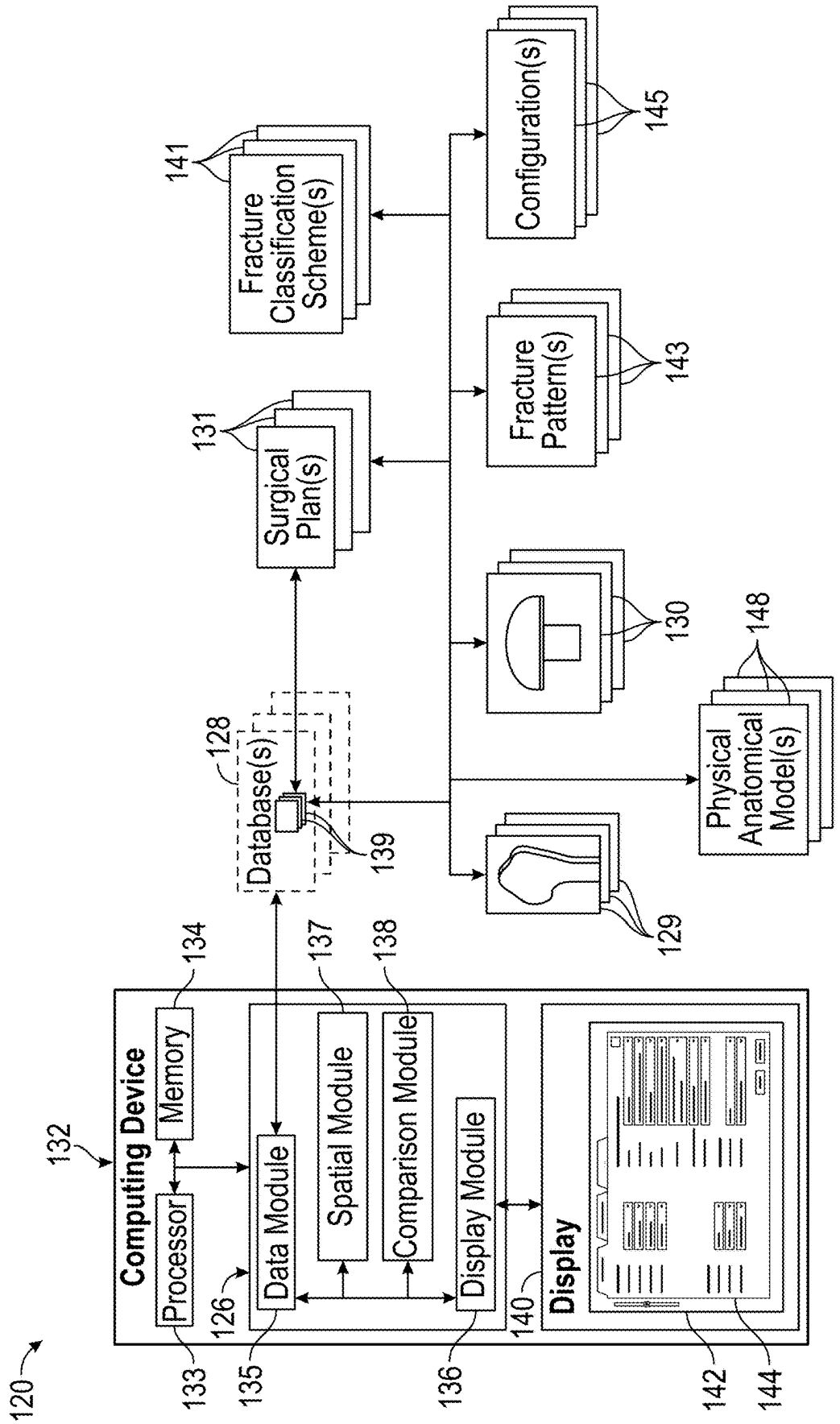

120
132
Computing Device
Memory
Processor
Data Module
Spatial Module
Comparison Module
Display Module
Display
134
137
138
126
140
133
135
136
142
144
Database(s)
128
139
Surgical Plan(s)
131
Fracture Classification Scheme(s)
141
Configuration(s)
145
Fracture Pattern(s)
143
130
Physical Anatomical Model(s)
148
129

FIG. 2

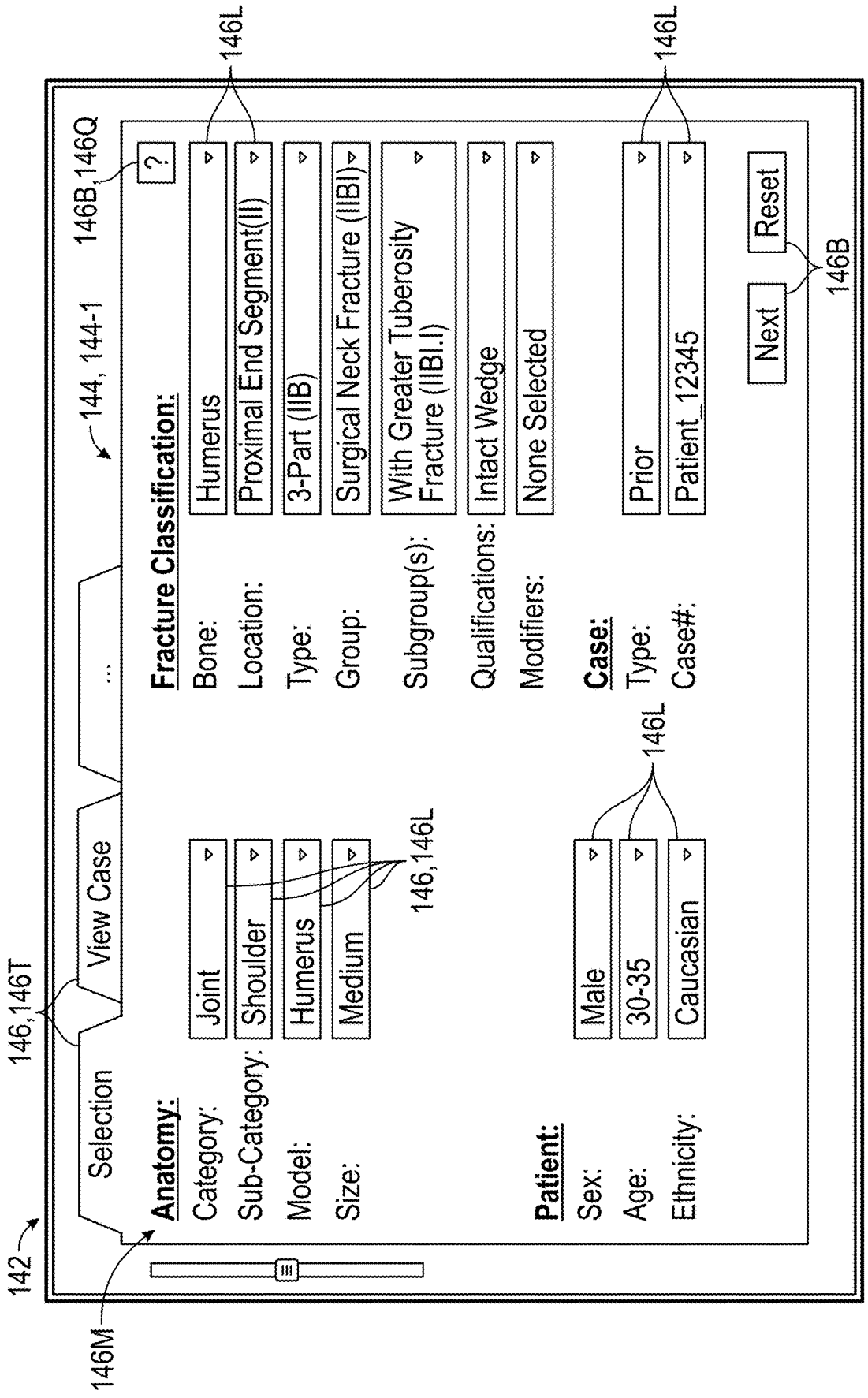

142
146M
146,146T
Selection
View Case
...
144, 144-1
146B,146Q
146L
146L
146L
146,146L
Anatomy:
Category:
Sub-Category:
Model:
Size:
Joint
Shoulder
Humerus
Medium
Patient:
Sex:
Age:
Ethnicity:
Male
30-35
Caucasian
Fracture Classification:
Bone:
Location:
Type:
Group:
Subgroup(s):
Qualifications:
Modifiers:
Humerus
Proximal End Segment(II)
3-Part (IIB)
Surgical Neck Fracture (IIBI)
With Greater Tuberosity Fracture (IIBI.I)
Intact Wedge
None Selected
Case:
Type:
Case#:
Prior
Patient_12345
?
Next
Reset
146B

FIG. 3

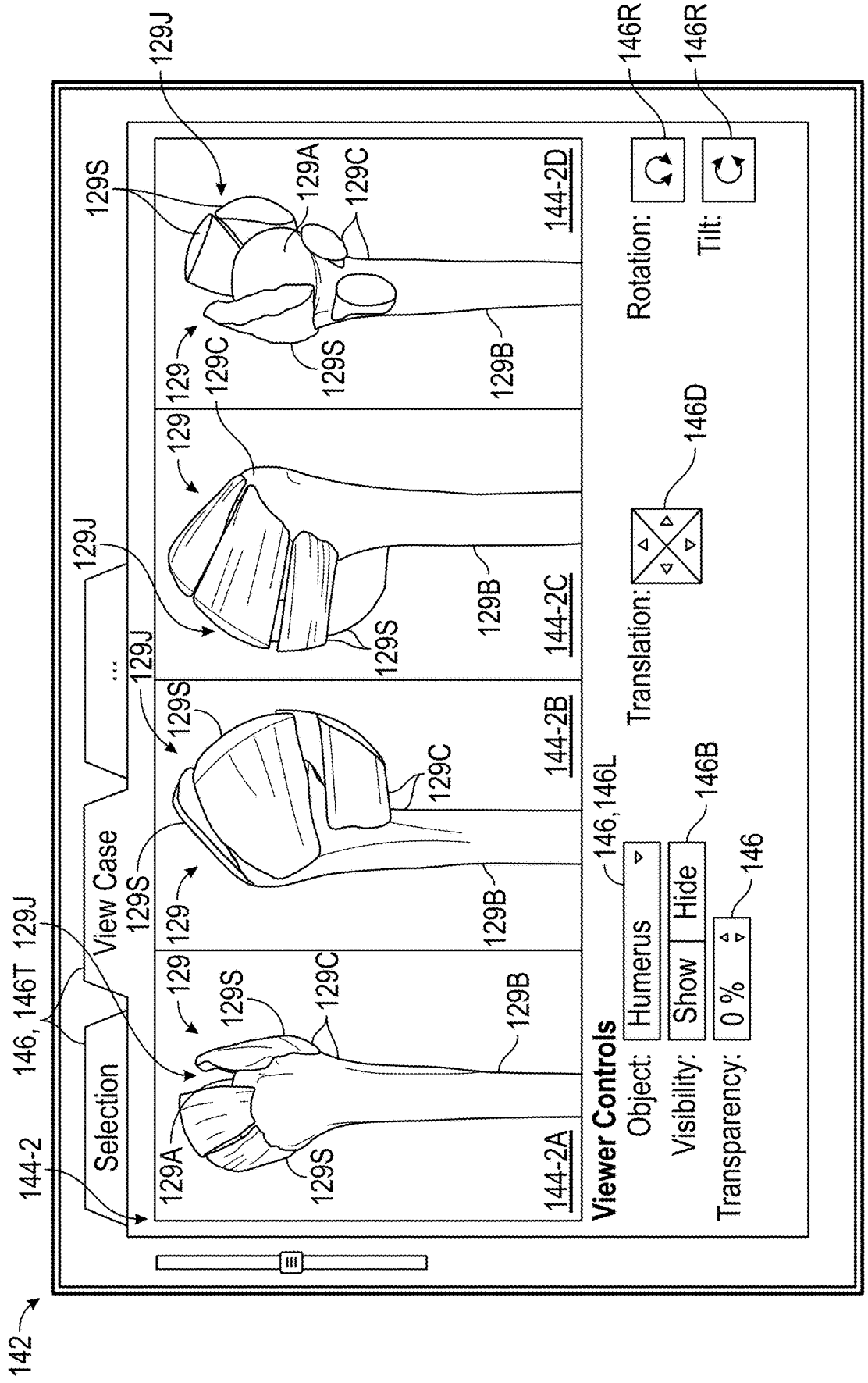

142
144-2
Selection
146, 146T
129J
View Case
129J
129S
129
129A
129C
129B
144-2A
144-2B
144-2C
144-2D
Viewer Controls
Object:
Humerus
146, 146L
Visibility:
Show
Hide
146B
Transparency:
0 %
146
Translation:
146D
Rotation:
146R
Tilt:
146R

FIG. 4

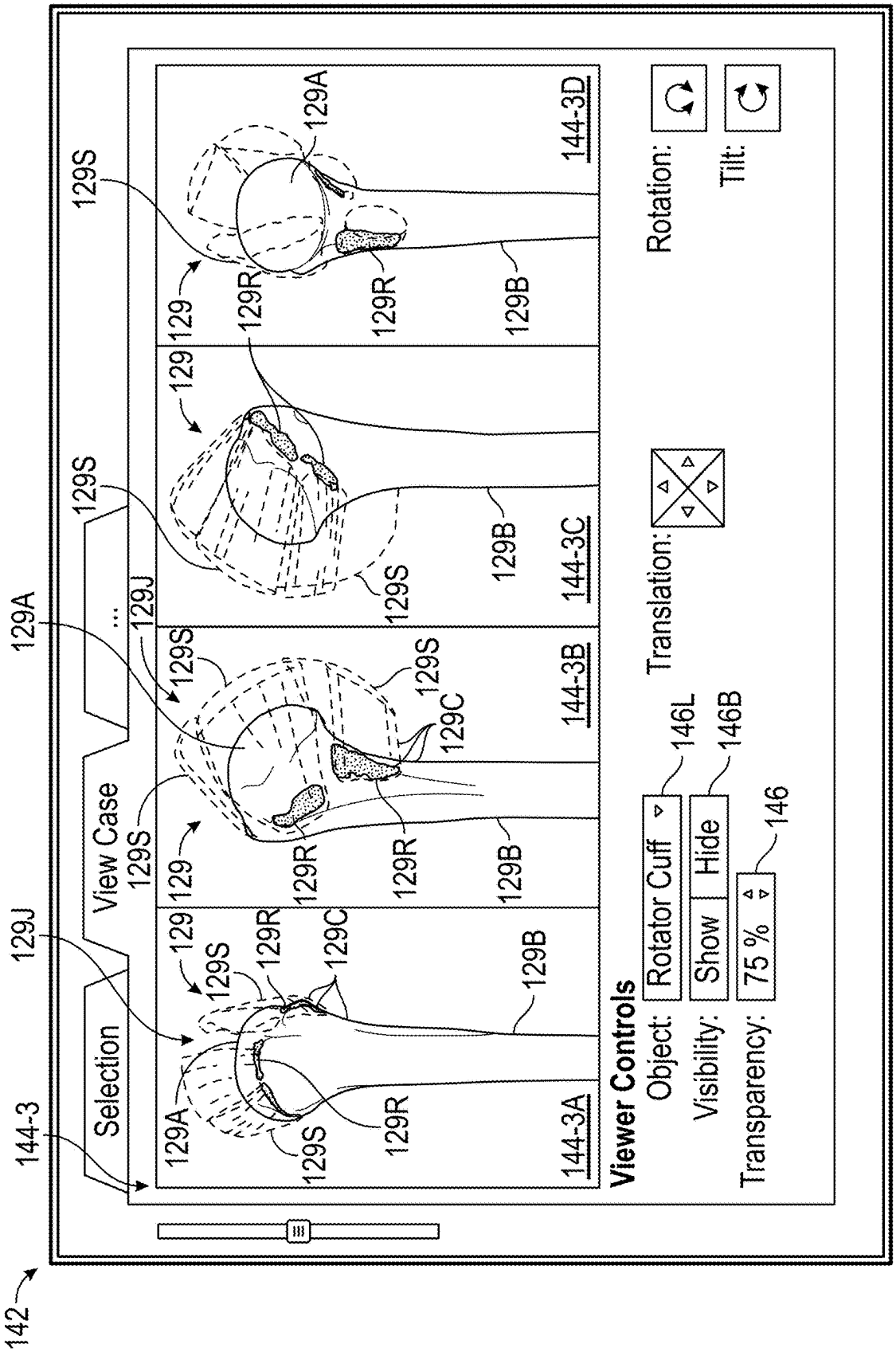

142
144-3
129A
129J
Selection
View Case
129S
129
129R
129B
129C
144-3A
144-3B
144-3C
144-3D
Viewer Controls
Object:
Rotator Cuff
146L
Visibility:
Show
Hide
146B
Transparency:
75 %
146
Translation:
Rotation:
Tilt:

FIG. 5

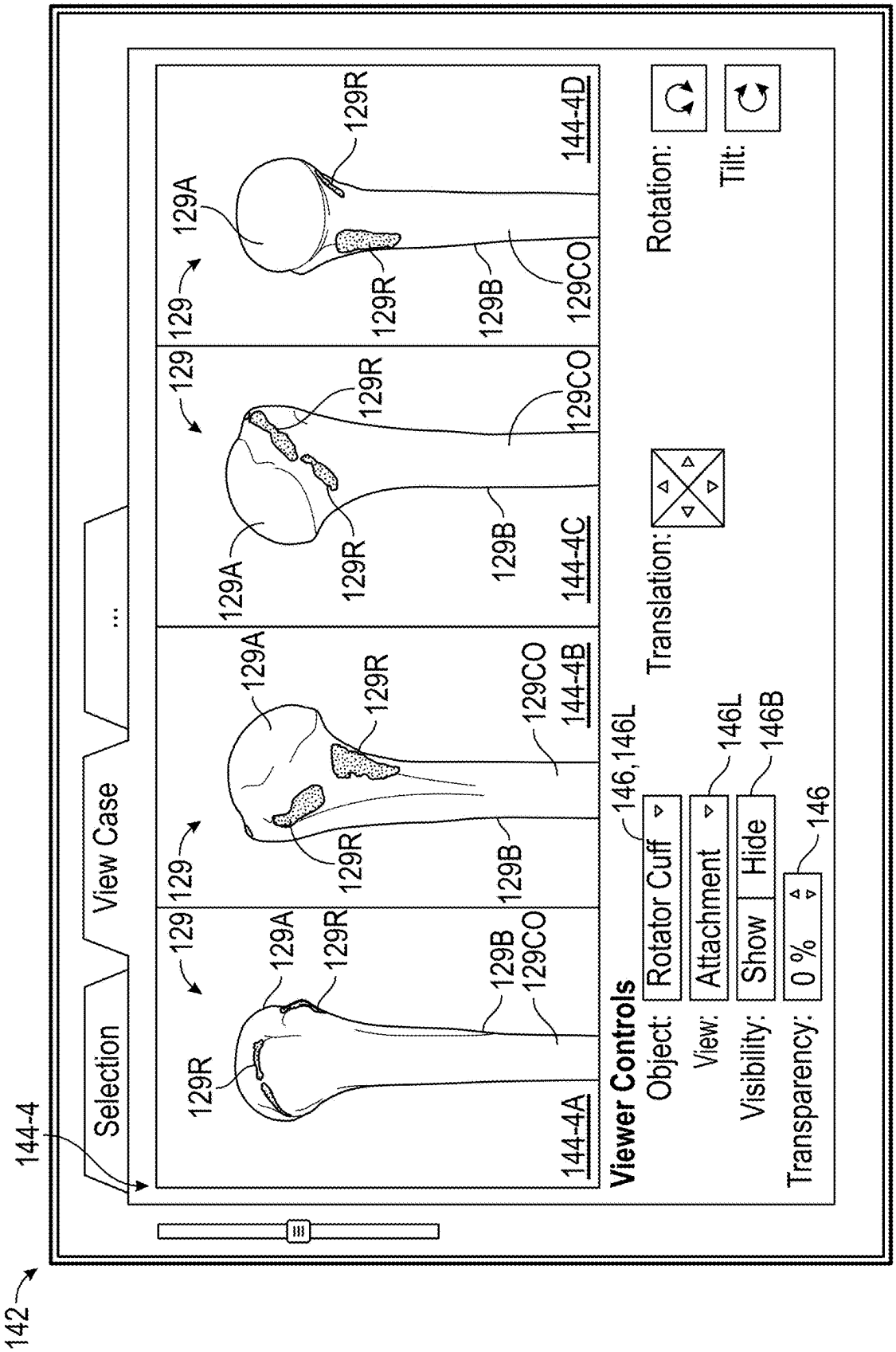

142
144-4
Selection
View Case
...
129
129R
129A
129B
129CO
144-4A
144-4B
144-4C
144-4D
Viewer Controls
146,146L
Object:
Rotator Cuff
View:
Attachment
146L
Visibility:
Show
Hide
146B
Transparency:
0 %
146
Translation:
Rotation:
Tilt:

FIG. 6

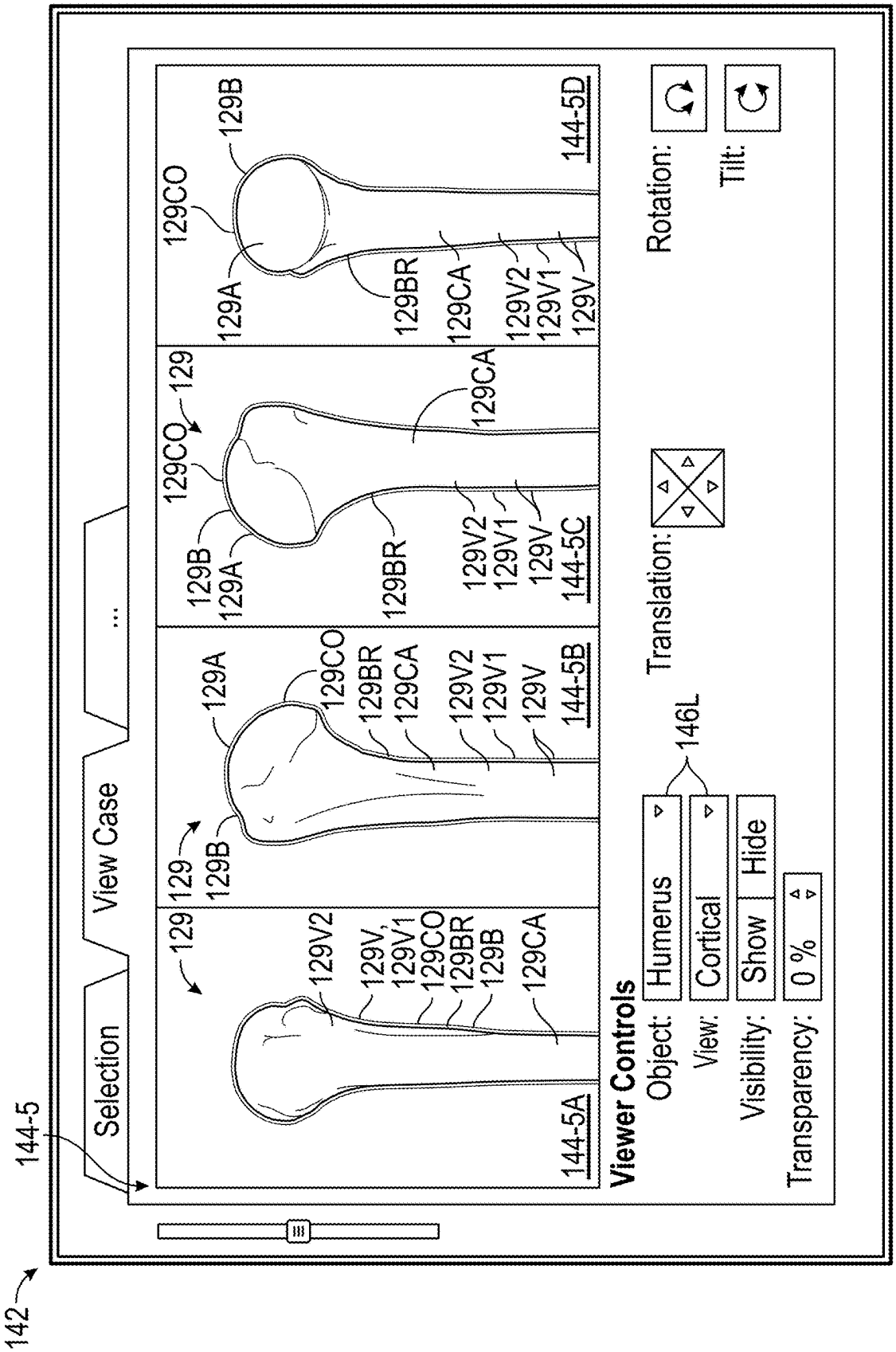

142
144-5
Selection
View Case
...
129
129V2
129V,
129V1
129CO
129BR
129B
129CA
144-5A
129
129B
129A
129CO
129BR
129CA
129V2
129V1
129V
144-5B
129CO
129
129B
129A
129BR
129CA
129V2
129V1
129V
144-5C
129CO
129B
129A
129BR
129CA
129V2
129V1
129V
144-5D
Viewer Controls
Object: Humerus
146L
View: Cortical
Visibility: Show Hide
Transparency: 0 %
Translation:
Rotation:
Tilt:

FIG. 7

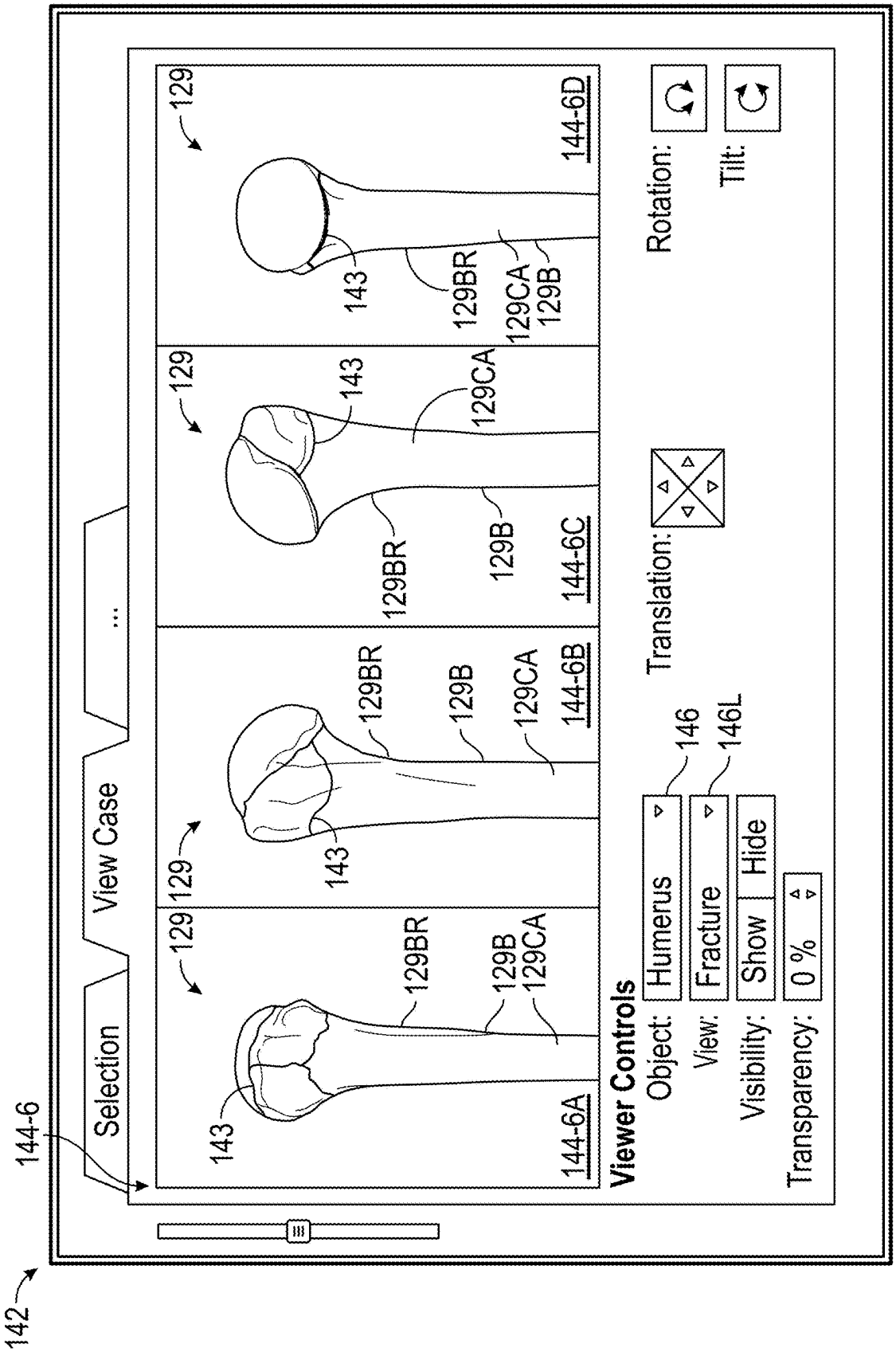

142
144-6
Selection
View Case
...
129
143
129BR
129B
129CA
144-6A
144-6B
144-6C
144-6D
Viewer Controls
Object:
Humerus
146
View:
Fracture
146L
Visibility:
Show
Hide
Transparency:
0 %
Translation:
Rotation:
Tilt:

FIG. 8

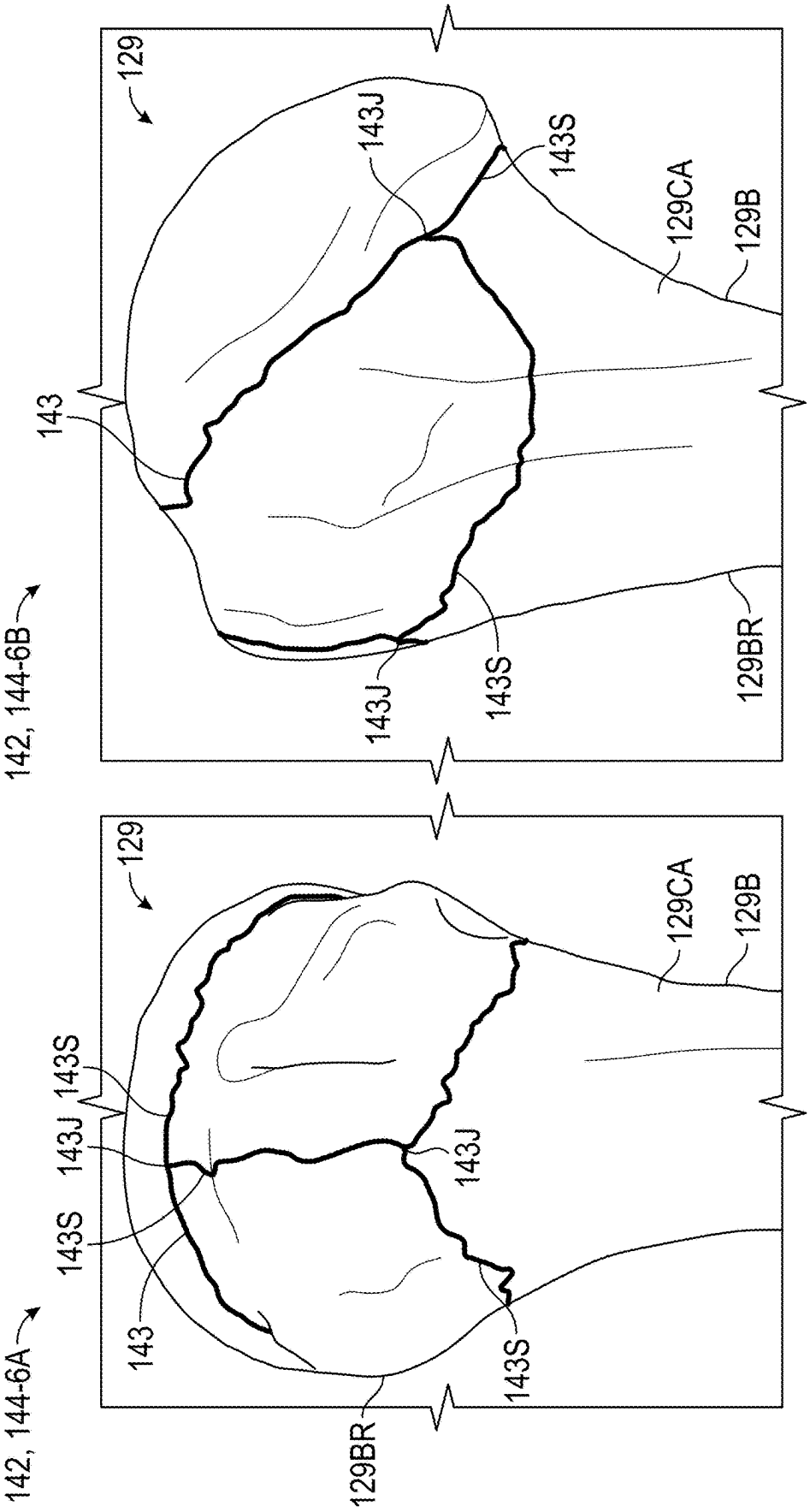

142, 144-6B
143
129
143J
143S
129CA
129B
143J
143S
129BR
142, 144-6A
143
129
143S
143J
143S
143J
129CA
129B
143S
129BR

FIG. 9B

FIG. 9A

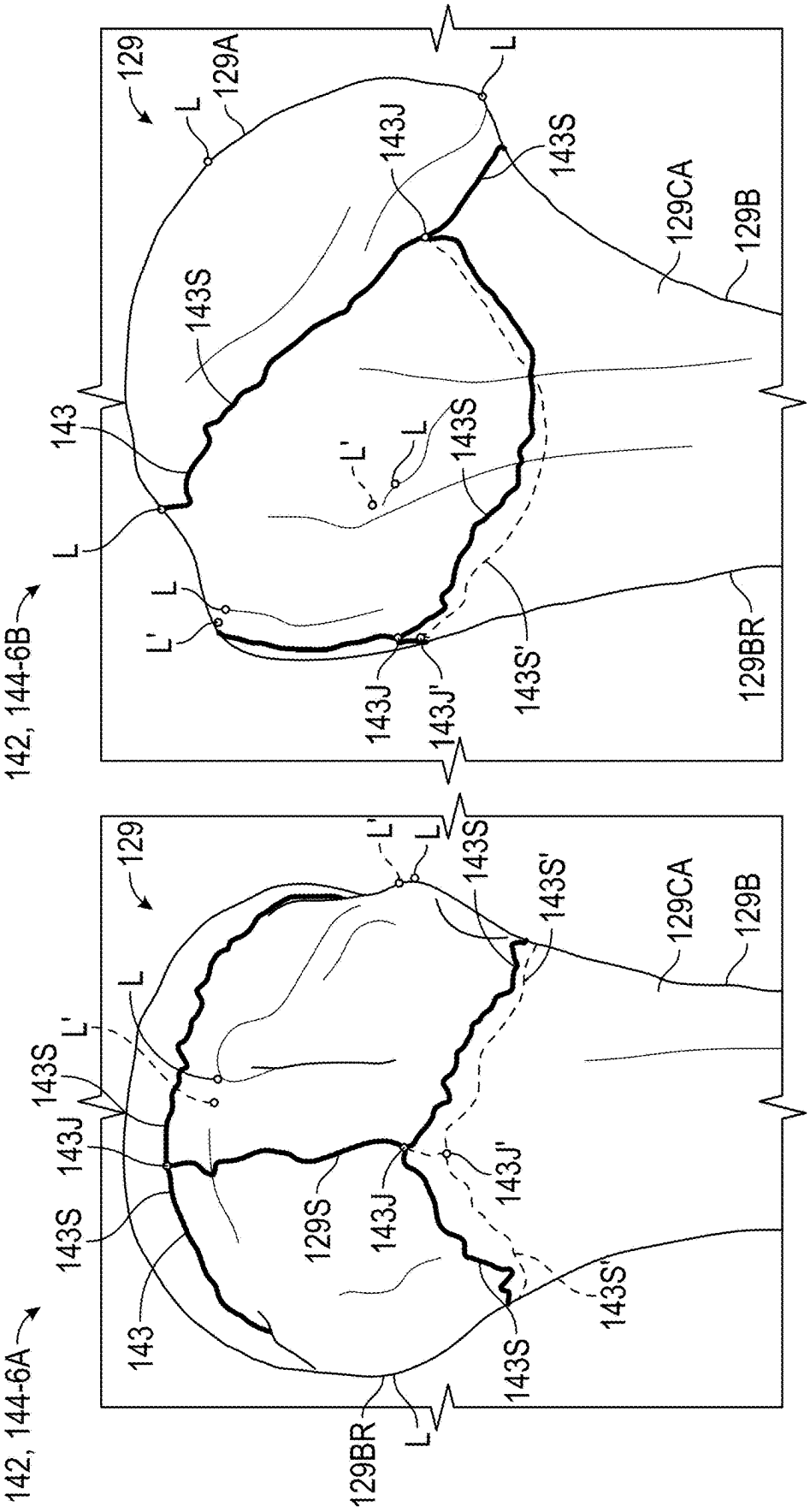

142, 144-6A
129
143
143S
L'
L
143J
129S
143J'
143S'
129CA
129B
129BR
142, 144-6B
129
129A
143
143S
143J
L'
143J'
143S'
129CA
129B
129BR

FIG. 9C

FIG. 9D

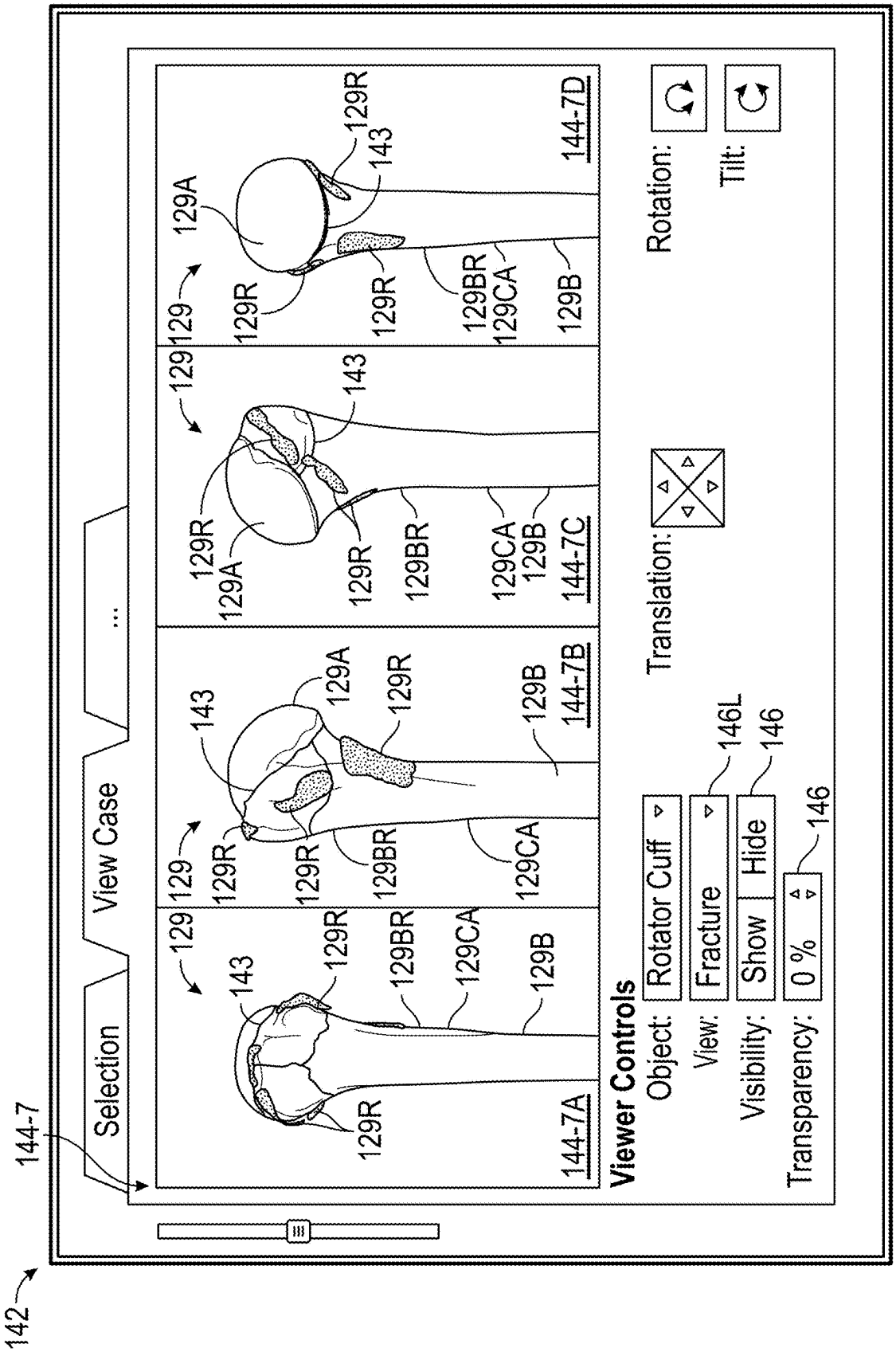

142
144-7
Selection
View Case
...
129
143
129R
129BR
129CA
129B
129A
144-7A
144-7B
144-7C
144-7D
Viewer Controls
Object:
Rotator Cuff
View:
Fracture
146L
Visibility:
Show
Hide
146
Transparency:
0 %
146
Translation:
Rotation:
Tilt:

