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(54) **ULTRASOUND PROBE**

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(57) **ABSTRACT**

An ultrasound probe includes: a probe main body section to which ultrasonic vibration generated by an ultrasound transducer is transmitted; a controller that is connected to the ultrasound transducer and controls generation of the ultrasonic vibration; and a treatment section that is provided on a distal side of the probe main body section and forms a hole in a bone, which is a treatment target, with the ultrasonic vibration. The treatment section has a distal end and a proximal end and includes a columnar portion, a cutting portion that cuts the bone by crushing the bone with the ultrasound vibration and forms the hole, and a discharge portion that discharges cutting debris of the bone cut by the cutting portion toward the proximal end from the cutting portion, the discharge portion including a recessed portion formed in a groove shape inclined with respect to the longitudinal axis.

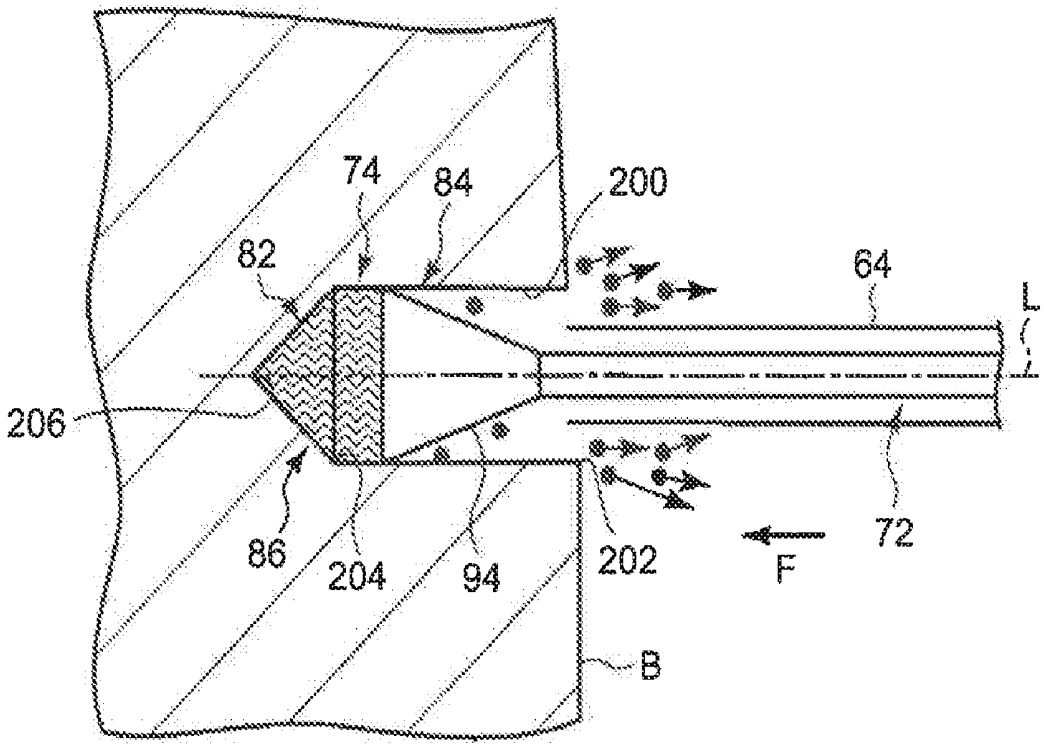
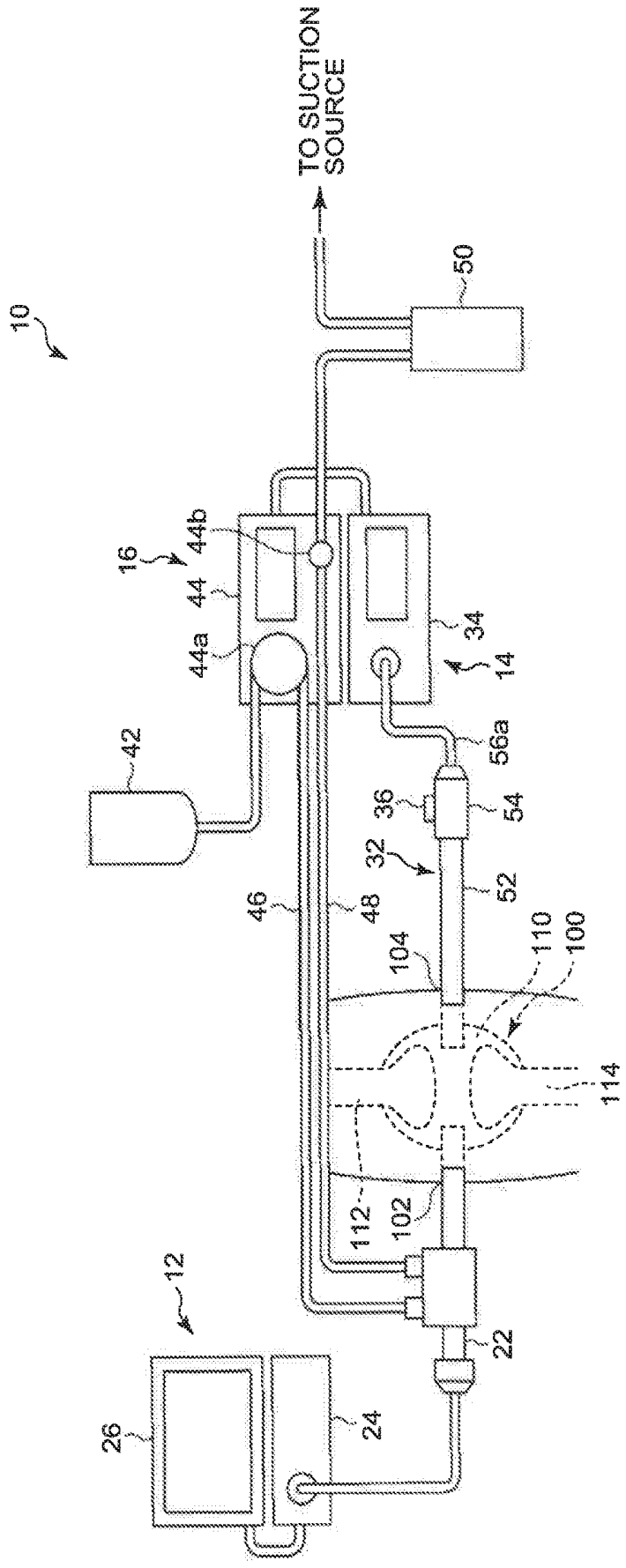