FIG. 10

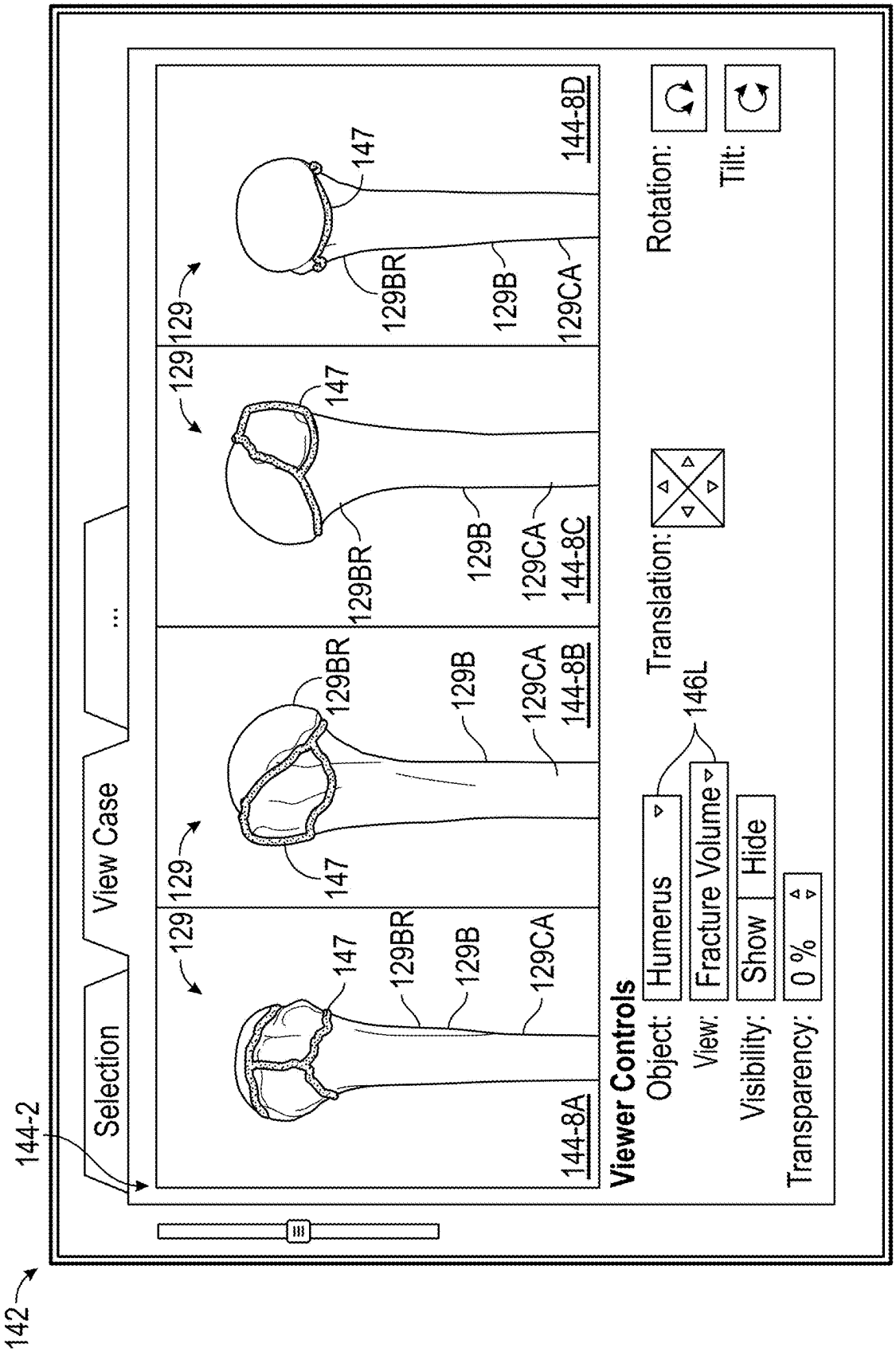

142
144-2
Selection
View Case
...
129
147
129BR
129B
129CA
144-8A
144-8B
144-8C
144-8D
Viewer Controls
Object:
Humerus
View:
Fracture Volume
146L
Visibility:
Show
Hide
Transparency:
0 %
Translation:
Rotation:
Tilt:

FIG. 11

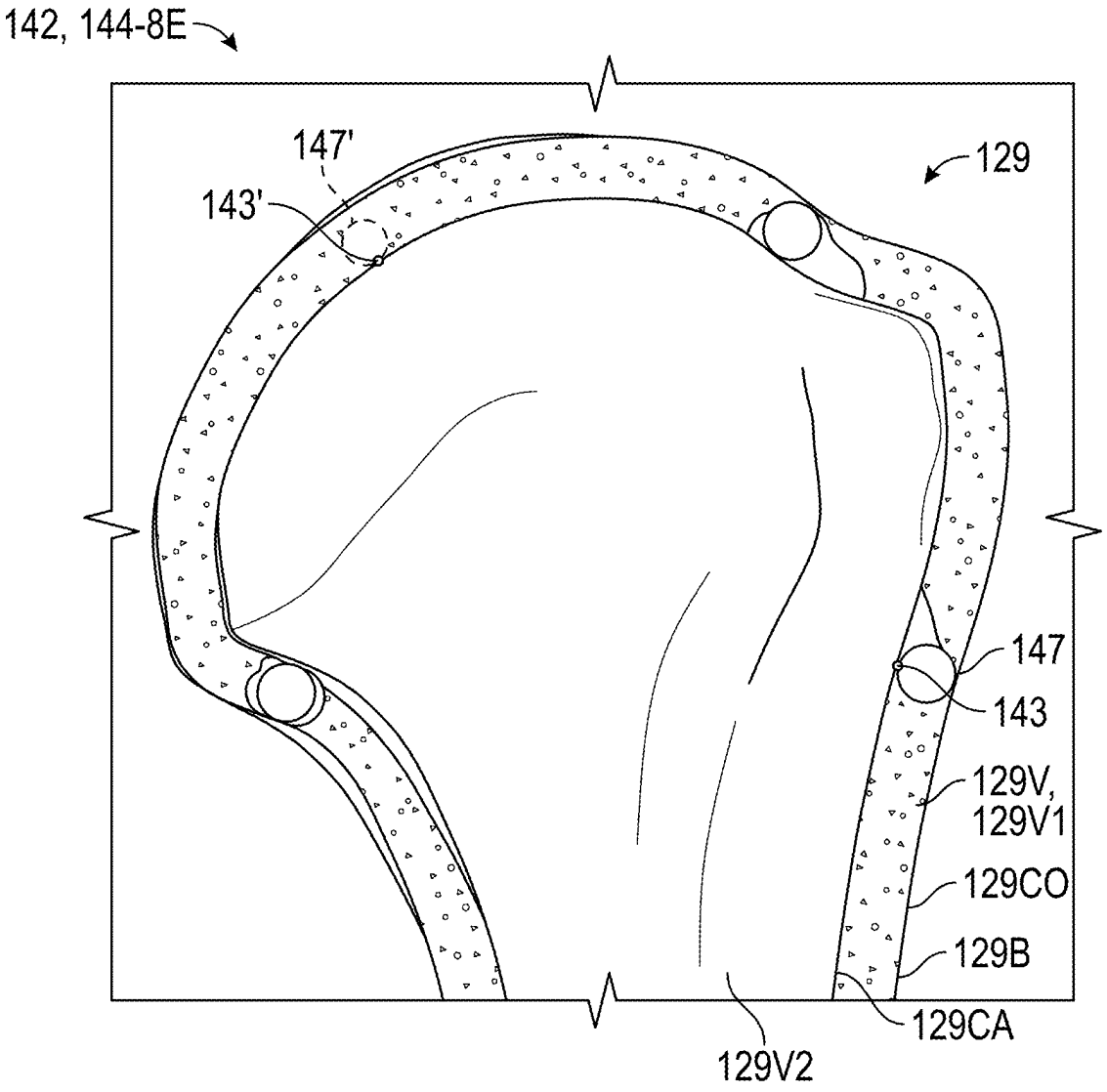

142, 144-8E
147'
143'
129
147
143
129V,
129V1
129CO
129B
129CA
129V2

FIG. 12A

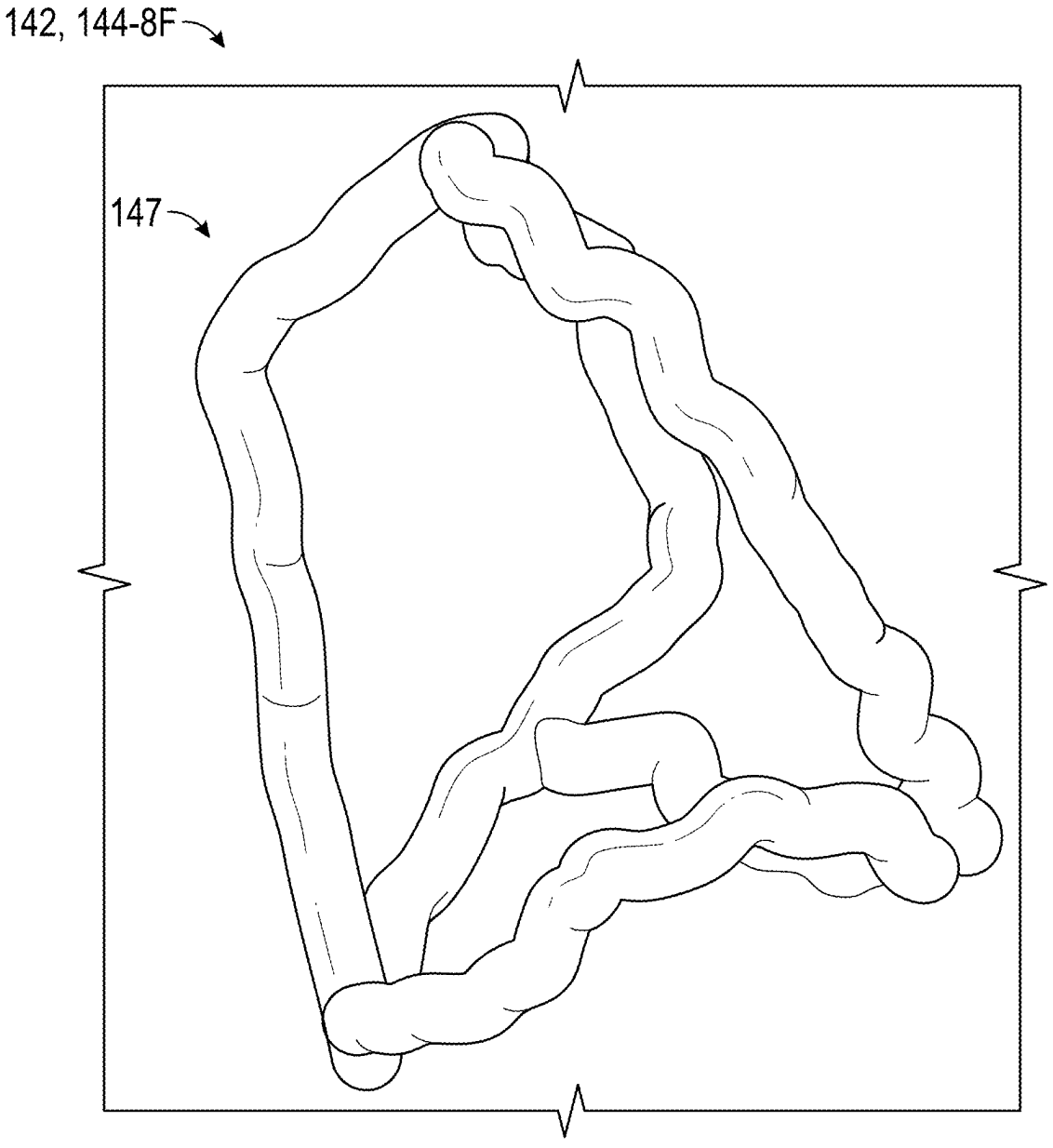


FIG. 12B

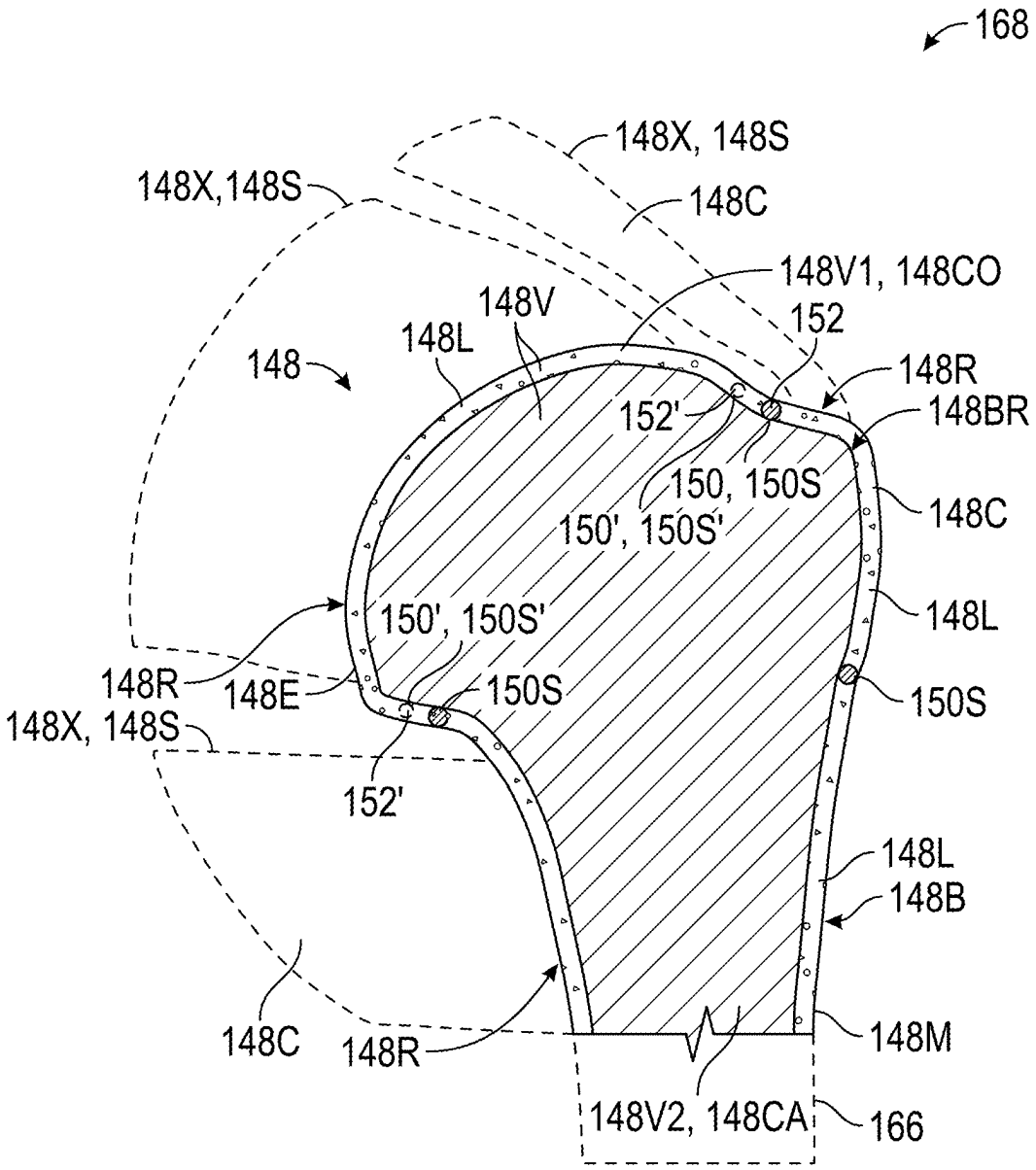

168
148X, 148S
148X,148S
148C
148V1, 148CO
148V
148L
152
148
148R
152'
148BR
150, 150S
148C
150', 150S'
150', 150S'
148L
148R
148E
150S
150S
148X, 148S
152'
148L
148B
148C
148R
148M
148V2, 148CA
166

FIG. 13

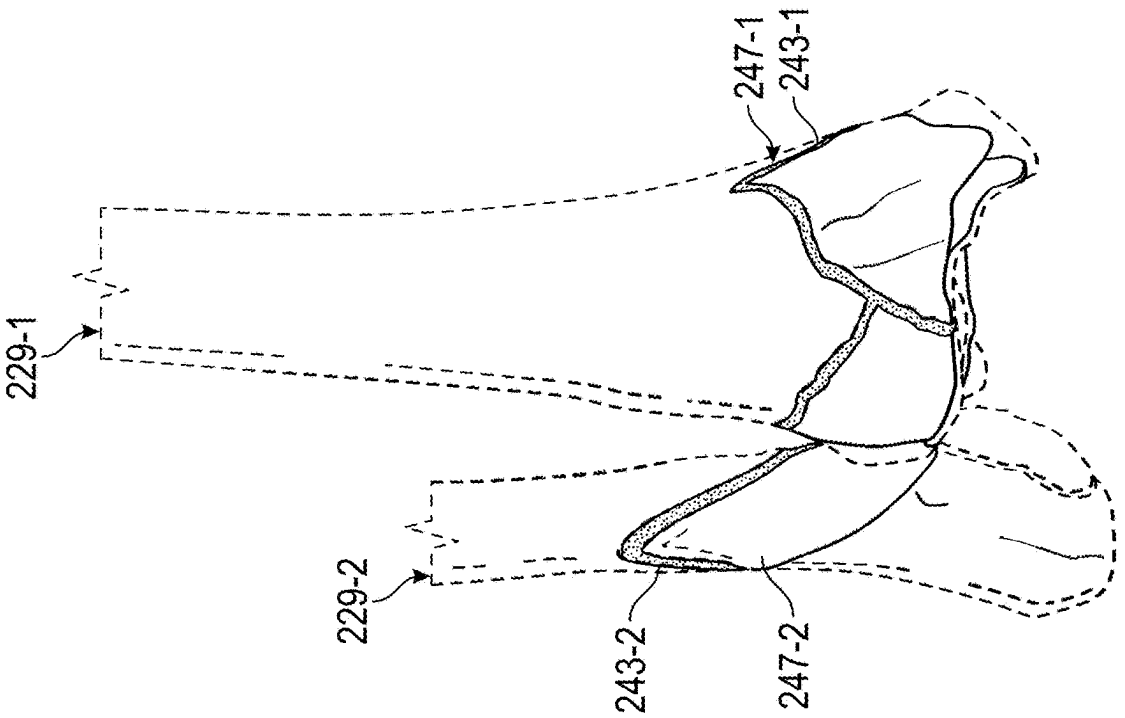

247-1
243-1
229-1
229-2
243-2
247-2

FIG. 15

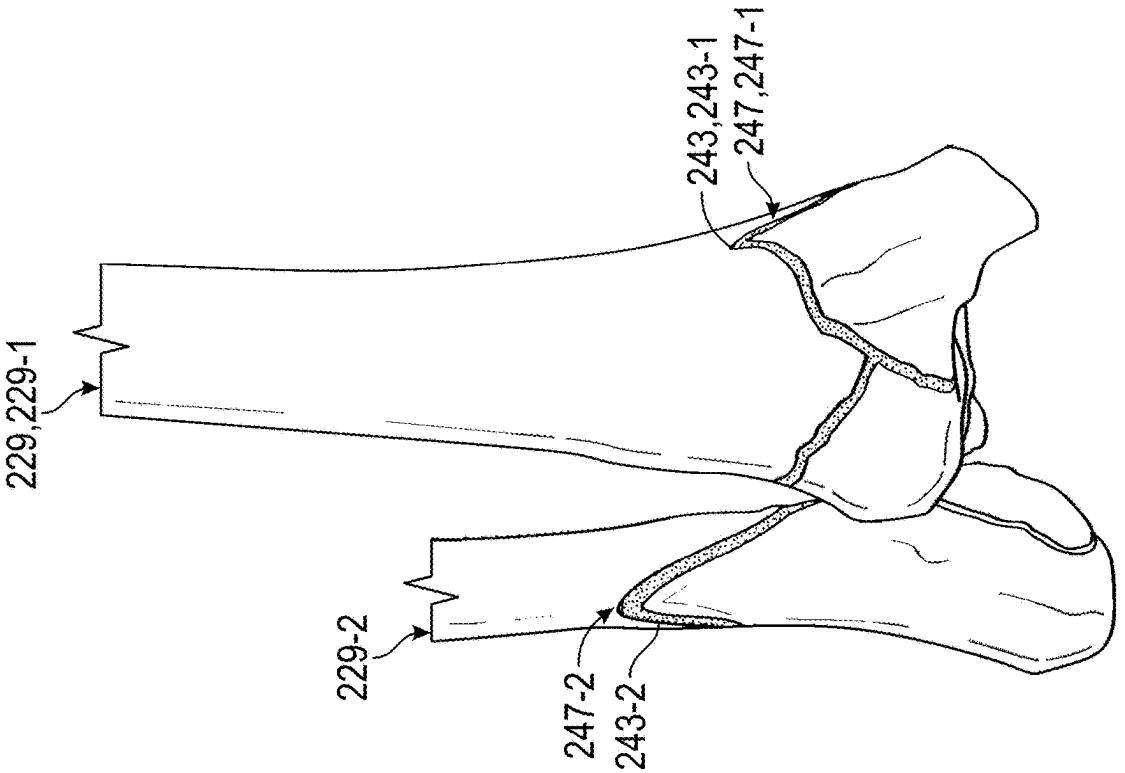

243,243-1
247,247-1
229,229-1
229-2
247-2
243-2

FIG. 14

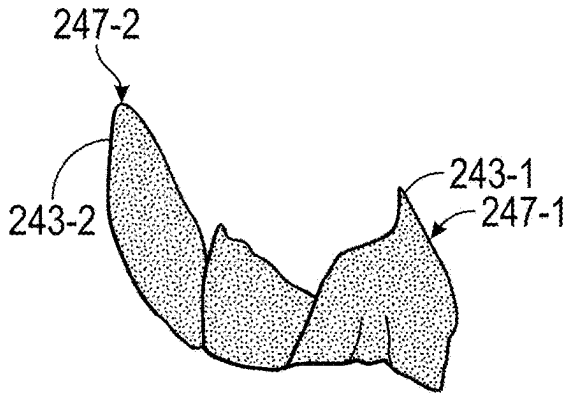


FIG. 16

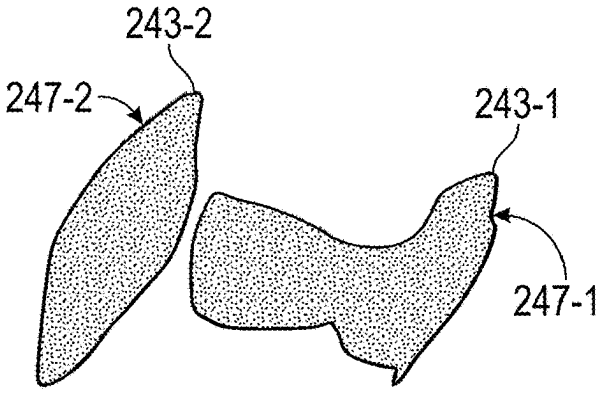


FIG. 17

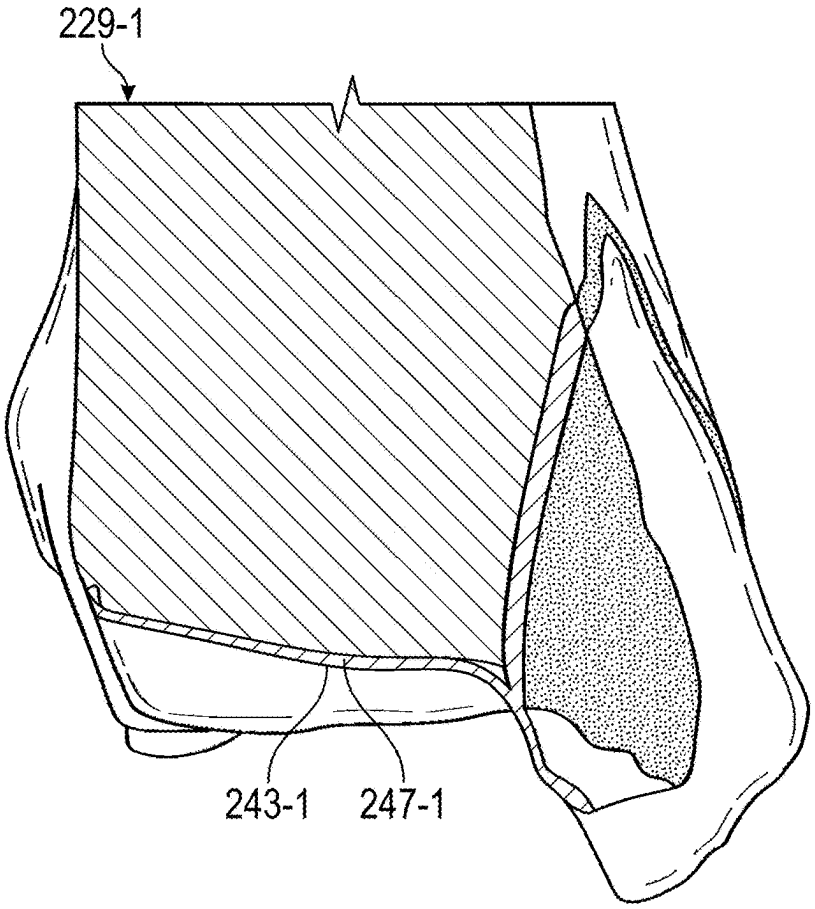


FIG. 18

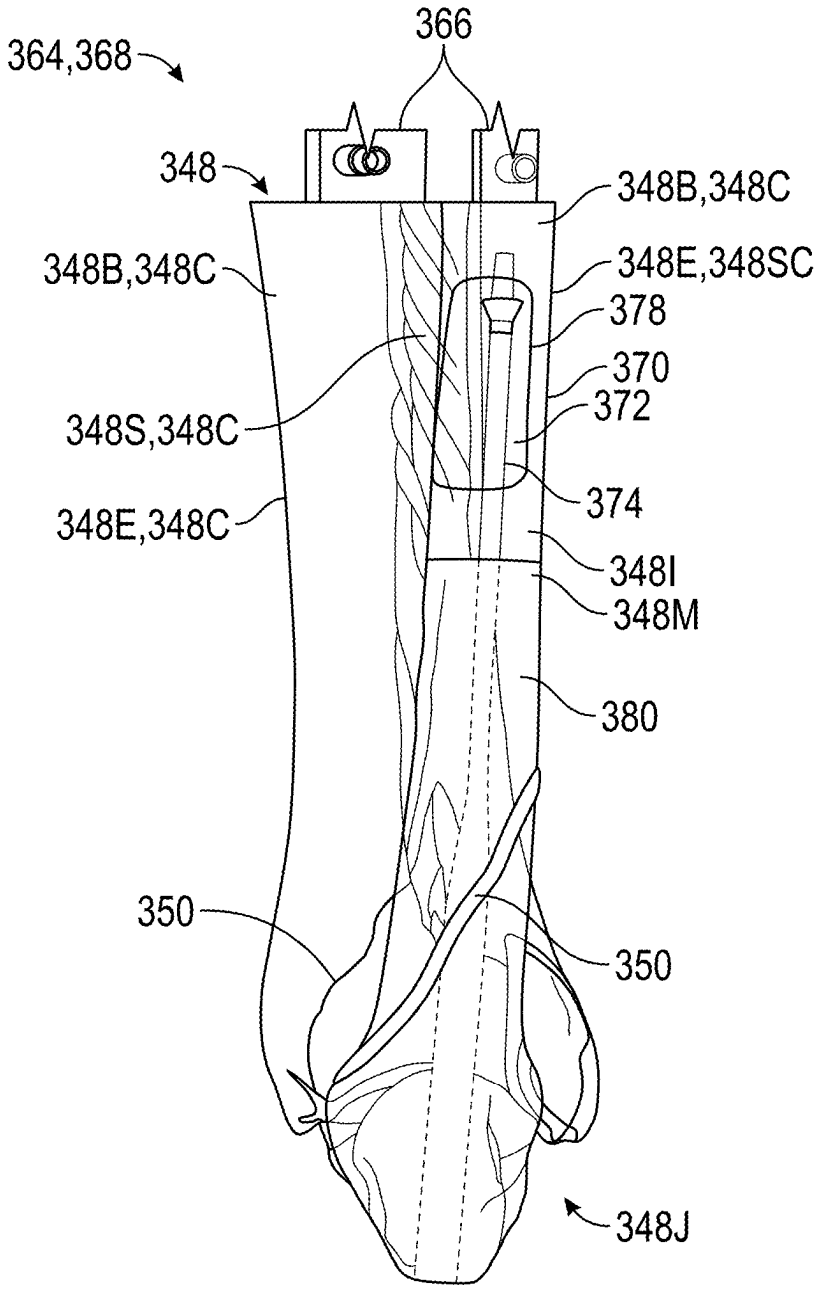

366
364,368
348
348B,348C
348B,348C
348E,348SC
378
370
372
348S,348C
374
348E,348C
348I
348M
380
350
350
348J

FIG. 19

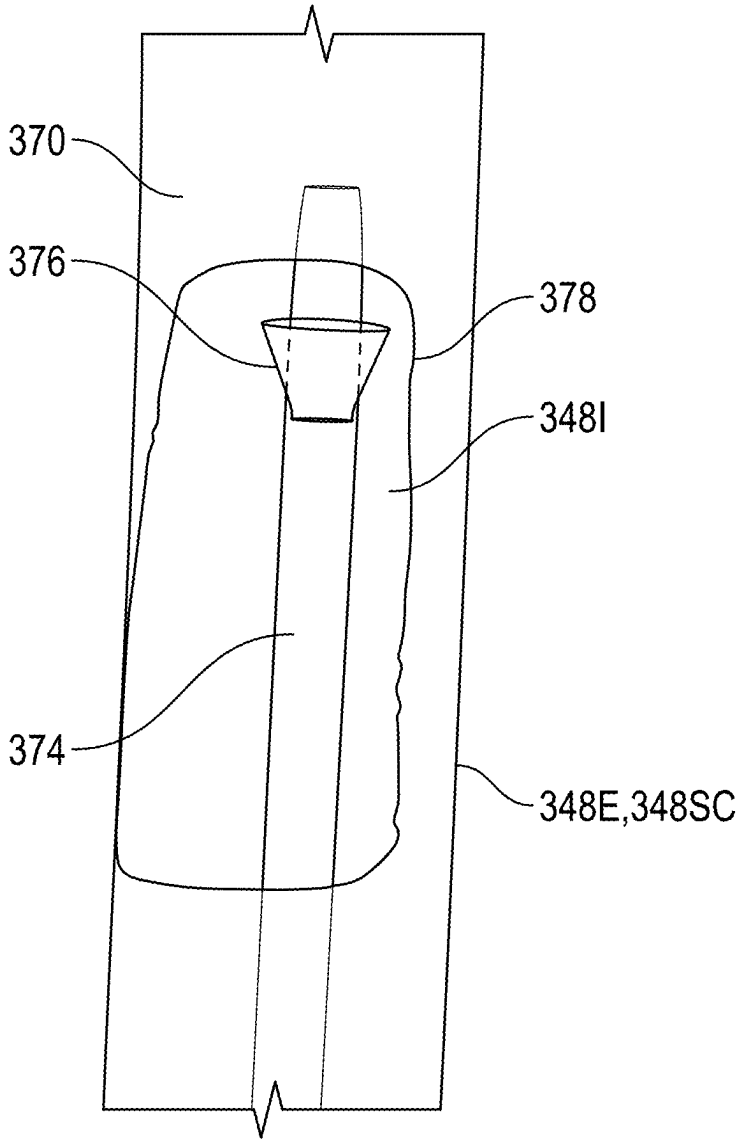


FIG. 20

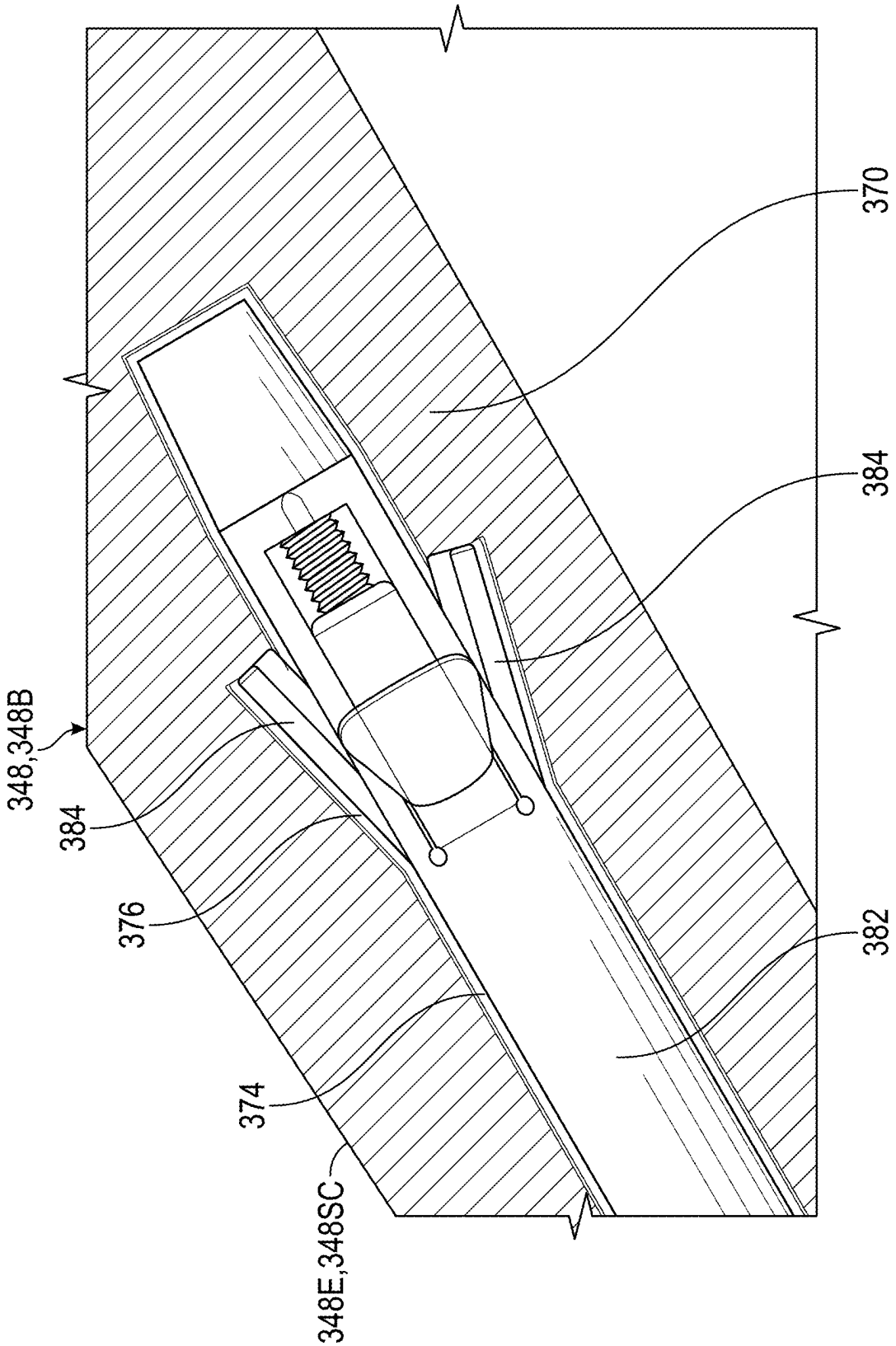


FIG. 21

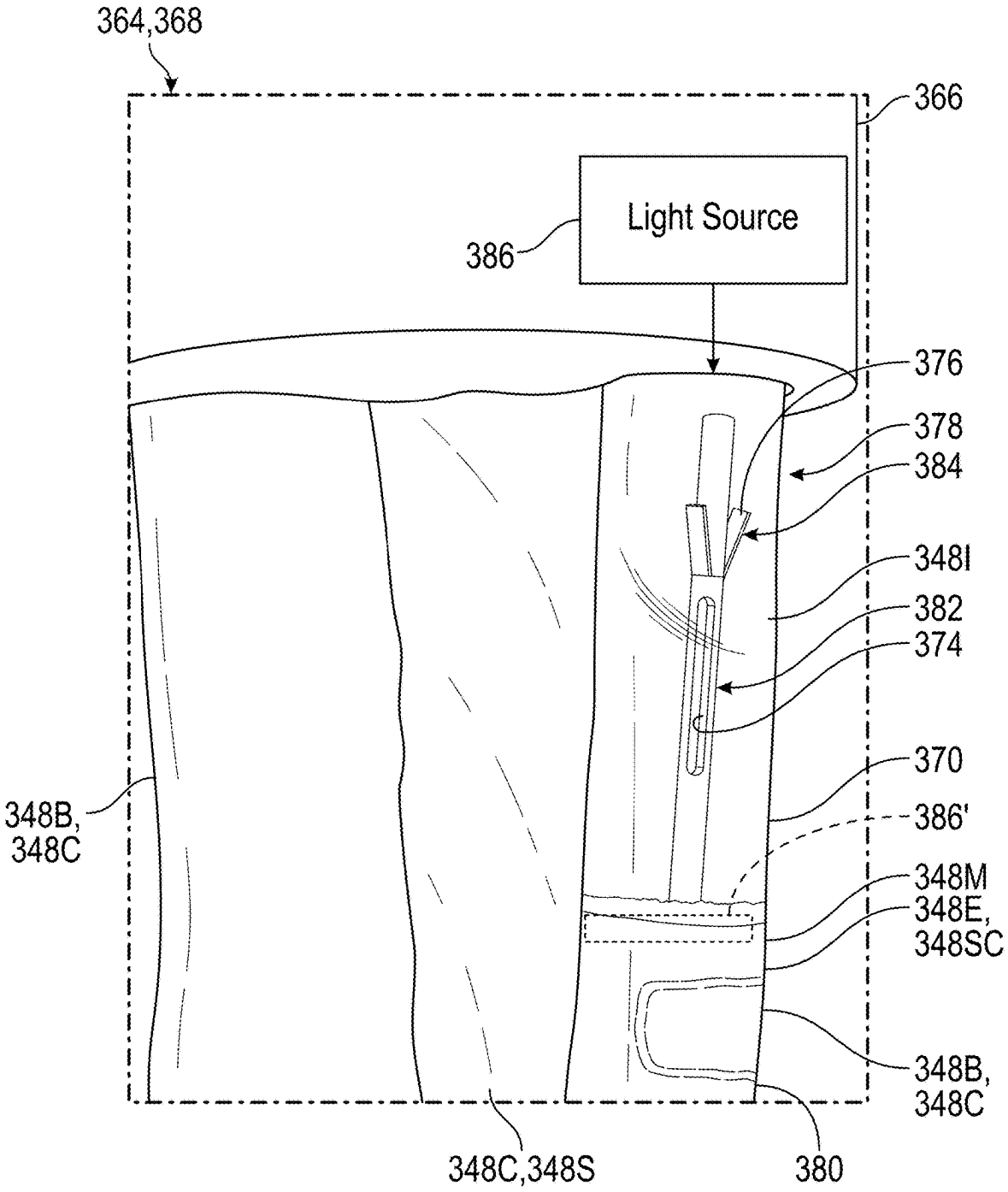

364,368
366
Light Source
386
376
378
384
348I
382
374
370
386'
348M
348E,
348SC
348B,
348C
348B,
348C
348C,348S
380

FIG. 22

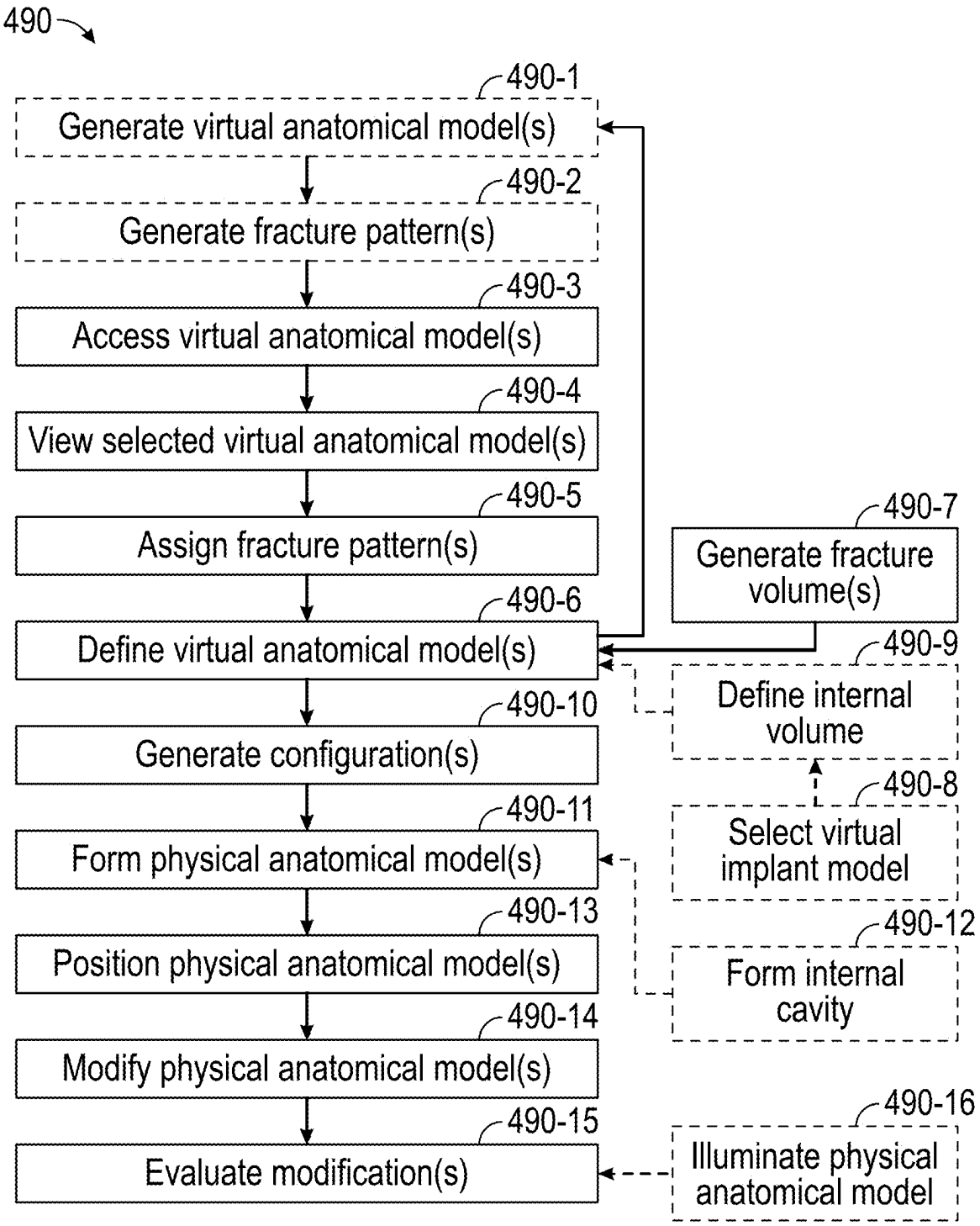

490
490-1
Generate virtual anatomical model(s)
490-2
Generate fracture pattern(s)
490-3
Access virtual anatomical model(s)
490-4
View selected virtual anatomical model(s)
490-5
Assign fracture pattern(s)
490-6
Define virtual anatomical model(s)
490-10
Generate configuration(s)
490-11
Form physical anatomical model(s)
490-13
Position physical anatomical model(s)
490-14
Modify physical anatomical model(s)
490-15
Evaluate modification(s)
490-7
Generate fracture volume(s)
490-9
Define internal volume
490-8
Select virtual implant model
490-12
Form internal cavity
490-16
Illuminate physical anatomical model

FIG. 23

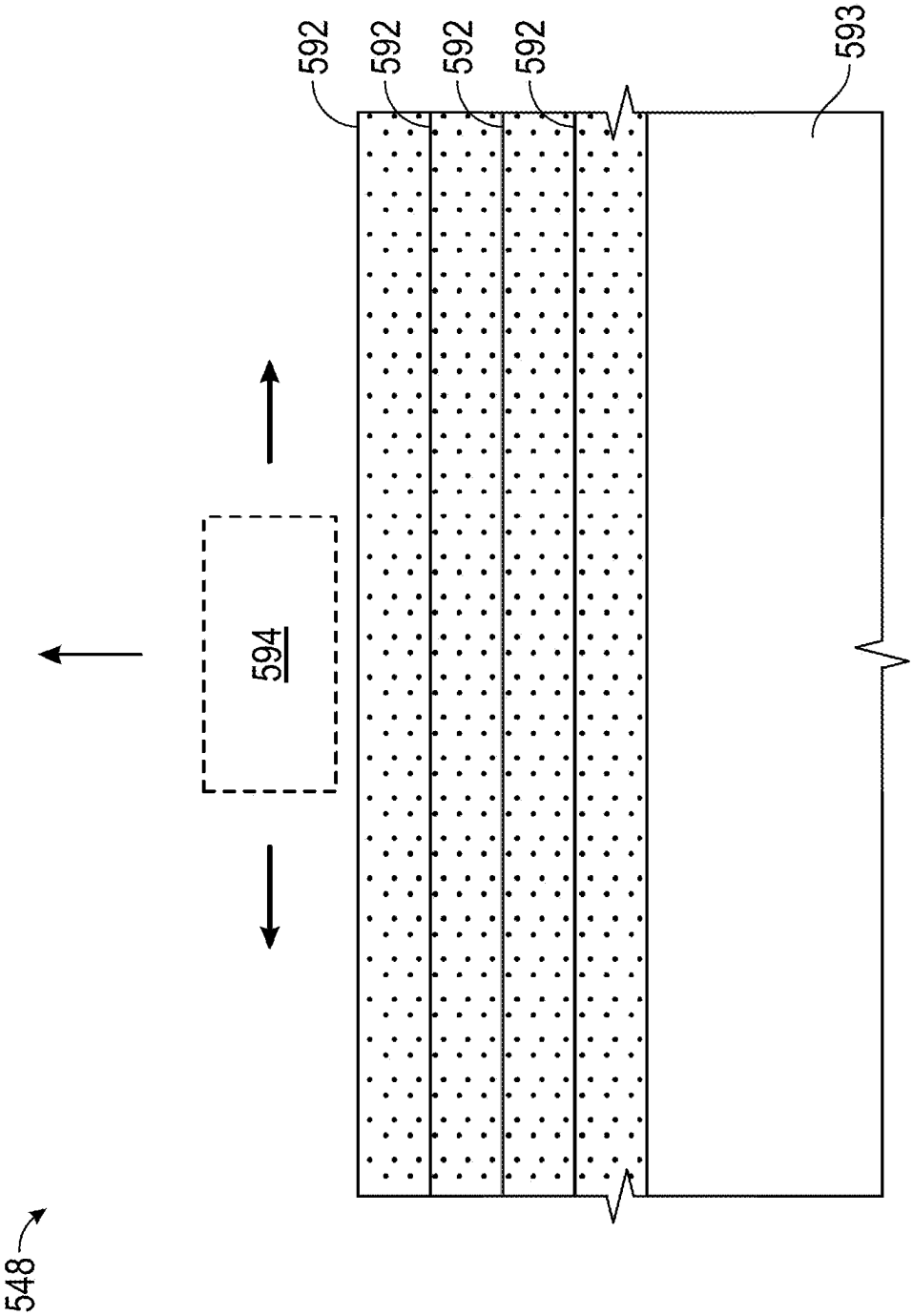


FIG. 24

ANATOMICAL MODELS AND ASSOCIATED METHODS

CROSS-REFERENCED TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application No. 63/551,565, which was filed on Feb. 9, 2024.