FIG. 1


TO SUCTION SOURCE
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14
42
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12
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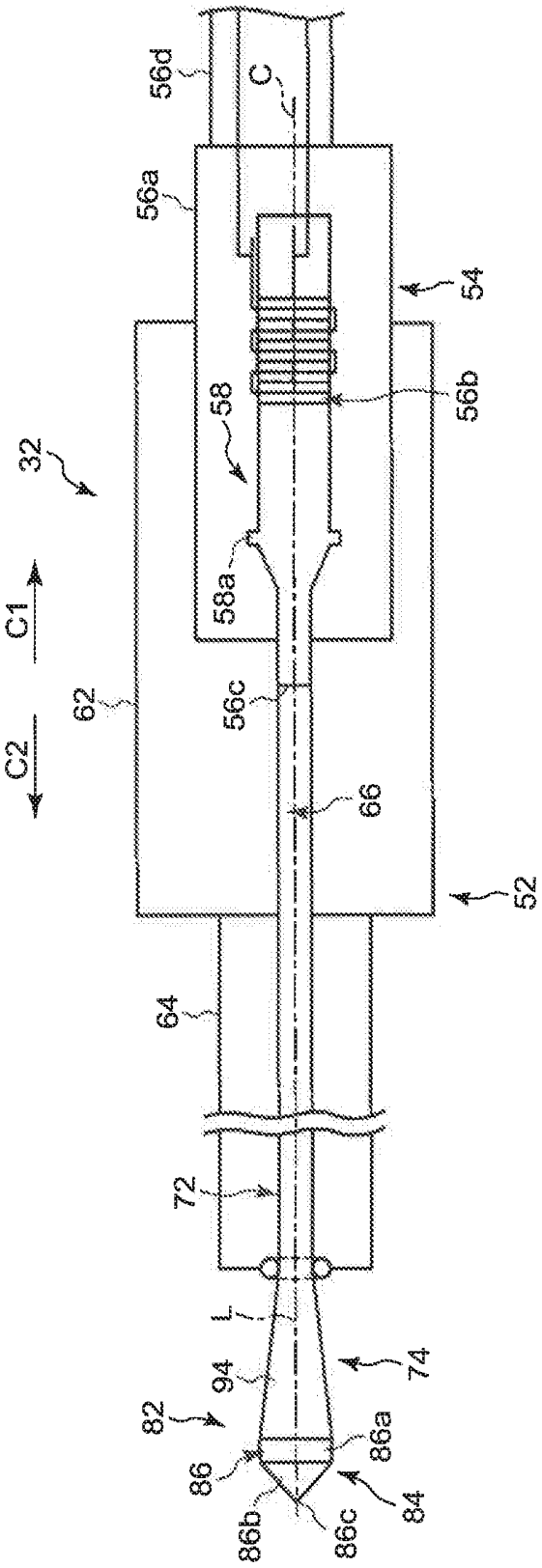
FIG.2