BACKGROUND

[0002] This disclosure relates to surgical systems, devices and methods for planning and implementing surgical procedures utilizing physical models of anatomy.

[0003] Deformities may form along various bones and joints of the human musculoskeletal system. Patients may experience a fracture of one or more bones due to trauma. A surgeon may reduce the fracture and may secure the fragments of the bone with an implant to restore functionality to the patient. Surgeons may prepare for an orthopaedic surgery by performing a procedure on a cadaveric or saw bone specimen.

SUMMARY

[0004] The systems and methods disclosed herein may be utilized to establish physical anatomical models of anatomy. The physical anatomical model may include one or more features for viewing an interior of the model.

[0005] A system for an orthopaedic procedure according to an implementation may include a physical anatomical model including a main body representative of anatomy. The main body may include a bone component. The bone component may include an exterior having a surface contour representative of a bone. The bone component may include a first portion establishing the exterior and a first material. The bone component may include a second portion adjacent to the first portion. The second portion may include a second material that may differ from the first material. The second material may transparent or translucent for viewing an interior of the bone component.

[0006] A system for a surgical procedure according to an implementation may include a physical anatomical model including a body associated with an anatomical profile of a bone. At least a first portion of the body may be formed of a first material that may be transparent or translucent, through which an interior of the body may be viewed. A light source may be operable to illuminate the interior of the body.

[0007] A method of rehearsing for a surgical procedure according to an implementation may include accessing a virtual anatomical model associated with an anatomy. The method may include generating a configuration associated with a physical anatomical model that may be representative of the virtual anatomical model. The method may include forming the physical anatomical model. The physical anatomical model may include a body associated with an anatomical profile of a bone. At least a first portion of the body may include a first material that may be transparent or translucent for viewing an interior portion of the body.

[0008] These and other features may be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** discloses a planning system according to an implementation.

[0010] FIG. **2** discloses another implementation of a planning system including a user interface.

[0011] FIG. **3** discloses the user interface of FIG. **2** including a display window including various parameters.

[0012] FIG. **4** discloses the user interface of FIG. **2** including display windows depicting a virtual anatomical model.

[0013] FIGS. **5-7** disclose the user interface of FIG. **2** including display windows depicting aspects of the virtual anatomical model of FIG. **4**.

[0014] FIG. **8** discloses the user interface of FIG. **2** including display windows depicting a fracture pattern relative to the virtual anatomical model of FIG. **7**.

[0015] FIGS. **9A-9D** disclose aspects of the fracture pattern of FIG. **8**.

[0016] FIG. **10** discloses the user interface of FIG. **2** including display windows depicting the fracture pattern relative to the virtual anatomical model of FIG. **8**.

[0017] FIG. **11** discloses the user interface of FIG. **2** including display windows depicting a fracture volume relative to the virtual anatomical model of FIG. **8**.

[0018] FIG. **12A** discloses a sectional view of aspects of the fracture volume of FIG. **11**.

[0019] FIG. **12B** discloses an isolated view of the fracture volume of FIG. **11**.

[0020] FIG. **13** discloses a sectional view of a physical anatomical model according to an implementation.

[0021] FIG. **14** discloses virtual anatomical models including respective fracture volumes according to an implementation.

[0022] FIG. **15** discloses the fracture volumes of FIG. **14** with the virtual anatomical models in phantom.

[0023] FIGS. **16-17** disclose isolated views of the fracture volumes of FIG. **14** at different orientations.

[0024] FIG. **18** discloses a sectional view of one of the virtual anatomical models and the associated fracture volume of FIG. **14**.

[0025] FIG. **19** discloses a system including a physical anatomical model according to another implementation.

[0026] FIG. **20** discloses selected portions of the physical anatomical model of FIG. **19**.

[0027] FIGS. **21** and **22** disclose an implant within the physical anatomical model of FIGS. **19** and **20**.

[0028] FIG. **23** discloses a method of planning and implementing a surgical procedure utilizing physical anatomical model(s).

[0029] FIG. **24** disclose a technique for forming a physical anatomical model.

[0030] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0031] This disclosure relates to surgical systems, devices and methods for planning and implementing surgical procedures utilizing physical models of anatomy. Physical anatomical models may be utilized to rehearse and train for various surgical procedures, including the repair of fractures and other deformities.

[0032] The disclosed techniques may be utilized to provide the surgeon a preoperative planning and/or training

experience that may be targeted or tailored to the surgeon based on procedure, skill set, experience, etc. The surgeon may select a particular configuration of a virtual anatomical model that may be fabricated or otherwise formed to establish a physical anatomical model based on the anatomy or pathology that the surgeon may intend to treat. The surgeon may utilize the physical anatomical model to train with particular instrumentation, implants and other devices that may be intended for a planned surgery to treat a patient.

[0033] The surgeon, assistant or other user may interact with a graphical user interface (GUI) to select various parameters or characteristics of the physical anatomical model. The parameters may include anatomy, patient, fracture classification, case, etc., to establish a desired configuration of the physical anatomical model. The surgeon may tailor or select one or more variables or parameters specific to a fracture classification scheme, depending on what the surgeon would like to train. The specified parameters may be represented in the physical anatomical model.

[0034] Various techniques may be utilized to establish the physical anatomical models, including any of the techniques disclosed herein. A virtual fracture pattern (e.g., virtual fracture path) and/or virtual fracture volume may be established relative to a virtual anatomical model. The fracture pattern may be established based on one or more parameters of a fracture classification scheme. The virtual fracture volume may be established along or otherwise adjacent to the fracture pattern. A physical fracture path and/or physical fracture volume may be established based on the virtual fracture pattern and/or virtual fracture volume, which may be incorporated in the physical anatomical model. The fracture volume may establish a relatively weaker localized region of the physical anatomical model, which may facilitate fragmentation of the physical anatomical model. The surgeon may reassemble (e.g., reduce) the fragment(s) of the physical anatomical model. The surgeon may secure the fragment(s) to each other and/or a remainder of the physical anatomical model, such as with a bone plate or another implant.

[0035] The physical anatomical model may include one or more portions that may incorporate a transparent or translucent material. The portion(s) may be utilized to view an interior of the physical anatomical model. In implementations, the transparent or translucent material may establish a viewing portal to the interior of the physical anatomical model. A light source may be utilized to illuminate the interior. Adjacent portion(s) of the physical anatomical model may be relatively more opaque than at least the material establishing the viewing portal. The adjacent portions may substantially surround a perimeter of the viewing portal.

[0036] The repaired physical anatomical model may serve as an artifact for the surgeon. The surgeon may leave a training facility with a revised physical anatomical model once training is completed. The surgeon may refer to the revised physical anatomical model prior to and during a surgical procedure on a respective patient.

[0037] A system for an orthopaedic procedure according to an implementation may include a physical anatomical model including a main body representative of anatomy. The main body may include a bone component. The bone component may include an exterior having a surface contour representative of a bone. The bone component may include a first portion establishing the exterior and a first material. The bone component may include a second portion adjacent to the first portion. The second portion may include a second material that may differ from the first material. The second material may transparent or translucent for viewing an interior of the bone component.

[0038] In any implementations, the second material may be transparent.

[0039] In any implementations, the second material may be translucent.

[0040] In any implementations, the second material may establish a viewing portal to the interior of the bone component. The interior of the bone component may include an internal cavity that may be at least partially aligned with the viewing portal. The internal cavity may be dimensioned to at least partially receive an orthopaedic implant.

[0041] In any implementations, the internal cavity may extend at least partially through the first portion of the bone component.

[0042] In any implementations, the internal cavity may include a deployment region dimensioned to at least partially receive a portion of the orthopaedic implant, which may be movable between an undeployed state and a deployed state. The deployment region may be at least partially aligned with the viewing portal.

[0043] In any implementations, the deployment region may include a conical void associated with a geometry of the portion of the implant in the deployed state.

[0044] In any implementations, the bone may be a fibula.

[0045] In any implementations, the second portion may be adjacent to an intermediate portion and/or a proximal portion of the bone component.

[0046] In any implementations, the first material may have a transparency that may be less than a transparency of the second material.

[0047] In any implementations, the first material may be substantially opaque.

[0048] In any implementations, the first portion may be distal to the second portion.

[0049] In any implementations, the first portion may include a joint region of the bone component. The joint region may be representative of an orthopaedic joint.

[0050] In any implementations, a light source may be at least partially embedded in the main body. The light source may be operable to illuminate the interior.

[0051] In any implementations, the light source may be at least partially embedded in the bone component.

[0052] In any implementations, the second material may establish a viewing portal to the interior of the bone component. An opaque material may surround a perimeter of the viewing portal.

[0053] In any implementations, a soft tissue component may be on the bone component. The soft tissue component may be representative of soft tissue.

[0054] In any implementations, the bone component may include a fracture path that may establish one or more localized regions. The bone component may be severable along the fracture path to establish one or more fragments that may be associated with a respective one of the one or more localized regions.

[0055] In any implementations, the interior of the bone component may include an internal cavity that may extend through the fracture path and may be at least partially aligned with a viewing portal established by the second

material. The internal cavity may be dimensioned to at least partially receive an orthopaedic implant.

[0056] A system for a surgical procedure according to an implementation may include a physical anatomical model including a body associated with an anatomical profile of a bone. At least a first portion of the body may be formed of a first material that may be transparent or translucent, through which an interior of the body may be viewed. A light source may be operable to illuminate the interior of the body.

[0057] In any implementations, the light source may be at least partially embedded in the body.

[0058] In any implementations, the bone may be a long bone.

[0059] A method of rehearsing for a surgical procedure according to an implementation may include accessing a virtual anatomical model associated with an anatomy. The method may include generating a configuration associated with a physical anatomical model that may be representative of the virtual anatomical model. The method may include forming the physical anatomical model. The physical anatomical model may include a body associated with an anatomical profile of a bone. At least a first portion of the body may include a first material that may be transparent or translucent for viewing an interior portion of the body.

[0060] In any implementations, the body may include an exterior having a surface contour representative of a cortical wall of the bone. The body may include a second portion that may establish the exterior adjacent to the first portion. The second portion may include a second material having an opacity that may be greater than an opacity of the first material.

[0061] In any implementations, the method may include illuminating the interior portion.

[0062] In any implementations, the illuminating step may include illuminating the interior portion with a light source that may be at least partially embedded in the body.

[0063] In any implementations, the forming step may include printing layers of material on each other to establish the physical anatomical model.

[0064] In any implementations, the method may include forming an internal cavity in the interior portion.

[0065] In any implementations, the forming step may include at least partially filling the internal cavity with a material having at least one characteristic that may differ from the first material.

[0066] In any implementations, the internal cavity may include a deployment region adjacent to the first portion that may be dimensioned to receive a portion of an orthopaedic implant, which may have an undeployed state and a deployed state.

[0067] In any implementations, the first portion may be at least partially aligned with the deployment region such that the deployment region may be visible from outside of the physical anatomical model.

[0068] In any implementations, the method may include inserting the orthopaedic implant at least partially into the internal cavity.

[0069] In any implementations, the method may include deploying the implant within the deployment region.

[0070] In any implementations, the method may include illuminating the first material when the implant is in the deployed state.

[0071] In any implementations, the bone may be a long bone.

[0072] In any implementations, the first portion may include a viewing portal for viewing the interior portion from outside of the physical anatomical model.

[0073] FIG. **1** discloses a planning system **20** that may be utilized for planning surgical procedures according to an implementation. The system **20** may be used for planning orthopaedic procedures, including pre-operatively, intra-operatively and/or post-operatively to create, edit, execute and/or review surgical plans. The system **20** may be used for training and rehearsing for various surgical procedures, including prior cases and surgical plans for patients and hypothetical cases.

[0074] The system **20** may include a host computer **21** and one or more client computers **22**. The host computer **21** may be configured to execute one or more software programs. In implementations, the host computer **21** may include more than one computer jointly configured to process software instructions serially or in parallel.

[0075] The host computer **21** may be operable to communicate with one or more networks such as a network **23** comprised of one or more computing devices. The network **23** may be a private local area network (LAN), a private wide area network (WAN), the Internet, or a mesh network.

[0076] The host computer **21** and each client computer **22** may include one or more of a computer processor, memory, storage means, network device and input and/or output devices and/or interfaces. The input devices may include a keyboard, mouse, etc. The output device may include a monitor, speakers, printers, etc. The memory may include UVPROM, EEPROM, FLASH, RAM, ROM, DVD, CD, a hard drive, or other computer readable medium which may store data and/or other information relating to the features and techniques disclosed herein. The host computer **21** and each client computer **22** may be a desktop computer, laptop computer, smart phone, tablet, or any other computing device. The interface may facilitate communication with the other systems and/or components of the network **23**.

[0077] Each client computer **22** may be configured to communicate with the host computer **21** directly via a direct client interface **24** or over the network **23**. The client computers **22** may be configured to execute one or more software programs, such as various surgical tools. Each client computer **22** may be operable to access and locally and/or remotely execute a planning environment **26**. The planning environment **26** may be a standalone software package or may be incorporated into another surgical tool. The planning environment **26** may be configured to communicate with the host computer **21** either over the network **23** or directly through the direct client interface **24**. In implementations, the client computers **22** may be configured to communicate with each other directly via a peer-to-peer interface **25**.

[0078] The planning environment **26** may provide a display or visualization of one or more virtual anatomical models **29** and related images and/or one or more implant models **30** via one or more graphical user interfaces (GUI). Each anatomical model **29**, implant model **30**, and related images and other information may be stored in one or more files or records according to a specified data structure.

[0079] The system **20** may include at least one storage system **27**, which may be operable to store or otherwise provide data to other computing devices. The storage system **27** may be a storage area network device (SAN) configured to communicate with the host computer **21** and/or the client

computers **22** over the network **23**. In implementations, the storage system **27** may be incorporated within or directly coupled to the host computer **21** and/or client computers **22**. The storage system **27** may be configured to store one or more of computer software instructions, data, database files, configuration information, etc.

[0080] In implementations, the system **20** may be a client-server architecture configured to execute computer software on the host computer **21**, which may be accessible by the client computers **22** using either a thin client application or a web browser executing on the client computers **22**. The host computer **21** may load the computer software instructions from local storage, or from the storage system **27**, into memory and may execute the computer software using the one or more computer processors.

[0081] The system **20** may include one or more databases **28**. The databases **28** may be stored at a central location, such as the storage system **27**. In implementations, one or more databases **28** may be stored at the host computer **21** and/or may be a distributed database provided by one or more of the client computers **22**. Each database **28** may be a relational database configured to associate one or more anatomical models **29** and/or one or more implant models **30** to each other and/or a surgical plan **31**. Each surgical plan **31** may be associated with a respective patient. Each anatomical model **29**, implant model **30** and surgical plan **31** may be assigned a unique identifier or database entry. The database **28** may be configured to store data corresponding to the anatomical models **29**, implant models **30** and surgical plans **31** in one or more database records or entries, and/or may be configured to link or otherwise associate one or more files corresponding to each respective anatomical model **29**, implant model **30** and surgical plan **31**. Anatomical models **29** stored in the database(s) **28** may correspond to respective patient anatomies from prior and/or planned surgical cases, and may be arranged into one or more predefined categories such as sex, age, ethnicity, size, defect category, procedure type, etc. The anatomical models **29** and/or implant models **30** may be associated with respective instrumentation and devices to implement the associated surgical plan **31**.

[0082] Each anatomical model **29** may include information obtained from one or more medical devices or tools, such as a computerized tomography (CT), magnetic resonance imaging (MRI) machine and/or X-ray machine, that may obtain one or more images of a patient. The anatomical model **29** may include one or more digital images and/or coordinate information relating to an anatomy of the patient obtained or derived from the medical device(s). In implementations, one or more of the anatomical models **29** may be created by a designer and may represent a hypothetical anatomy. Each implant model **30** may include coordinate information associated with a predefined design. The planning environment **26** may incorporate and/or interface with one or more modeling packages, such as a computer aided design (CAD) package, to render the models **29**, **30** as two-dimensional (2D) and/or three-dimensional (3D) volumes or constructs. Each anatomical model **29** and implant model **30** may correspond to 2D and/or 3D geometry, and may be utilized to generate a wireframe, mesh and/or solid construct in a display.

[0083] The implant models **30** may correspond to implants and components of various configurations, shapes, sizes, procedures, instrumentation, etc. Each implant may include one or more components that may be situated at a surgical site including plates, anchors, screws, nails, suture, grafts, etc. Each implant model **30** may correspond to a single component or may include two or more components that may be configured to establish an assembly. The implant models **30** may include base plates coupled to an articulation member, bone plates configured to interconnect adjacent bones or bone fragments, intermedullary nails, suture anchors, etc. The articulation member may have an articular surface dimensioned to mate with an articular surface of an opposed bone or implant.

[0084] Each surgical plan **31** may be associated with one or more of the anatomical models **29** and/or implant models **30**. The surgical plan **31** may include one or more revisions to the anatomical model **29** and information relating to a position of an implant model **30** relative to the original and/or revised anatomical model **29**. The surgical plan **31** may include coordinate information relating to the revised anatomical model **29** and a relative position of the implant model **30** in predefined data structure(s). Revisions to each anatomical model **29**, implant model **30** and surgical plan **31** may be stored in the database **28** automatically and/or in response to user interaction with the system **20**.

[0085] One or more surgeons, assistants and other clinical users may be provided with a planning environment **26** via the client computers **22** and may simultaneously access each anatomical model **29**, implant model **30** and surgical plan **31** stored in the database(s) **28**. Each user may interact with the planning environment **26** to create, view and/or modify various aspects of the surgical plan **31**. Each client computer **22** may be configured to store local instances of the anatomical models **29**, implant models **30** and/or surgical plans **31**, which may be synchronized in real-time or periodically with the database(s) **28**. The planning environment **26** may be a standalone software package executed on a client computer **22** or may be provided as one or more services executed on the host computer **21**.

[0086] FIG. **2** discloses a surgical system **120** according to an implementation. The system **120** be utilized to facilitate planning, rehearsing and/or training for a surgical procedure. The system **120** may be utilized to plan, rehearse, train and implement various orthopaedic and other surgical procedures, such as an arthroplasty to repair a joint. The system **120** may be utilized in planning a resection or revision of one or more bones. The system **120** may be utilized in planning placement of an implant to restore functionality to a bone and/or joint. The system **120** may be utilized in planning the repair of a fracture of one or more bones, including one or more long bones such as a fibula, tibia, femur or humerus. The planning system **120** may be utilized in the repair of locations of the patient and other surgical procedures including repair of joints such as an ankle, wrist, hand, hip or knee, shoulder and including repair of other tissue such as cartilage, muscles, tendons and ligaments.

[0087] The system **120** may be configured to generate one or more physical anatomical models, including any of the physical anatomical models disclosed herein. The surgeon may perform one or more modifications to the physical anatomical model or otherwise interact with the physical anatomical model to rehearse or train for a surgical procedure. The system **120** may be configured to generate configuration(s) associated with respective physical anatomical model(s). The configuration may be utilized in the formation of a physical anatomical model. Each physical anatomical model may be representative of a virtual anatomical model

129, including a substantially or generally corresponding geometry, texture density, porosity, color, opacity, etc. as the virtual anatomical model **129**. The virtual anatomical model **129** may be associated with an anatomy, such as the anatomy of a patient and/or a hypothetical anatomy. The anatomical models **129** may include one or more anatomical features. The anatomical features may be representative of anatomy, including one or more bones including cartilage, cortical and/or cancellous bone tissue, soft tissue including muscle, ligaments and/or tendons, etc., and/or other tissue.

[0088] The system **120** may include a computing device **132**. The computing device **132** may include one or more processors **133** coupled to memory **134**. The computing device **132** may include any of the computing devices disclosed herein, such as the host computer **21** and/or client computer **22** of FIG. **1**. The processor(s) **133** may be configured to individually and/or collectively execute a planning environment **126** for creating, editing, executing and/or reviewing one or more surgical (e.g., pre-operative) plans **131** during pre-operative, intra-operative and/or post-operative phases of a surgical procedure. The processor **133** may be configured to access one or more virtual anatomical models **129** from a storage location such as the memory **134**. The anatomical model **129** and surgical plan **131** may be associated with an actual case for a patient or may be a hypothetical case established for rehearsal and/or training surgeons, assistants, medical staff and other clinical users.

[0089] The planning environment **126** may include at least a data module **135**, display module **136**, spatial module **137** and comparison module **138**. The processor(s) **133** may be configured to individually and/or collectively execute the data module **135**, display module **136**, spatial module **137** and comparison module **138**. Although four modules are disclosed in the implementation of FIG. **2**, it should be understood that fewer or more than four modules may be utilized and/or one or more of the modules may be combined to provide the disclosed functionality.

[0090] The data module **135** may be configured to access, retrieve and/or store data and other information in the database(s) **128** corresponding to one or more virtual anatomical model(s) **129**, implant model(s) **130** and/or surgical plan(s) **131**. The data and other information may be stored in the database **128** as one or more records or entries **139**. In implementations, the data and other information may be stored in one or more files that may be accessible by referencing one or more objects or memory locations referenced by the records **139**.

[0091] The memory **134** may be configured to access, load, edit and/or store instances of one or more anatomical models **129**, implant models **130** and/or surgical plans **131** in response to one or more commands from the data module **135**. The data module **135** may be configured to cause the memory **134** to store a local instance of the anatomical model(s) **129**, implant model(s) **130** and/or surgical plan(s) **131** which may be synchronized with records **139** in the database(s) **128**.

[0092] The display module **136** may be configured to display data and other information relating to one or more surgical plans **131** in at least one graphical user interface (GUI) **142**. The computing device **132** may be coupled to a display device **140**. The display module **136** may be configured to cause the display device **140** to display the virtual anatomical model **129** in the user interface **142**. A surgeon or other clinical user may interact with the user interface **142** via the planning environment **126** to create, edit and/or review aspects of one or more anatomical models **129**. The surgeon or other user may interact with the user interface **142** via the planning environment **126** to create, edit, execute and/or review aspects of one or more surgical plans **131**.

[0093] Each surgical plan **131** may be associated with one or more (e.g., original) virtual anatomical models **129** prior to any revisions, which may substantially or generally approximate an anatomy. Each surgical plan **131** may be associated with one or more (e.g., revised) virtual anatomical models **129** that may incorporate one or more revisions to the anatomy and/or an associated physical anatomical model. The original and revised anatomical models **129** may be associated with each other in the surgical plan **131**. In implementations, the revisions may be stored as one or more parameters of the original anatomical model **129**.

[0094] The planning system **120** may be configured to generate a link to a surgical plan **131**. The surgeon, assistant or other clinical user may interact with the link to review and edit the surgical plan **131**. Interacting with the link may cause the planning system **120** to display or otherwise present aspects of the surgical plan **131** in the graphical user interface **142**.

[0095] The planning system **120** may be utilized to generate a physical instance of a virtual anatomical model **129** that a surgeon may utilize for rehearsing or training for an orthopaedic procedure, such as the repair of a fracture. The surgeon may interact with a fractured state of a physical anatomical model, which may be associated with the virtual anatomical model **129**. Each fracture may be classified according to one or more fracture classification schemes **141**. Various fracture classification schemes may be utilized in accordance with the teachings disclosed herein, including predefined industry classification schemes and/or user-defined classification schemes. Industry defined classification schemes may include the Müller AO Classification of fractures, the Neer Classification, and the AO Foundation and Orthopaedic Trauma Association (AO/OTA) Fracture Classification Scheme. The AO/OTA Fracture Classification Scheme may include a 2018 revision of the AO/OTA Fracture and Dislocation Classification Compendium released by the AO Foundation. Other fracture classification schemes may be utilized in accordance with the teachings disclosed herein, including any known classification scheme recognized in the medical community.

[0096] The planning system **120** may be adapted to access one or more fracture classification schemes **141**. The comparison module **138** may be adapted to access one or more fracture patterns (e.g., virtual fracture path) **143**. Various techniques may be utilized to establish the fracture pattern **143**, including any of the techniques disclosed herein. The planning system **120** may be adapted to associate each fracture patterns **143** with one or more of the fracture classification schemes **141**. The data module **135** may be configured to access, retrieve and/or store data and other information in the database(s) **128** corresponding to one or more fracture classification schemes **141** and/or fracture patterns **143**. The fracture classification schemes **141** and/or fracture pattern **143** may be predefined and/or may be established by the comparison module **138**. In implementations, the planning system **120** may generate one or more fracture classification schemes **141** and/or fracture patterns **143** automatically and/or in response to user input. The

fracture patterns **143** may be generated utilized various techniques, such as finite element analysis (FEA) and other parametric modeling.

[0097] The comparison module **138** may be adapted to associate each anatomical model **129** with one or more fracture classification schemes **141** and/or fracture patterns **143**. The comparison module **138** may be adapted to assign one or more fracture classification schemes **141** to each fracture pattern **143**, either automatically and/or in response to user interaction with the user interface **142** and/or another portion of the planning system **120**. The data module **135** may be adapted to store and/or access an instance of each anatomical model **129** and an associated fracture classification scheme **141** and/or fracture pattern **143** in the database (s) **128** or another memory location. The comparison module **138** may be adapted to generate, revise or otherwise associate a surgical plan **131** with an anatomical model **129**, fracture classification scheme **141** and/or fracture pattern **143**.

[0098] Each fracture classification scheme **141** and/or fracture pattern **143** may be stored in a respective predefined data structure(s) in the database **128** or another portion of the system **120**. The data and other information associated with the respective fracture classification scheme **141** and/or fracture pattern **143** may be stored in the database **128** as one or more respective records or entries **139**. In implementations, the data and other information may be stored in one or more files that may be accessible by referencing one or more objects or memory locations referenced by the records **139**. The memory **134** may be configured to access, load, edit and/or store instances of one or more fracture classification schemes **141** and/or fracture patterns **143** in response to one or more commands from the data module **135**. The data module **135** may be configured to cause the memory **134** to store a local instance of the fracture classification scheme(s) **141** and/or fracture pattern(s) **143**, which may be synchronized with records **139** in the database(s) **128**.

[0099] The planning system **120** may be utilized to establish one or more physical anatomical models **148**, including any of the physical anatomical models disclosed herein. The physical anatomical model **148** may be representative of an associated virtual anatomical model **129**.

[0100] Referring to FIG. **3**, with continuing reference to FIG. **2**, the user interface **142** may include one or more display windows **144** and one or more objects **146**, such as a first display window **144-1**. The objects **146** may include graphics such as menus, tabs, lists, entry fields and buttons accessible by user interaction, such as tabs **146**T, buttons **146**B, drop-down lists **146**L, menus **146**M, directional indicators **146**D, **146**R (e.g., FIG. **4**), and graphics associated with respective display window(s) **144**. In implementations, one or more entries may be specified in respective entry fields, including any parameters associated with the lists **146**L. Geometric objects, including selected virtual anatomical model(s) **129**, implant model(s) **130**, fracture pattern (s) **143** and/or other information relating to a surgical plan **131** may be displayed in one or more of the display windows **144**.

[0101] The comparison module **138** may be configured to assign a fracture pattern **143** to the virtual anatomical model **129** based on one or more parameters, including any of the parameters disclosed herein. The parameters may be associated with a predefined fracture classification scheme **141**. The comparison module **138** may be configured to assign the fracture pattern **143** to the virtual anatomical model **129** in response to setting one or more parameters associated with the fracture classification scheme **141**.

[0102] The surgeon or clinical user may interact with the display window **144** and/or another portion of the user interface **142** to select one or more anatomical models **129**. Various parameters may be utilized to select the anatomical model(s) **129**. The anatomical models **129** may be categorized by anatomy, patient, defect (e.g., fracture classification), case, etc. The parameters may be associated with respective objects **146** of the user interface **142**. The parameters of the display window **144** may be interconnected to provide a filtering feature such that each selection of a parameter may cause the remaining parameter(s) to be filtered to depict available options. Each parameter may be associated with a set of anatomical models **129** accessible by the planning environment **126**.

[0103] The display module **136** may be adapted to present one or more parameters associated with the anatomy, patient, fracture classification scheme and/or case to the surgeon or clinical user in the display window **144**. The surgeon or clinical user may interact with the user interface **142** to select or otherwise specify one or more of the parameters. Anatomical parameters may be arranged in one or more lists **146**L by category (e.g., joint, etc.), sub-category (e.g., shoulder, ankle, hip, hand, foot, etc.), model (e.g., glenoid, humerus, femur, pelvis, tibia, fibula, etc.) and anatomical size (e.g., small, medium, large). The categories may be subdivided by gross anatomy including surface anatomy (e.g., the external body), regional anatomy (e.g., specific regions of the body), and systemic anatomy (e.g., specific organ systems). The data module **135** may be adapted to cause the display module **136** to populate entries associated with the virtual anatomical model(s) **129** and other parameters including category, sub-category, model and/or size in respective lists **146**L. The spatial module **137** may be configured to scale a geometry of the selected anatomical model **129** in response to selection of an anatomical size. The surgeon or clinical user may select or otherwise specify the anatomical parameters including category, sub-category, model and/or size of the anatomy in response to interaction with the display window **144** and/or another portion of the user interface **142**. Each list **146**L may be associated with one or more virtual anatomical model(s) **129**. The anatomical model **129** may be associated with an anatomy of a patient, such as a prior case or a planned case, and/or a hypothetical anatomy. The surgeon or clinical user may select or otherwise specify parameter(s) associated with respective virtual anatomical model(s) **129**.

[0104] The anatomical models **129** may be categorized by patient parameters. Various patient parameters may be utilized, such as sex, age and ethnicity. The patient parameters may be presented in respective lists **146**L. The data module **135** may be adapted to cause the display module **136** to populate one or more patient parameters associated in the respective lists **146**L. The data module **135** may be adapted to cause the display module **136** to populate entries associated with the anatomy and other parameters including category, sub-category, model and/or size in the respective lists **146**L in response to specifying parameters associated with the patient population.

[0105] Case parameters may include case type (e.g., prior, planned and hypothetical), case number, etc. The surgeon may interact with the list(s) **146**L and/or another portion of

the user interface **142** to select and/or review a particular case, such as a prior, planned or hypothetical case associated with a surgical plan **131**, which may be filtered by the data module **135** based on previous selection(s) of the parameters. The surgeon may interact with the user interface **142** to review prior cases, including prior cases for a particular surgical procedure, anatomy and/or group of patients. The planning system **120** may be configured to provide analysis of the prior case such as biometric testing of a repaired joint, finite element analysis (FEA), etc. The surgeon or clinical user may select a virtual anatomical model **129** corresponding to an intended patient. The selected virtual anatomical model **129** may correspond to an acquired CT scan of the patient. The surgeon may select a virtual anatomical model **129** that may be associated with a particular classification.

[0106] The data module **135** may be adapted to cause the display module **136** to populate entries associated with a case, such as type (e.g., prior, planned or hypothetical) and/or case number in respective lists **146**L. The data module **135** may be adapted to cause the display module **136** to populate entries associated with the case and other parameters including type and/or case number in the respective lists **146**L in response to specifying parameters associated with the patient population.

[0107] The surgical plan **131** may be associated with an anatomical model **129** prior to any revisions and may be associated with another (e.g., revised) anatomical model **129** incorporating one or more revisions based on implementation of an associated surgical procedure. Revisions may include removal of material utilizing one or more drilling, milling, resection, reaming and cutting operations. Revisions may include one or more fragmentary states of the anatomical model **129**, including prior to and/or subsequent to registration of any associated fragments.

[0108] The display module **136** may be adapted to present one or more parameters of a fracture classification scheme **141** associated with the virtual anatomical model **129** in the user interface **142**. The display module **136** may be adapted to display the parameter(s) associated with the classification scheme **141** in the first display window **144-1**. The display module **136** may be configured to present one or more parameters of a respective classification scheme **141** in response to selection of a bone type and/or fracture location. The display module **136** may be adapted to present one or more parameters associated with the classification scheme **141** in response to selection of a bone type (e.g., humerus, femur, tibia, fibula, etc.) and/or fracture location (e.g., proximal humeral fracture location, distal fibula fracture location, etc.) from one or more menus **146**L and/or another portion of the user interface **142**. The data module **135** may be adapted to cause the display module **136** to populate entries associated with parameter(s) of a fracture classification scheme **141** in respective lists **146**L and/or other portion of the user interface **142**. The fracture classification scheme **141** may be selected automatically and/or manually in response to one or more selections associated with anatomy, patient and/or case. The entries may include bone type (e.g., humerus or fibula), location (e.g., proximal or distal end segment), type (e.g., two-part, three-part or four-part), group (e.g., surgical neck fracture) and subgroup(s) (e.g., with greater tuberosity fracture) and other parameters of the associated fracture classification scheme **141** such as qualifier(s) and/or modifier(s) in respective lists **146**L.

[0109] The data module **135** may be adapted to access a virtual anatomical model **129** from memory, such as the memory **134** and/or database **128**, in response to selecting one or more parameters in the display window **144** of the graphical user interface **142**. The data module **135** may be configured to select an anatomical model **129** from memory, such as the database **128** or memory **134**, in response to user interaction with the display window **144** or another portion of the user interface **142**. The data module **135** may select a fracture pattern **143** in response to one or more of the parameters of the fracture classification scheme **141** of the selected virtual anatomical model **129** being selected or otherwise specified.

[0110] The surgeon or clinical user may select the virtual anatomical model **129** according to a severity of various defects, such as mild, severe, non-pathological, fractures, etc. Defect parameters may be established for the various defects and may be arranged by classification, subclassification, etc. The surgeon, assistant or other user may interact with a button **146**B (see, e.g., question mark button **146**Q) for an explanation of the defect parameters. In implementations, selection of a virtual anatomical model **129** from the list **146**L may cause a help screen to be generated and displayed with one or more fracture classification options in response to selection of the button **146**Q. The fracture classification options may be associated with a respective fracture classification scheme **141**, including any of the fracture classification schemes disclosed herein. The surgeon or clinical user may select from the various classification parameters to rehearse and/or train for a surgical procedure, including the treatment of a fractured bone.

[0111] Referring to FIG. **4**, with continuing reference to FIG. **2**, a selected virtual anatomical model **129** may be displayed in one or more display windows **144** of the user interface **142**. In the implementation of FIG. **4**, the various views of the virtual anatomical model **129** may be displayed in display windows **144-2**, such as a second set of display windows **144-2**A through **144-2**D. Each virtual anatomical model **129** may include one or more components **129**C. The components **129**C may include various representations of tissue, such as bone and soft tissue. Bone(s) may be represented by respective bone volume(s) **129**B. Soft tissue(s) may be represented by respective soft tissue volume(s) **129**S. Various representations of soft tissue may be utilized, such as tendons, ligaments, musculature and other soft tissue. The anatomical model **129** may establish a portion of a joint **129**J. The bone volume(s) **129**B may include at least articular surface **129**A that may be dimensioned to cooperate with an adjacent articular surface to establish the joint **129**J. Although four display windows **144-2**A to **144-2**D are shown in FIG. **4**, it should be understood that fewer or more than four display windows **144** may be utilized in accordance with the teachings disclosed herein. The surgeon or clinical user may interact with one or more of the objects **146** to observe various aspects of the anatomical model **129**. In implementations, the surgeon or clinical user may interact with list(s) **146**L to select the respective component **129**C (e.g., humerus, fibula, etc.).

[0112] Referring to FIG. **5**, with continuing reference to FIGS. **2** and **4**, the surgeon or clinical user may interact with the user interface **142** to observe one or more aspects of the anatomical model **129**. The user interface **142** may include one or more display windows **144-3**, such as a third set of display windows **144-3**A to **144-3**D. The user may interact

with a list **146**L to select a specific portion of the soft tissue volume **129**S, such as a rotator cuff. The display module **136** may be adapted to display one or more components **129**C of the anatomical model **129**, such as attachment regions **129**R. The attachment regions **129**R may be established along an interface between the bone volume **129**B and the respective soft tissue volume **129**S. The surgeon or clinical user may interact with one of the objects **146** to specify a transparency of one or more of these selected components **129**C, such as one or more of the soft tissue volume **129**S. Referring to FIG. **6**, with continuing reference to FIGS. **2-3** and **5**, the surgeon or clinical user may interact with the user interface **142** such as by interacting with one of the buttons **146**B or another object **146** to select an attachment view within a list **146**L such that the display module **136** may display a view of the attachment regions **129**R with the soft tissue omitted (see, e.g., FIG. **5**). The attachment regions **129**R may be displayed in one or more display windows **144-4**, such as a fourth set of display windows **144-4**A to **144-4**D.

[0113] Referring to FIG. **7**, with continuing reference to FIGS. **2**, and **6**, the surgeon or clinical user may interact with the user interface **142** to observe an isolated view of the bone volume **129**B. The virtual anatomical model **129** may be displayed in one or more display windows **144-5**, such as a set of fifth display windows **144-5**A to **144-5**D. The display module **136** may be adapted to display one or more aspects of the bone volume **129**B, such as a cortical bone volume **129**CO and/or cancellous bone volume **129**CA. In implementations, the cortical bone volume **129**CO may be displayed in phantom, and the cancellous bone volume **129**CA may be displayed as a two-dimensional or three-dimensional solid.

[0114] The virtual anatomical model **129** may include one or more volumes **129**V. One or more characteristics of the volumes **129**V may be the same or may differ. The characteristics may include any of the characteristics disclosed herein, such as material composition and/or construction. In implementations, the volumes **129**V may include a first volume **129**V**1** and a second volume **129**V**2**. The first (e.g., cortical bone) volume **129**V**1** may be representative of cortical bone. The second (e.g., cancellous bone) volume **129**V**2** may be representative of cancellous bone. The cortical bone volume **129**CO may establish the first volume **129**V**1**. The cancellous bone volume **129**CA may establish the second volume **129**V**2**. The first volume **129**V**1** and the second volume **129**V**2** may include one or more characteristics that may be the same or may differ, such as material composition and/or construction. In implementations, the first and second volumes **129**V**1**, **129**V**2** may differ in density. The different densities may be associated with different bone densities of an associated anatomy.

[0115] Referring to FIG. **8**, with continuing reference to FIGS. **2** and **7**, one or more fracture patterns **143** may be selected or assigned to each virtual anatomical model **129**. In implementations, the data module **135** may be configured to access one or more fracture patterns **143** from the database(s) **128** and/or another data location internal and/or external to the planning system **120**. The spatial module **137** may be configured to generate the fracture pattern **143**.

[0116] The fracture pattern **143** may extend along a boundary region **129**BR between the first volume **129**V**1** and the second volume **129**V**2** (see, e.g., FIG. **7**). The boundary region **129**BR may be established along an interface between the cortical bone volume **129**CO and the cancellous bone volume **129**CA (see, e.g., FIG. **7**). The boundary region **129**BR may follow along an external surface of the cancellous bone volume **129**CA and/or an internal surface of the cortical bone volume **129**CO.

[0117] The surgeon or clinical user may interact with the user interface **142** to observe one or more aspects of the selected or assigned fracture pattern **143**. The spatial module **137** may be adapted to arrange the assigned or selected fracture pattern **143** relative to the respective bone volume **129**B. In the implementation of FIG. **8**, the display module **136** may be adapted to display one or more views of the bone volume **129**B and the associated fracture pattern **143** in one or more display windows **144**, such as a sixth set of display windows **144-6**A to **144**-D. The surgeon or clinical user may interact with the one or more objects such as a list **146**L to select a fracture view.

[0118] Referring to FIGS. **9**A-**9**B, with continuing reference to FIGS. **2** and **8**, aspects of the anatomical model **129** of FIG. **8** are shown. Each fracture pattern **143** may be generated automatically and/or in response to user interaction with the user interface **142**. In implementations, the user may interact with the user interface **142** to manually specify a geometry of the fracture pattern **143**.

[0119] Each fracture pattern **143** may include one or more segments **143**S. The fracture pattern **143** may include two or more segments **143**S that may be continuous or may be spaced apart from each other. Two or more of the segments **143**S may meet at one or more junctions **143**J. Each segment **143**S may be a continuous loop and/or may be established between a pair of junctions **143**J. In implementations, each of the segments **143**S may extend along a surface of a portion of the bone volume **129**B such as an external surface of the cancellous bone volume **129**CA. In other implementations, one or more of the segments **143**S may extend along a surface of the cortical bone volume **129**CO (see, e.g., FIG. **7**). Each of the segments **143**S may be a linear or non-linear path extending between two junctions **143**J. In implementations, each of the segments **143**S may include one or more undulations. The undulations may be representative of a fracture line observed in prior case(s) and/or hypothetical case(s) based on empirical data, parametric modeling, etc.