56d
C
56a
54
56b
58
32
58a
C1
C2
62
56c
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86a
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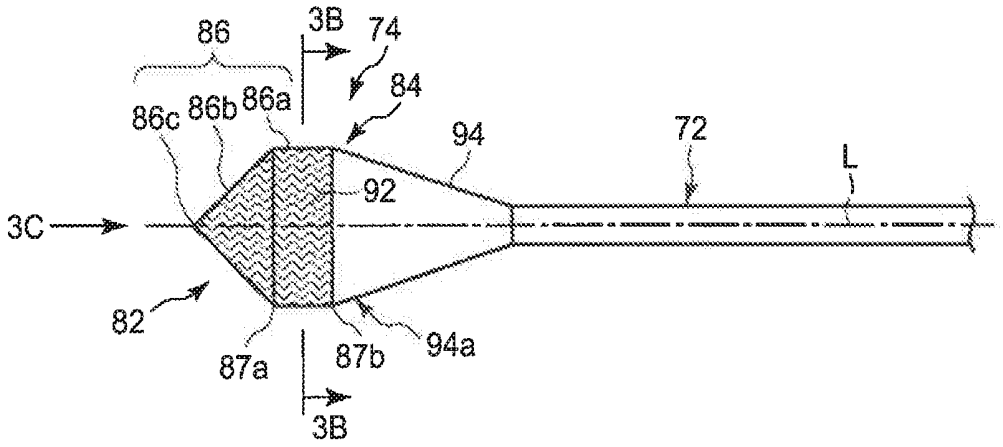
FIG.3A


86
3B
74
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86b
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L
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3C
82
87a
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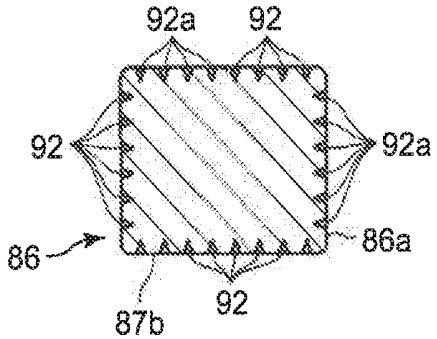
3B