[0120] Referring to FIGS. **9**C-**9**D, with continuing reference to FIGS. **2**, **8** and **9**A-**9**B, various techniques may be utilized to establish the fracture pattern **143**. The spatial module **137** may be adapted to establish or identify one or more landmarks L relative to the bone volume **129**B and/or another portion of the virtual anatomical model **129**. In implementations, the comparison module **138** may be adapted to determine one or more landmarks L based on a comparison of the anatomical model **129** and one or more prior cases. In implementations, the surgeon or clinical user may interact with the display window **144**, such as the display window **144-6**A or **144-6**B to adjust a position of one or more landmarks L (see, e.g., landmarks L'). The spatial module **137** may be adapted to adjust the position of one or more segments **143**S in response to adjusting one or more associated landmarks L (see, e.g., segments **143**S' and association junctions **143**J').

[0121] The display model **136** may be adapted to display an isolated view of the fracture pattern **143** relative to the bone volume **129**B and/or attachment regions **129**R. In the implementation of FIG. **10**, the surgeon or clinical user may interact with one or more display windows **144-7** such as a seventh set of display windows **144-7**A to **144-7**D, or

another portion of the user interface **142** such as one of the lists **146**L, to hide the representation of the cortical bone volume **129**CO (see FIG. **7**). Selectively hiding the cortical bone volume **129**CO may assist the surgeon or clinical user in observing a relative position between the fracture pattern **143** and attachment region(s) **129**R.

[0122] Referring to FIG. **11**, with continuing reference to FIGS. **2** and **9**A-**9**D, various techniques may be utilized to establish the fracture pattern **143** relative to the virtual anatomical model **129**. The display module **136** may be configured to display the virtual anatomical model **129** in one or more display windows **144-8**, such as an eighth set of display windows **144-8**A to **144-8**D.

[0123] The spatial module **137** may be configured to generate a virtual fracture volume **147**, which may be associated with a fracture pattern **143**. The virtual fracture volume **147** may substantially or generally follow a length of a respective fracture pattern **143** (see, e.g., FIG. **10**). For the purposes of this disclosure, the term "substantially" means±10 percent of the stated relationship or value unless otherwise indicated. A configuration (e.g., definition) **145** (FIG. **2**) may be established according to the virtual fracture volume **147**.

[0124] Referring to FIG. **12**A, with continuing reference to FIGS. **2** and **11**, various techniques may be utilized to establish the virtual fracture volume **147**. The display module **136** may be adapted to display the virtual fracture volume **147** in one or more display windows **144**, such as display windows **144-8**E, **144-8**F (FIG. **12**B). The virtual fracture volume **147** may be established by extruding a shape along a length of the fracture pattern **143**. The display module **136** may be adapted to display the virtual fracture volume **147** in the display windows **144-8**E, **144-8**F. Various shapes may be utilized, such as a straight or curved line segment, an ellipse (e.g., circle), a polygon (e.g., rectangle) and/or complex shape. A geometry of the virtual fracture volume **147** may be selected to facilitate severing of a physical anatomical model. In implementations, the virtual fracture volume **147** may be dimensioned to span between an external surface of the cancellous bone volume **129**CA and an external surface of the cortical bone volume **129**CO. FIG. **12**B discloses an isolated view of the virtual fracture volume **147** of FIG. **12**A in the display window **144-8**F. In other implementations, fracture volume **147'** may be spaced apart from the external surface of the cortical bone volume **129**CO (volume **147'** shown in dashed lines in FIG. **12**A).

[0125] The fracture volume **147** may have various constructions. The fracture volume **147** may be homogenous or may have two or more heterogenous regions. In implementations, the fracture volume **147** may be substantially hollow or may include one or more voids that may serve to weaken a localized region of an associated physical anatomical model.

[0126] Referring to FIG. **13**, with continuing reference to FIGS. **2** and **12**A-**12**B, the virtual anatomical model **129** may be utilized to establish a physical anatomical model **148**. The comparison module **138** may be configured to generate one or more configurations **145** (FIG. **2**) associated with the virtual anatomical model(s) **129**. The comparison module **138** may be adapted to generate the configuration **145** in response to specifying one or more parameters associated with a respective virtual anatomical model **129**, including any of the parameters disclosed herein such as parameter(s) of the fracture classification scheme **141**.

[0127] The configuration **145** may specify various information for forming an instance of an associated physical anatomical model **148**, which may be based on a respective virtual anatomical model **129**. The configuration **145** may include one or more files in a predetermined data structure or format. In implementations, the configuration **145** may include a coordinate set and/or other information such as material selection(s) associated with volume(s) of the physical anatomical model **148**. Each physical anatomical model **148** may be formed utilizing various techniques, including any of the techniques disclosed herein such as rapid prototyping (e.g., printing) and other additive manufacturing techniques, casting, machining, etc.

[0128] The configuration **145** may specify a fracture path (e.g., fracture pattern) **150** that may be associated with a physical anatomical model **148**. Each fracture path **150** may be established according to an assigned fracture pattern **143** such that the fracture patterns **143** may be reproduceable. The configuration **145** may specify coordinate data and/or other information to establish the fracture path **150** according to the assigned fracture pattern **143**. The configuration **145** may be generated such that the respective physical anatomical model **148** may be severable along the fracture path **150** to establish one or more fragments to establish a fragmentary state of the physical anatomical model **148**.

[0129] The physical anatomical model **148** may include a main body **148**M. For the purposes of this disclosure, the alphanumeric suffixes associated with each indicator of the virtual anatomical models are utilized in a like manner in describing similar aspects of the physical anatomical models unless otherwise indicated. The main body **148**M may include an external surface **148**E associated with an anatomical profile of a bone, including any of the bones disclosed herein. In implementations, the anatomical profile of the bone may be associated with a long bone, such as a humerus, femur, fibula, or tibia. The physical anatomical model **148** may be secured to at least one fixture **166** to establish an assembly **168** (shown in dashed lines).

[0130] The physical anatomical model **148** may include one or more physical components **148**C. Each component **148**C may be representative of an associated component **129**C of the respective virtual anatomical model **129**. The components **148**C of the physical anatomical model **148** may include any of the components **129**C of the respective virtual anatomical model **129**, such as bone volume **148**B. A representation of one or more of the components **129**C may be omitted from the physical anatomical model **148** to provide tailored training to the surgeon or clinical user (e.g., different difficulty level, etc.).

[0131] The physical anatomical model **148** may include one or more extensions **148**X (shown in dashed lines). Each extension **148**X may extend from the external surface **148**E of the main body **148**M. One or more of the extensions **148**X may be representative of respective soft tissue volume(s) **148**S, including any of the soft tissue disclosed herein. The soft tissue volume **148**S may be attached to the bone volume **129**B at a respective attachment region **148**R.

[0132] The main body **148**M of the physical anatomical model **148** may include one or more volumes **148**V. The main body **148**M may include a first volume **148**V**1** and a second volume **148**V**2**. The first volume **148**V**1** may establish the external surface **148**E of the main body **148**M. The

first volume **148**V**1** may be representative of cortical bone. The second volume **148**V**2** may be representative of cancellous bone.

[0133] At least one fracture path **150** may be established along the physical anatomical model **148**. The fracture path **150** may be established according to a predetermined fracture pattern **143** (see, e.g., FIG. **12**A). The main body **148**M may include the fracture path **150**. The fracture path **150** may establish one or more localized regions **148**L of the physical anatomical model **148**. The fracture path **150** may divide the main body **148**M into one or more localized regions **148**L. The fracture path **150** may include one or more segments **150**S. Each of the segments **150**S may establish a loop about a respective localized region **148**L (see also fracture volume **152**). The external surface **148**E along at least one of the localized regions **148**L may be associated with an articular surface of a joint, including any of the joints and bones disclosed herein. Each extension **148**X may extend from the external surface **148**E of the main body **148**M adjacent to one or more segments **150**S of the fracture path **150**.

[0134] The main body **148**M of the physical anatomical model **148** may include at least one, or more than one, physical fracture volume **152**. The physical fracture volume **152** may be established along the fracture path **150**. The main body **148**M may be severable along the fracture volume **152** to establish one or more fragments. The physical fracture volume **152** may establish frangible connection (s) between the localized regions **148**L and each other and/or the main body **148**M of the physical anatomical model **148**.

[0135] The fracture path **150** may extend along a boundary region **148**BR between adjacent volumes **148**V of the physical anatomical model **148**, such as between the first volume **148**V**1** and second volume **148**V**2**. The fracture volume **152** may be established along the fracture path **150** such that the fracture volume **152** may be at least partially embedded in one or more of the volumes **148**V, such as the first volume **148**V**1** of the main body **148**M. The main body **148**M may be severable along the fracture volume **152** to establish the one or more fragments. In implementations, the physical fracture volume **152** may be spaced apart from the external surface of the main body **148**M of the physical anatomical model **148** (see, e.g., fracture volume **147'** of FIG. **12**A).

[0136] The volumes **148**V of the physical anatomical model **148** may have various properties. The first volume **148**V**1** may have a first property. The second volume **148**V**2** may have second property. The fracture volume **152** may have a third property. The first, second and/or third properties may be the same or may differ from each other. The first, second and third properties may include respective first, second and third material strengths. The second and/or third material strengths of the second volume **148**V**2** and fracture volume **152** may be less than the first material strength of the first volume **148**V**1**. The first material strength may be representative of cortical bone. The second material strength may be representative of cancellous bone. The lesser material strength may establish relatively weaker region(s) in the physical anatomical model **148** to promote fragmentation of the physical anatomical model **148** in a reproduceable manner. The fracture volume **152** may incorporate any of the materials disclosed herein, such as a silica-based material.

[0137] FIGS. **14-15** disclose virtual anatomical models **229** according to another implementation. The anatomical models **229** may include a first anatomical model **229-1** and a second anatomical model **229-2**, which may be adjacent to the first anatomical model **229-1**. FIG. **15** depicts the anatomical models **229** in phantom. The anatomical models **229** may incorporate any of the features disclosed herein, including anatomical features representative of anatomy, such as one or more bones including cartilage, cortical and/or cancellous bone tissue, soft tissue including muscle, ligaments and/or tendons, etc., and/or other tissue. Each anatomical model **229** may be associated with a surgical plan (e.g., surgical plan **131** of FIG. **2**). In implementations, the anatomical models **229** may be associated with respective bones of a limb of a patient. The bones may be adjacent to each other. The anatomical model **229-1** may include portions associated with a joint of a patient, including any of the joints disclosed herein such as an ankle joint. The anatomical model **229-1** may be associated with a tibia of a patient. The anatomical model **229-2** may be associated with a fibula of the patient.

[0138] The anatomical models **229-1**, **229-2** may be associated with respective virtual fracture volumes **247** (indicated by **247-1**, **247-2**). Each fracture volume **247-1**, **247-2** may be established by a respective fracture pattern **243** (indicated by **243-1**, **243-2**). The fracture pattern **243** may be established utilizing any of the techniques disclosed herein. The fracture pattern **243** and associated fracture volume **247** may be established based on an associated fracture classification scheme **141** (FIG. **2**). In implementations, the fracture pattern **243** may be dimensioned to substantially follow an outer periphery of the respective anatomical model **229**. The outer periphery may be associated with an inner cortical wall or an outer cortical wall of a bone. The fracture volume **247** may be dimensioned to span between opposite sides of a perimeter of the fracture pattern **243** such that the fracture volume **247** may extend substantially through a main body of the virtual anatomical model **229**.

[0139] A portion of the virtual fracture volume **247** may be established by extruding a shape along a length of the perimeter of the fracture pattern **243**. The fracture volume **247** may include a portion (e.g., area) within a periphery of the fracture pattern **243** such that the fracture volume **247** may have a contiguous (e.g., enclosed) three-dimensional profile. The fracture volume **247** may have various geometries, such as a substantially planar or complex geometry. In the implementation of FIG. **15**, each of the fracture volumes **247** has a contoured geometry associated with a profile of the fracture pattern **243**. FIG. **16** discloses the fracture volumes **247-1**, **247-2** at the orientation of FIGS. **14-15**. FIG. **17** discloses the fracture volumes **247-1**, **247-2** at a different orientation.

[0140] Various techniques may be utilized to establish a geometry of the portion of the fracture volume **247** inside of the perimeter of the fracture pattern **243**, such as manual sculpting or automated techniques. Automated techniques may include a "close holes" operation in which an interior of an object is filled by a two-dimensional or three-dimensional mesh. The spatial module **137** (FIG. **2**) may be configured to generate the fracture pattern **243** and associated fracture volume **247** utilizing any of the techniques disclosed herein.

[0141] FIG. **18** discloses a sectional view of the virtual anatomical model **229-1** and the respective fracture volume **247-1**. In the implementation of FIG. **18**, the fracture volume **247-1** may extend completely, or at least substantially, through a volume of the anatomical model **229-1**. The

fracture volume **247-1** may be established in the anatomical model **229-1** to facilitate at least partial or complete separation of adjacent portions of an associated physical anatomical model. The virtual anatomical model **229** may be utilized to establish a physical anatomical model utilizing any of the techniques disclosed herein. The anatomical model **229** and fracture volume **247** may be associated with the same and/or different structures, materials, porosities, etc., including any of those disclosed herein, for establishing the physical anatomical model. A configuration **145** (FIG. **2**) for fabrication the physical anatomical model may specify a geometry associated with the fracture volumes **247-1**, **247-2** for establishing a physical fracture path (e.g., pattern) and associated fracture volume in the physical anatomical model.

[0142] FIG. **19** discloses a system **364** for an orthopaedic procedure. The system **364** may incorporate any of the features disclosed herein. The system **364** may include a physical anatomical model **348**. The physical anatomical model **348** may include one or more physical components **348**C. The physical anatomical model **348** may be secured to at least one fixture **366** to establish an assembly **368**. A main body **348**M of the physical anatomical model **348** may be representative of anatomy. In implementations, the main body **348**M may be associated with an anatomical profile of one or more bones, including any of the bones disclosed herein. In implementations, the bone may be a long bone, such as a fibula, tibia, femur or humerus.

[0143] The main body **348**M of the physical anatomical model **348** may include one or more physical bone volumes (e.g., components) **348**B. The bone component **348**B may include an exterior **348**E having a surface contour **348**SC representative of the respective bone. The main body **348**M of the physical anatomical model **348** one or more soft tissue components **348**S on the bone component(s) **348**B. The soft tissue component **348**S may be representative of soft tissue.

[0144] The bone component **348**B may include a first portion **370** and/or a second portion **380**. The first portion **370** may be adjacent to the second portion **380**. In implementations, the first portion **370** may be incorporated into the second portion **380**, or vice versa. The first portion **370** and second portion **380** may be a unitary structure or may be separate and distinct components that may be attached or otherwise secured to each other. The first portion **370** and/or second portion **380** may include a joint region **348**J of the bone component **348**B. The joint region **348**J may be representative of an orthopaedic joint, including any of the joints disclosed herein, such as an ankle joint. The first portion **370** and/or second portion **380** may establish the exterior **348**E of the bone component **348**B. The first portion **370** may be adjacent to an intermediate portion and/or a proximal portion of the bone component **348**B, and the second portion **380** may be adjacent to a distal portion of the bone component **348**B, or vice versa. The first portion **370** may be distal to the second portion **380**, or vice versa. In implementations, the bone component **348**B of the physical anatomical model **348** may be representative of a fibula. The second portion **380** may be associated with a distal portion of the representative fibula. The first portion **270** may be associated with an intermediate and/or proximal portion of the representative fibula.

[0145] The physical anatomical model **348** may incorporate one or more features for viewing an interior **3481** of the model **348**. The physical anatomical model **348** may incorporate various materials to facilitate viewing the interior **3481**. In implementations, the first portion **370** may include a first material. The second portion may include a second material. The first and second materials may be the same or may differ with respect to one or more material characteristics. The first material may be translucent or may be completely or substantially transparent. The first portion **370** may be formed of the first material such that an interior portion **372** of the body **348**M, including the interior **3481** of the bone component **348**B, may be viewed through the first material from outside of the physical anatomical model **348**. The second material associated with the second portion **380** may have a transparency that may be less than a transparency of the first material associated with the first portion **370**. The second material associated with the second portion **380** may have an opacity that may be greater than an opacity of the first material associated with the first portion **370**. The second material may be substantially or completely opaque. For the purposes of this disclosure, the term "transparent" refers to the physical property of allowing light to pass through the material without appreciable scattering of light. The term "translucent" is used herein to describe elements that are both partially reflective and partially transmitting of light incident on them. An "opaque" material is a material that does not allow light to pass through, blocking the transmission of light.

[0146] The physical anatomical model **348** may include at least one a viewing portal (e.g., window) **378** for viewing the interior **3481** of the bone component **348**B from outside the physical anatomical model **348**. The first portion **370** and/or another portion of the main body **348**M may include the viewing portal **378**. In implementations, the viewing portal **378** may be relatively more transparent or translucent than one or more other portions of the main body **348**M of the physical anatomical model **348**. In implementations, the first material of the first portion **370** may establish the viewing portal **378**. A perimeter of the viewing portal **378** may be bounded by a material that may be opaque or may otherwise have a relatively lesser transparency than the first material establishing the viewing portal **378**. In implementations, the second portion **380** may substantially surround the perimeter of the viewing portal **378**.

[0147] The interior portion **372** of the main body **348**M viewable through the viewing portal **378** and/or another section of the first portion **370** may be an interior area of interest associated with an orthopaedic procedure. In implementations, the interior portion **372** of the bone component **348**B may include an internal cavity **374**. The cavity **374** may be at least partially bound by the transparent or translucent material. Some, or all, of the cavity **374** may be viewable through the first portion **370** from outside of the model **348**. The cavity **374** may include a portion in the shape of a longitudinal (e.g., intramedullary) canal.

[0148] The internal cavity **374** may be dimensioned to at least partially receive an orthopaedic implant (e.g., orthopaedic implant **382** of FIG. **21**). The cavity **374** may extend at least partially through the first portion **370** and/or the second portion **380** of the bone component **348**. In implementations, the cavity **374** may extend inwardly from the exterior **348**E of the bone component **348**B, such as the joint region **348**J. The internal cavity **374** may be at least partially aligned with the viewing portal **378**.

[0149] The internal cavity **374** may have various geometries. In implementations, the cavity **374** may be represen-

tative of a reaming path for receiving an intramedullary nail. The cavity **374** may be formed with the physical anatomical model **348** utilizing any of the techniques disclosed herein, such as through rapid prototyping (e.g., printing) and other additive manufacturing techniques. In other implementations, the cavity **374** may be established subsequent to forming the physical anatomical model **348**. The cavity **374** may be established using a machining or other material removal technique. The surgeon or other user may utilize a surgical instrument such as a drill to establish the cavity **374**.

[0150] The bone component(s) **348**B and/or another portion of the physical anatomical model **248** may include one or more fracture paths **350**. The fracture paths **350** may establish one or more localized regions. The bone component **348**B may be severable along the fracture path **350** to establish one or more fragments associated with a respective one of the localized regions. The fracture paths **350** may be established utilizing any of the techniques disclosed herein. The cavity **374** may extend through one or more of the fracture paths **350** (e.g., FIG. **19**). The cavity **374** may be at least partially aligned with the viewing portal **378**, which may be spaced apart from the facture path **350**.

[0151] Referring to FIG. **20**, with continuing reference to FIG. **19**, the cavity **274** may include a deployment region **376**. The deployment region **376** may be dimensioned to at least partially receive a (e.g., deployable) portion of an orthopaedic implant movable between an undeployed state and a deployed state (e.g., implant **382** of FIG. **21**). The deployment region **376** may be at least partially aligned with the viewing portal **378** such that the deployment region **376** may be viewable through the viewing portal **378**.

[0152] The deployment region **376** may be an (e.g., localized) area of interest associated with an orthopaedic procedure. The deployment region **376** may be established in or otherwise adjacent to the first portion **370** such that the deployment region **376** may be viewed from outside of the physical anatomical model **348**. In implementations, the deployment region **376** may include a conical void. The conical void may be associated with a geometry of the portion of the implant in the deployed state (e.g., FIG. **21**).

[0153] Referring to FIG. **21**, with continuing reference to FIGS. **19-20**, an orthopaedic implant **382** may be at least partially receivable within the internal cavity **374**. The implant **382** may include one or more components that may be situated at a surgical site, including plates, anchors, screws, nails, suture, grafts, etc. In implementations, the implant **382** may be an intramedullary (e.g., fibular) nail. The implant **382** may include a portion having an undeployed state and a deployed state. In implementations, the portion of the implant **382** may include one or more deployable (e.g., bendable) members (e.g., anchors or talons) **384**. The deployable members **384** may be movable between the undeployed state (e.g., position) and the undeployed state (e.g., position). The deployment region **376** may be dimensioned to receive the portion of the implant **382** including the deployable members **384**. The deployable members **384** may be adapted to deploy outward from an undeployed position to a deployed position within the deployment region **376** of the cavity **374** to secure the implant **382** to the bone component **348**B. In the implementation of FIGS. **19-20**, deployment of the deployable members **384** of the implant **382** to the deployed position may be viewable through the first portion **370** of the bone component **348**B. Being able to view the deployment of the implant may assist a surgeon in training, rehearsing and/or evaluating an orthopaedic procedure.