FIG.3B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86a
87b
92

FIG.3C

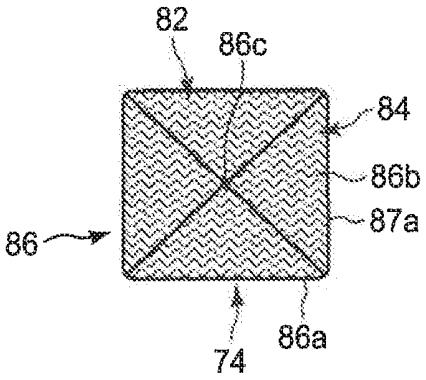


FIG.3D

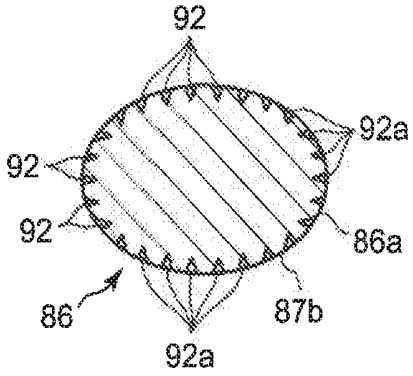


FIG.3E

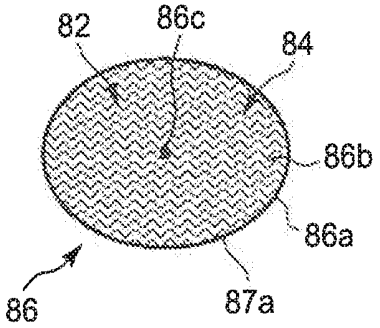


FIG.4A

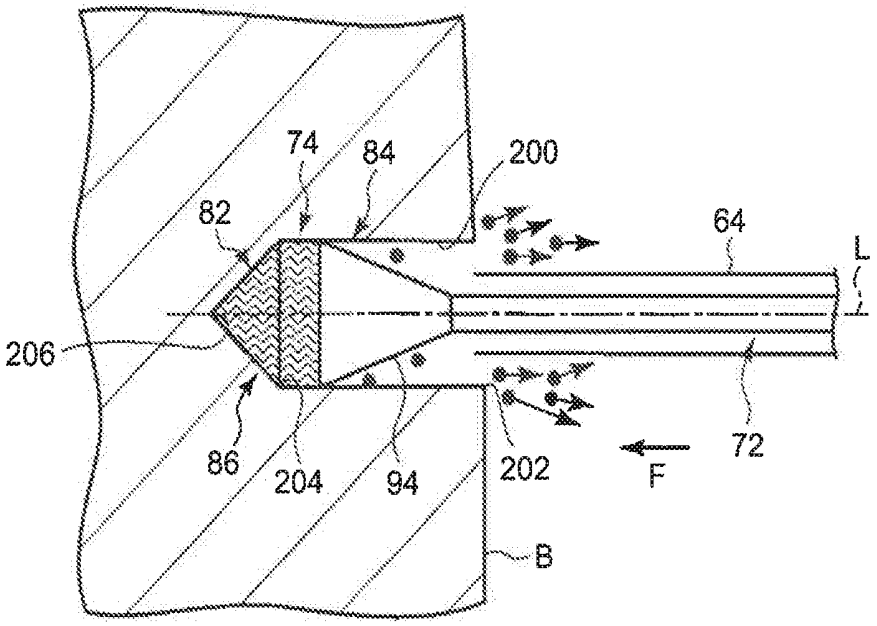


FIG.4B

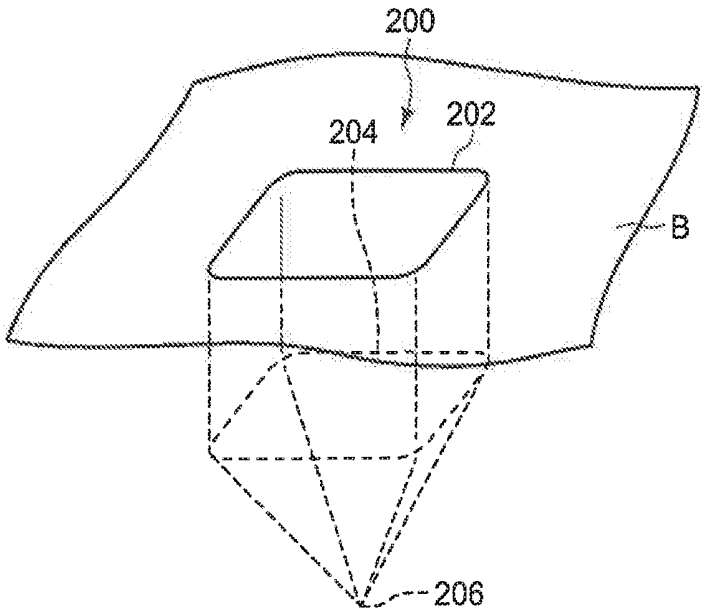
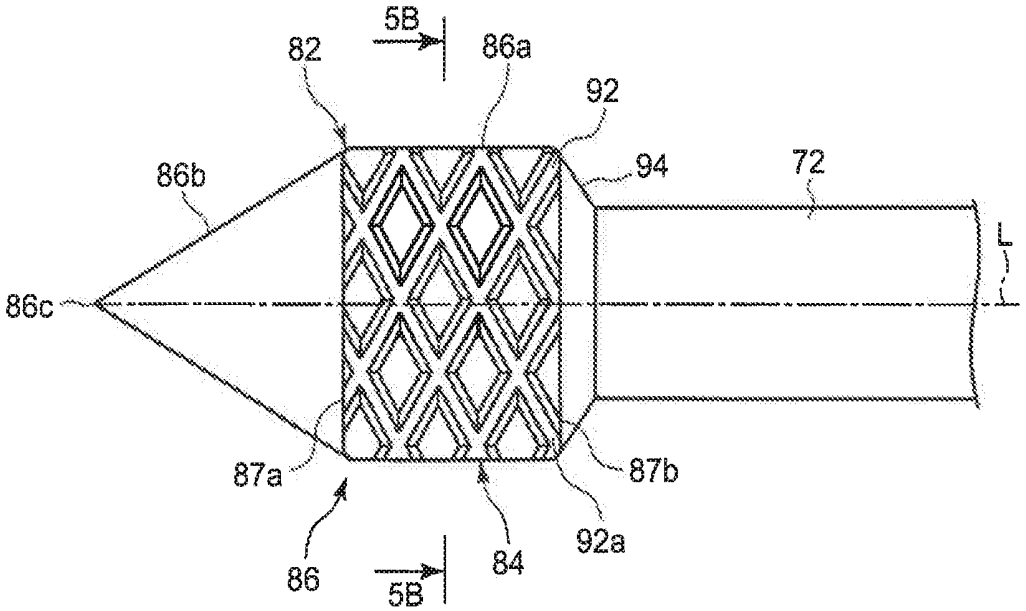


FIG.5A


5B
82
86a
92
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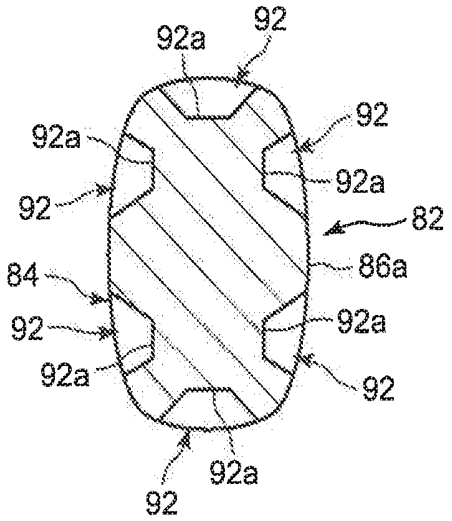
94
72
L
86c
87a
87b
92a
86
84
5B

FIG.5B


92a
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92

FIG.5C

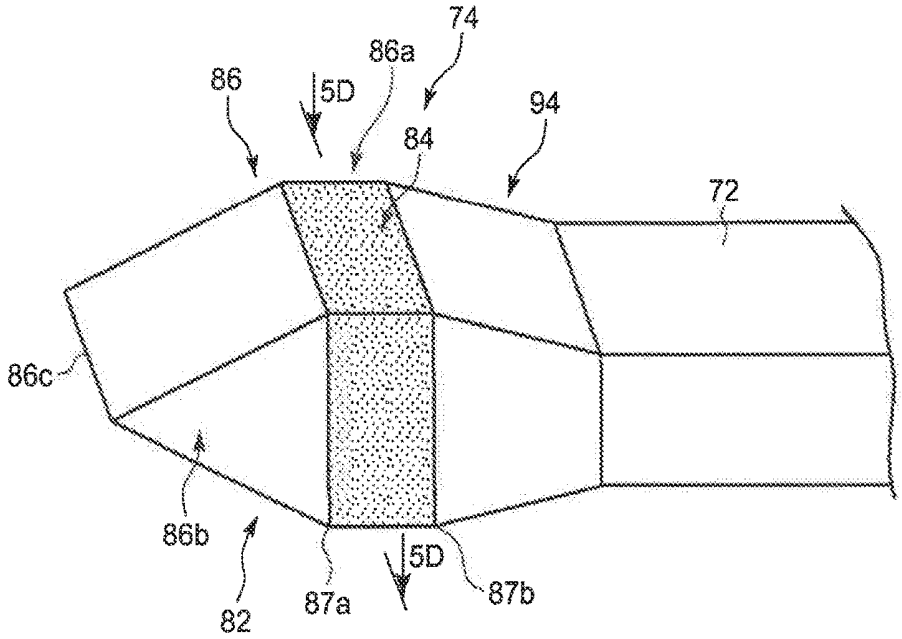


FIG.5D

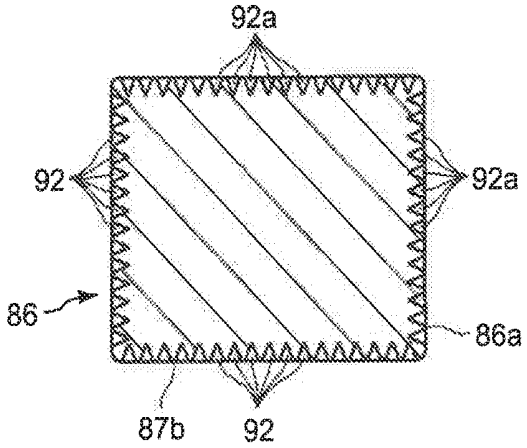


FIG.6A