[0154] Referring to FIG. **22**, with continuing reference to FIGS. **19-21**, the system **364** may include one or more light sources **386**. The light source(s) **386** may be operable to illuminate the interior (e.g., interior portion) **3481** of the physical anatomical model **348**, including at least a portion of the first material of the first portion **370**, the internal cavity **374** and/or the orthopaedic implant **382**. The interior **3481** may be viewable through the first material. The light source(s) **386** may be positioned at various locations relative to the physical anatomical model **348**. The light source **386** may be at least partially embedded in the main body **348**M of the physical anatomical model **348**, including the first portion **370** and/or another portion of the bone component **348**B (e.g., light source **386'** shown in dashed lines in FIG. **22**). In other implementations, the light source **386** may be external to the main body **348**M. The light source **386** may be operable to illuminate the first portion **370** of the bone component **348**B adjacent to the viewing portal **378**. Illumination may allow for relatively clearer viewing, which may assist the surgeon or user in positioning, deploying and/or evaluating the implant **382** in the cavity **374**.

[0155] Various light sources may be utilized to illuminate the physical anatomical models and systems disclosed herein, including incandescent, fluorescent, halogen, and/or light emitting diodes (LED). The light source **386** may be coupled to a power supply. The power supply may be external or may be embedded in the physical anatomical model (e.g., battery powered).

[0156] The light source **386** may be configured to generate light in one or more frequencies and/or frequency ranges of visible and/or non-visible light. The frequencies and/or frequency ranges may be defined in a visual light spectrum (e.g., 400 nm to 700 nm), near infrared light spectrum (e.g., 2.5 μm to 750 nm) and/or infrared light spectrum (e.g., 25 μm to 2.5 μm). The light source **256** may be configured to generate light characterized by various hue, saturation and/or brightness. The light source **386** may include a plurality of modes associated with distinct frequencies and/or frequency ranges of visible and/or non-visible light. The plurality of modes may include first and second modes associated with first and second frequency ranges, respectively.

[0157] FIG. **23** discloses a method in a flowchart **490** for a surgical procedure. The method **490** may be utilized to pre-operatively plan, rehearse and/or train for various orthopaedic procedures, such as an arthroplasty for restoring functionality to shoulders, ankles, knees, hips and other joints. The method **490** may be utilized with any of the planning systems, virtual anatomical models and/or physical anatomical models disclosed herein. The method **490** may be utilized to establish physical anatomical model(s) for training and rehearsing for a surgical procedure. The method **490** may be utilized to evaluate the accuracy in which a surgeon may implement a surgical procedure on a physical anatomical model associated with an anatomy of a patient or hypothetical case. Fewer or additional steps than are recited below could be performed within the scope of this disclosure, and the recited order of steps is not intended to limit this disclosure. Reference is made to the system **120** and user interface **142** for illustrative purposes.

[0158] Referring to FIG. **2**, with continuing reference to FIG. **23**, at step **490-1** one or more virtual anatomical models

129 may be generated. Each virtual anatomical model 129 may be associated with an anatomy of a patient and/or hypothetical case. The virtual anatomical models 129 may be generated utilizing any of the techniques disclosed herein. The virtual anatomical models 129 may include any of the anatomies and tissue types disclosed herein, including bone, ligament, tendon, cartilage, etc. At step 490-2, one or more fracture patterns 143 may be generated. The fracture patterns 143 may be generated utilizing any of the techniques disclosed herein.

[0159] At step 490-3, one or more virtual anatomical models 129 may be accessed. The virtual anatomical model 129 may be accessed from memory 134, the network 23 and/or another computing device, such as the storage system 27 (FIG. 1). Step 490-3 may include selecting one or more virtual anatomical models 129 from a set of virtual anatomical models 129. Each virtual anatomical model 129 may be associated with an anatomy. Various techniques may be utilized to select the virtual anatomical model 129. The virtual anatomical models 129 may be stored in memory of a computing device, such as in the database 128 or the memory 134 of the computing device 132.

[0160] Referring to FIG. 3, with continuing reference to FIGS. 2 and 23, selecting the virtual anatomical model 129 may include selecting or otherwise specifying various parameters associated with the set of virtual anatomical models 129. The parameters may include any of the parameters disclosed herein, including anatomy, patient classification, fracture classification and/or case. The parameters may be selected in response to user interaction with the graphical user interface 142.

[0161] Referring to FIGS. 4-7, with continuing reference to FIGS. 2 and 23, at step 490-4 the selected virtual anatomical model(s) 129 may be viewed in the graphical user interface 142. Step 490-4 may include setting the parameter(s) in response to user interaction with the graphical user interface 142. The parameters may be specified in response to the surgeon or clinical user interacting with the user interface 142. One or more of the parameters may be associated with predefined fracture classification scheme(s) 141. The fracture classification schemes 141 may include any of the fracture classification schemes disclosed herein.

[0162] Referring to FIGS. 9A-9D, with continuing reference to FIGS. 2-3, 8 and 23, one or more fracture patterns 143 may be assigned to the virtual anatomical model 129 at step 490-5. The fracture pattern 143 may be assigned to the virtual anatomical model 129 utilizing any of the techniques disclosed herein. The fracture pattern 143 may be assigned to the virtual anatomical model 129 based on one or more parameters, including any of the parameters disclosed herein such as anatomy, patient classification, fracture classification and/or case. Assigning the fracture pattern 143 may occur in response to setting one or more parameters associated with the fracture classification scheme 141. Step 490-5 may include causing the virtual anatomical model 129 and/or the assigned fracture pattern 143 to be displayed in one or more display windows 144 of the graphical user interface 142, such as the display windows 144-6A to 144-6D (FIG. 8).

[0163] At step 490-6, aspects of one or more of the virtual anatomical models 129 may be defined. Each virtual anatomical model 129 may be defined prior, during and/or subsequent to generating the virtual anatomical model(s) 129 at step 490-1, generating the fracture pattern(s) 143 at step 490-2, selecting the virtual anatomical model(s) 129 at step 490-3, viewing the selected virtual anatomical model(s) 129 at step 490-4 and/or assigning fracture pattern(s) 143 to the virtual anatomical model(s) 129 at step 490-5. Defining the virtual anatomical model 129 may include setting one or more parameters of the virtual anatomical model 129, including any of the parameters disclosed herein. The parameters may be selected in response to user interaction with the graphical user interface 142 (e.g., FIG. 3). The parameters may be associated with one or more fracture classifications 141 (FIG. 2) and/or fracture patterns 143 (e.g., FIGS. 2 and 9).

[0164] Referring to FIGS. 11 and 12A-12B, with continuing reference to FIGS. 2 and 23, defining the virtual anatomical model 129 may include generating one or more virtual fracture volumes 147 at step 490-7. Each virtual fracture volume 147 may be established utilizing any of the techniques disclosed herein.

[0165] Defining the virtual anatomical model 129 at step 490-6 may include selecting at least one virtual implant model 30 (FIG. 2) at step 490-8. The implant model 30 may be associated with a physical orthopaedic implant suitable for treating the anatomy associated with the virtual anatomical model 129. The implant model 30 may be associated any of the implants disclosed herein, such as the implant 382 (FIG. 21). At step 490-9, an internal volume may be defined in the virtual anatomical model 129. The internal volume may be dimensioned to accommodate a profile of the implant model 30 based on a position of the implant model 30 in the virtual anatomical model 129.

[0166] At step 490-10, one or more configurations (e.g., definitions) 145 may be generated. Each configuration 145 may be associated with at least one virtual anatomical model 129, fracture pattern 143, physical anatomical model 148, fracture path 150 and/or physical fracture volume 152. Each configuration 145 may be generated utilizing any of the techniques disclosed herein. The configuration 145 may be associated with a physical anatomical model 148 that may be representative of a selected virtual anatomical model 129. Each configuration 145 may be generated in response to selecting the respective virtual anatomical model 129 at step 490-3, assigning the respective fracture pattern 143 at step 490-5 and/or defining the selected virtual anatomical model 129 at step 490-6. The configuration may be established according to the selection or setting of any parameters associated with the selected virtual anatomical model 129, including any fracture pattern 143 and/or fracture volume 152. The configuration 145 may include data and other information sufficient to establish a physical anatomical model 148 based on the parameters of the selected virtual anatomical model 129, including coordinate information, color, texture and/or moduli of elasticity of the associated tissues, geometry associated with one or more fracture paths 150, characteristics of the assigned materials including any of the material characteristics disclosed herein such as transparency or opacity, etc. The configuration 145 may specify one or more fracture paths 150 established in the physical anatomical model 148 according to the assigned fracture pattern 143. In implementations, the configuration 145 may include geometry associated with an internal cavity, such as the internal cavity 374 (e.g., FIGS. 19-21).

[0167] Referring to FIG. 13, with continuing reference to FIGS. 2, 12A-12B and 23, one or more physical anatomical models may be fabricated or otherwise formed at step

490-11, including any of the physical anatomical models disclosed herein, such as the physical anatomical model **148** (e.g., FIG. **13**) and/or the physical anatomical model **348** (e.g., FIGS. **19-22**). The physical anatomical model **148** may be formed to closely resemble or approximate a geometry of the associated anatomy, including bone and/or soft tissue. The physical anatomical model may be representative of any of the bones and joints disclosed herein, including a long bone such as a fibula, tibia, femur and/or humerus. In implementations, the surgeon may interact with the physical anatomical model **148** such that portion(s) of the physical anatomical model **148** may feel similar to soft (e.g., cancellous) bone tissue, muscle and other soft tissue, etc. The physical anatomical model **148** may be printed or otherwise formed according to the various parameters selected in the user interface **142**. Various parameters may be utilized to form the physical anatomical model **148**, including any of the parameters disclosed herein, such as density of bone and soft tissue, thickness of cortical bone, indicators, patient age, etc.

[0168] Each physical anatomical model **148** may be fabricated or otherwise formed based on a configuration **145** generated at step **490-11**. Various materials may be utilized to form the physical anatomical models, including any of the materials disclosed herein. The physical anatomical model **148** including the main body **148**M may incorporate metallic and/or non-metallic materials, including any of the materials disclosed herein such as a polymeric material. In implementations, the main body **148**M may be formed from a substantially rigid material, such as a polymeric material, including photopolymers, silicones and thermoplastics. Portions of the physical anatomical model **148** may be formed from a relatively flexible material, including an elastomeric material such as rubber or silicone, to establish soft tissue volume(s) representative of any of the soft tissue disclosed herein. Portions of the physical anatomical model may include transparent and/or translucent material(s) for viewing an interior of the physical anatomical model, such as an interior (e.g., interior portion) **3481** of the physical anatomical model **348** (e.g., FIGS. **19-20** and **22**).

[0169] Various techniques may be utilized to form the physical anatomical models. Each physical anatomical model may be formed utilizing any of the techniques disclosed herein, such as rapid prototyping (e.g., printing) and other additive manufacturing techniques, casting, machining, etc. The physical anatomical model may have a unitary construction or may have two or more components fixedly attached or otherwise secured to each other to establish a unit.

[0170] In the implementation of FIG. **24**, one or more layers **592** of material may be printed or otherwise formed on a substrate **593** to establish a physical anatomical model **548**. The physical anatomical model **548** may be representative of a virtual anatomical model, including any of the virtual anatomical models disclosed herein. A device **594** such as a three-dimensional printer may be configured to form the layers **592** according to data and other information associated with the respective configuration **145**. The layers **592** of material may include any of the constructions, materials, color schemes, textures, porosities, etc. disclosed herein. The layers **592** may have respective moduli of elasticity that may substantially correspond to moduli of elasticity of respective biomaterial of the anatomy. The porosities of the material forming the physical anatomical model **548** may substantially approximate the porosity or density of the respective tissue. The physical anatomical model **548** may be formed with materials having different transparencies, translucence, opacity, etc., utilizing any of the techniques disclosed herein.

[0171] In the implementation of FIG. **13**, the physical anatomical model **148** may include a first volume **148V1** and a second volume **148V2**. The first volume **148V1** may be representative of cortical bone. The second volume **148V2** may be representative of cancellous bone. The fracture path **150** may establish one or more localized regions **148**L of the physical anatomical model **148**. The configuration **145** established at step **490-9** may specify a fracture volume **152** that may follow a length of the fracture path **150**. The physical anatomical model **148** may be severable along the fracture path **150** and/or fracture volume **152** to establish one or more fragments associated with the respective localized regions **148**L. The physical fracture volume **152** may establish a frangible connection between the localized region **148**L and adjacent localized region(s) **148**L and/or main body **148**M of the physical anatomical model **148**.

[0172] In the implementation of FIGS. **19-22**, step **490-11** may include forming the physical anatomical model **348**. The physical anatomical model **348** may include a body **348**M associated with an anatomical profile of a bone. At least a first portion **370** of the body **348** may include a first material that may be transparent or translucent for viewing an interior (e.g., interior portion) **3481** of the body **348**M. The body **348**M may include an exterior **348**E having a surface contour **348**SC representative of a cortical wall of the bone. The body **348**M may include a second portion **380** that may establish the exterior **348**E adjacent to the first portion **370**. The second portion **380** may include a second material having an opacity that may be greater than an opacity of the first material. The physical anatomical model **348** may be established such that the first portion **370** and/or another portion of the model **348** may include a viewing portal (e.g., window) **378** for viewing the interior **3481** from outside of the physical anatomical model **348**.

[0173] Step **490-11** may include forming an internal cavity **374** in the interior **3481** of the physical anatomical model **348** at step **490-12**. The internal cavity **374** may be dimensioned and formed according to any of the techniques disclosed herein. The first portion **370** may be at least partially aligned with the deployment region **376** of the internal cavity **374** such that the deployment region **376** may be visible from outside of the physical anatomical model **348**. In implementations, the internal cavity **374** may extend through fracture path(s) **350** in the physical anatomical model **348** (e.g., FIG. **19**).

[0174] In implementations, step **490-11** may include at least partially, or completely, filling the internal cavity **347** with a material (e.g., filler), which may have at least one characteristic that may differs from the first material associated with the first portion **370** and/or the second portion **380**. The filler may be removeable from the internal cavity **347** subsequent to formation of the physical anatomical model **348**.

[0175] At step **490-13**, the surgeon or clinical user may position or otherwise prepare the physical anatomical model **148**. The physical anatomical model **148** may be secured to at least one fixture **166** to establish an assembly **168** (shown in dashed lines in FIG. **13**). The fixture(s) **166** may be

arranged relative to a static structure and/or one or more reusable components. The fixture(s) **166** may be representative of surrounding tissue or a portion of a joint. The surgeon may utilize the fixture(s) **166** to simulate rotating or moving a limb in an operating room. Fixture(s) **166** may be representative of skin tissue and may be formed from a relatively flexible material, such as an elastomeric material. The surgeon may form one or more openings in the fixture **166** to simulate performing an incision to expose a joint, bone and/or another portion of the anatomy.

[0176] Still referring to FIGS. **2** and **23**, one or more modifications to the physical anatomical model(s) may be performed at step **490-11**. In implementations, the surgeon or clinical user may use instrumentation to form the internal cavity **374** in the physical anatomical model **348** (FIGS. **19-22**), which may occur subsequent to forming the physical anatomical model **348** at step **490-11**. The internal cavity **374** may be formed utilizing various techniques, such as a drilling, milling or reaming operation. The surgeon or clinical user may perform various modifications to the physical anatomical model to simulate surgical operations performed on an anatomy to restore functionality to a patient. The simulated surgical operations may include one or more repairs to the anatomy, such as one or more cutting, drilling, reaming, resection and implantation operations. Each modification may result in permanently altering a geometry of the physical anatomical model.

[0177] At step **490-15**, one or more modifications to the physical anatomical model(s) may be evaluated utilizing any of the techniques disclosed herein. Step **490-15** may include inserting an orthopaedic implant **382** at least partially into the internal cavity **374** (FIGS. **19-22**). Step **490-15** may include deploying one or more deployment members **384** of the implant **382** and viewing the deployment through a transparent or translucent material, including through a viewing portal **378** (e.g., window). Step **490-15** may include deploying the deployment member(s) **384** within the deployment region **376**.

[0178] In the implementation of FIG. **22**, step **490-15** may include illuminating the physical anatomical model **348** at step **490-16**. Step **490-16** may include illuminating the interior (e.g., interior portion) **3481** of the main body **248**M, such as the transparent or translucent material. The interior **3481** of the physical anatomical model **348** may be illuminated with one or more light sources **386**. The light source(s) **386** may be at least partially embedded in, or may otherwise be adjacent to, the body **348**M physical anatomical model **348**. The light source(s) **386** may be arranged to at least partially illuminate the viewing portal **378** and/or the internal cavity **374** including the deployment region **376**. Step **490-16** may include illuminating at least the first material associated with the first portion **370** when the implant **382** is in the deployed state.

[0179] The novel devices and methods of this disclosure provide versatility in planning, rehearsing and training for surgical procedures utilizing physical anatomical models. The physical anatomical models may be representative of various anatomy, including anatomy associated with various fracture classifications. The surgeon may interact with the disclosed system to gain familiarity with the selected anatomy and various surgical procedures that may be utilized to implement a surgical plan, including the repair of fractures that may be associated with different fracture classifications. The physical anatomical models may be representative of various tissue types and may incorporate transparent or translucent materials. The transparent or translucent portions may assist the surgeon in determining the accuracy and effectiveness of implementing surgical procedures on the physical anatomical model.

[0180] Although the different non-limiting embodiments are illustrated as having specific components or steps, the embodiments of this disclosure are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the other non-limiting embodiments.

[0181] It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should further be understood that although a particular component arrangement is disclosed and illustrated in these exemplary embodiments, other arrangements could also benefit from the teachings of this disclosure.

[0182] The foregoing description shall be interpreted as illustrative and not in any limiting sense. A worker of ordinary skill in the art would understand that certain modifications could come within the scope of this disclosure. For these reasons, the following claims should be studied to determine the true scope and content of this disclosure.

1. A system for an orthopaedic procedure comprising:

a physical anatomical model including a main body representative of anatomy, wherein the main body includes a bone component, the bone component including an exterior having a surface contour representative of a bone, the bone component comprising:

a first portion establishing the exterior and comprising a first material; and

a second portion adjacent to the first portion, the second portion including a second material that differs from the first material, and the second material is transparent or translucent for viewing an interior of the bone component.

2. The system of claim **1**, wherein the second material is transparent.

3. The system of claim **1**, wherein the second material is translucent.

4. The system of claim **1**, wherein the second material establishes a viewing portal to the interior of the bone component, the interior of the bone component includes an internal cavity at least partially aligned with the viewing portal, the internal cavity dimensioned to at least partially receive an orthopaedic implant.

5. The system of claim **4**, wherein the internal cavity extends at least partially through the first portion of the bone component.

6. The system of claim **4**, wherein the internal cavity includes a deployment region dimensioned to at least partially receive a portion of the orthopaedic implant movable between an undeployed state and a deployed state, the deployment region at least partially aligned with the viewing portal.

7. The system of claim **6**, wherein the deployment region includes a conical void associated with a geometry of the portion of the implant in the deployed state.

8. The system of claim **1**, wherein the bone is a fibula, and the second portion is adjacent to an intermediate portion and/or a proximal portion of the bone component.

9. (canceled)
10. (canceled)
11. The system of claim 1, wherein the first material has a transparency that is less than a transparency of the second material, and the first material is substantially opaque.
12. The system of claim 1, wherein the first material has a transparency that is less than a transparency of the second material, and the first portion is distal to the second portion.
13. The system of claim 12, wherein the first portion includes a joint region of the bone component, the joint region representative of an orthopaedic joint.
14. The system of claim 1, further comprising:
a light source at least partially embedded in the main body; and
wherein the light source is operable to illuminate the interior.
15. (canceled)
16. The system as recited in claim 14, wherein the second material establishes a viewing portal to the interior of the bone component, and an opaque material surrounds a perimeter of the viewing portal.
17. The system as recited in claim 1, further comprising:
a soft tissue component on the bone component, wherein the soft tissue component is representative of soft tissue.
18. The system as recited in claim 1, wherein:
the bone component includes a fracture path that establishes one or more localized regions; and
wherein the bone component is severable along the fracture path to establish one or more fragments associated with a respective one of the one or more localized regions.
19. The system of claim 18, wherein the interior of the bone component includes an internal cavity that extends through the fracture path and is at least partially aligned with a viewing portal established by the second material, and the internal cavity is dimensioned to at least partially receive an orthopaedic implant.
20. (canceled)
21. (canceled)
22. (canceled)
23. A method of rehearsing for a surgical procedure comprising:
accessing a virtual anatomical model associated with an anatomy;
generating a configuration associated with a physical anatomical model that is representative of the virtual anatomical model; and
forming the physical anatomical model, the physical anatomical model including a body associated with an anatomical profile of a bone, at least a first portion of the body including a first material that is transparent or translucent for viewing an interior portion of the body.
24. (canceled)
25. The method of claim 23, comprising:
illuminating the interior portion.
26. (canceled)
27. (canceled)
28. (canceled)
29. (canceled)
30. (canceled)
31. (canceled)
32. (canceled)
33. (canceled)
34. (canceled)
35. (canceled)
36. (canceled)
37. A system for an orthopaedic procedure comprising:
a physical anatomical model including a main body representative of anatomy, wherein the main body includes a bone component, the bone component including an exterior having a surface contour representative of a bone, the bone component comprising:
a first portion establishing the exterior and comprising a first material; and
a second portion adjacent to the first portion, the second portion including a second material that differs from the first material, the second material being transparent or translucent for viewing an interior of the bone component, the first material having a transparency that is less than a transparency of the second material, the second material establishing a viewing portal to the interior of the bone component, the interior of the bone component including an internal cavity at least partially aligned with the viewing portal, the internal cavity dimensioned to at least partially receive an orthopaedic implant; and
a light source at least partially embedded in the bone component and operable to illuminate the interior.
38. The system of claim 37, wherein:
the bone component includes a fracture path that establishes one or more localized regions;
the bone component is severable along the fracture path to establish one or more fragments associated with a respective one of the one or more localized regions; and
the internal cavity extends through the fracture path.

* * * * *