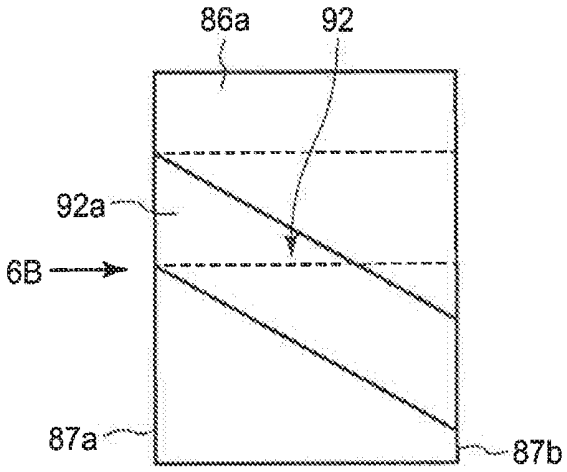


FIG.6B

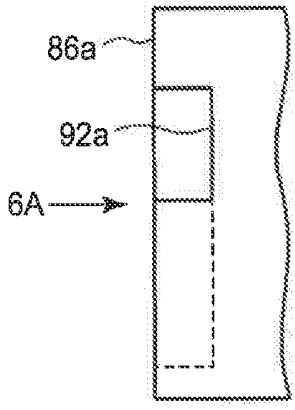


FIG.7A

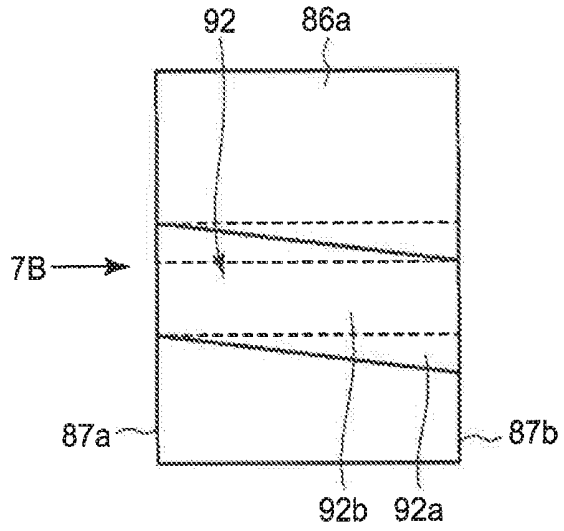


FIG.7B

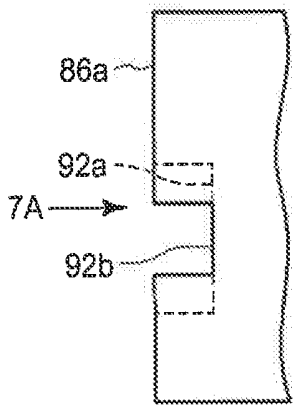


FIG.8A

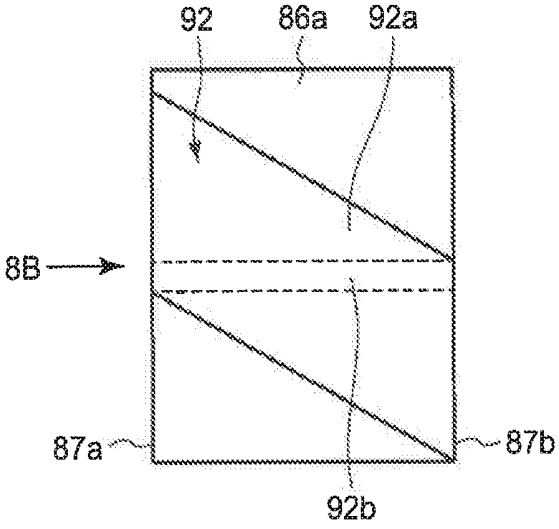


FIG.8B

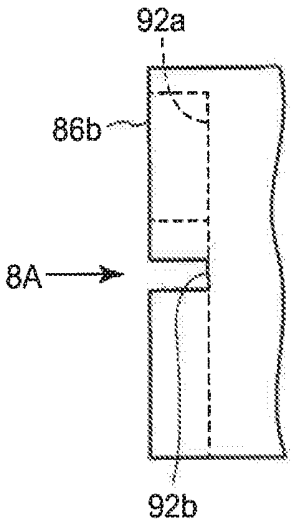
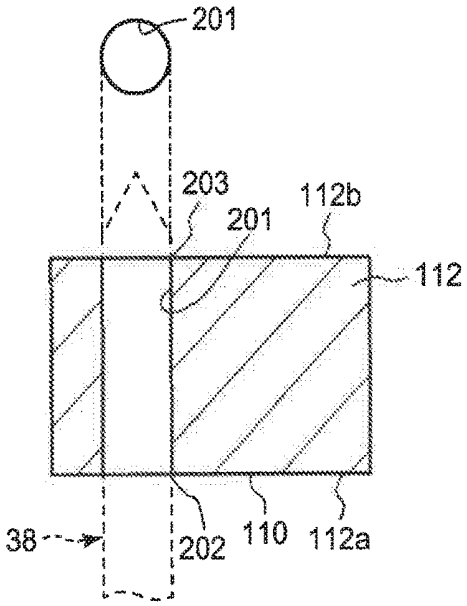


FIG.9A


201
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112b
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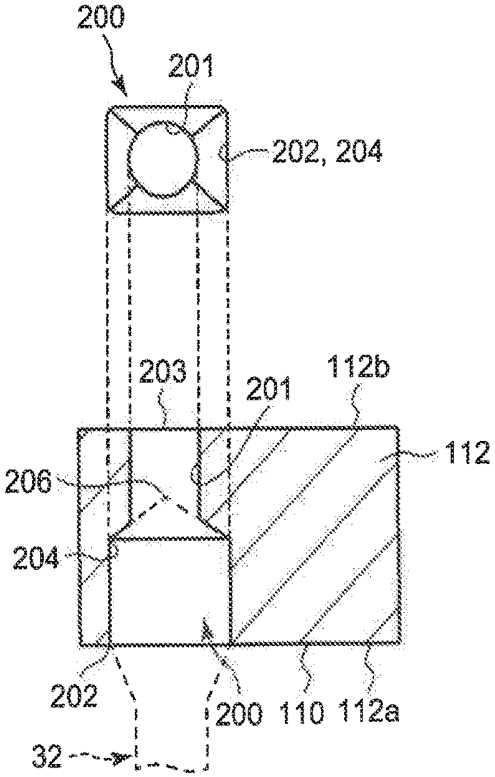
FIG.9B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32

FIG.9C

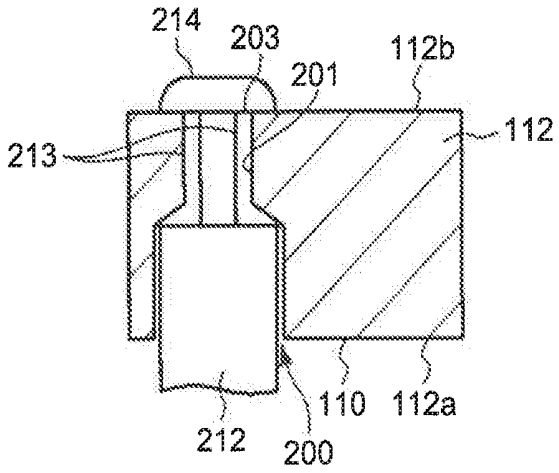


FIG.10A

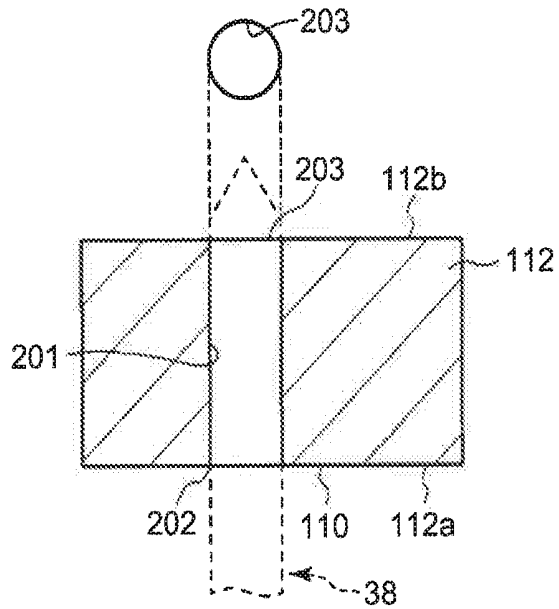


FIG.10B

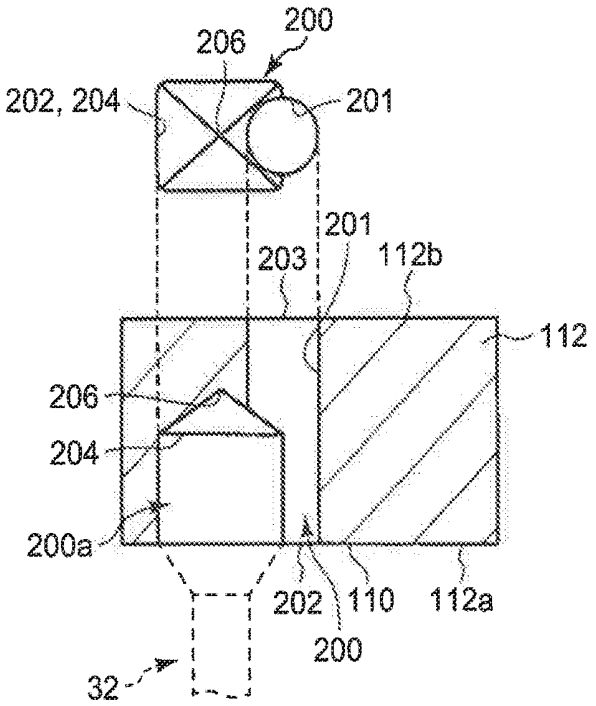


FIG.10C

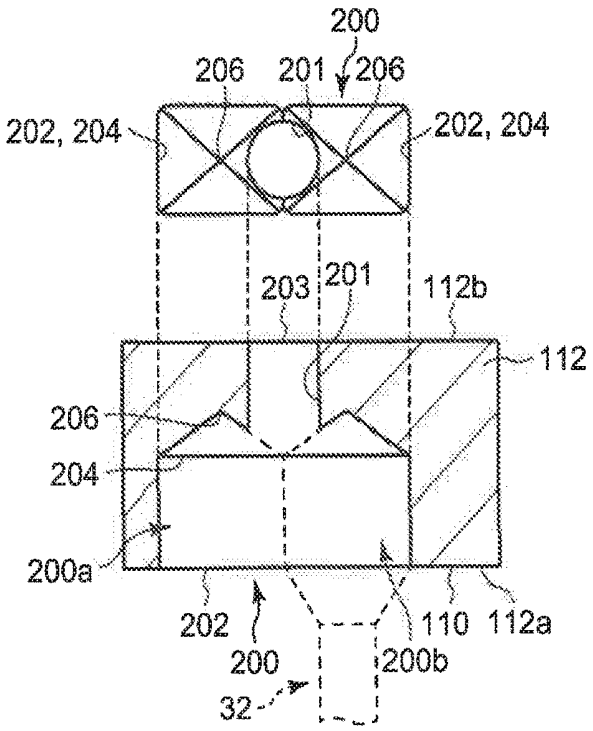


FIG.10D

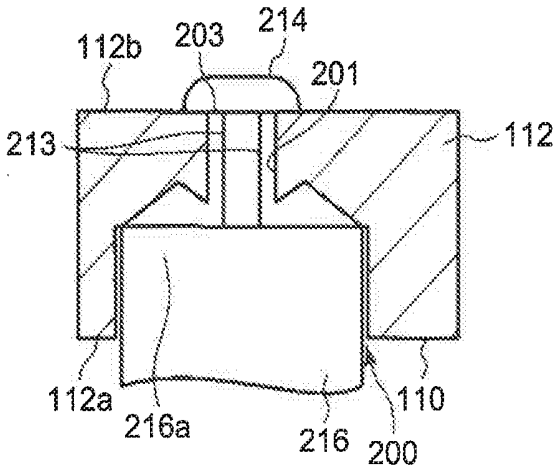


FIG.11A

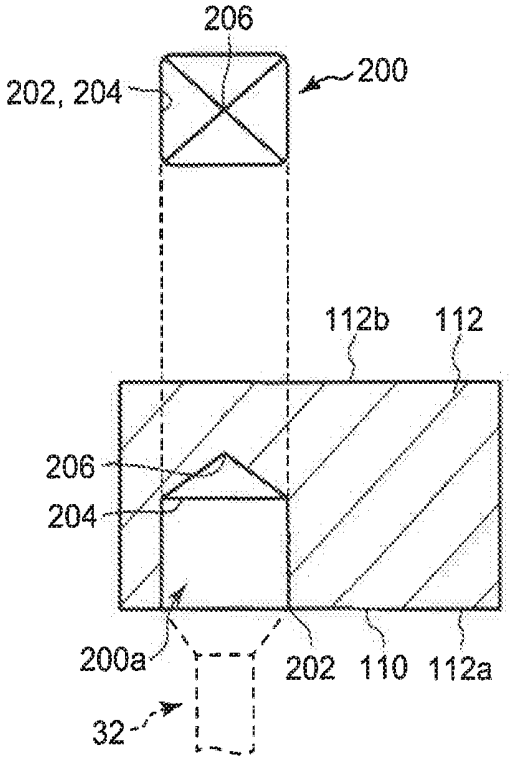


FIG.11B

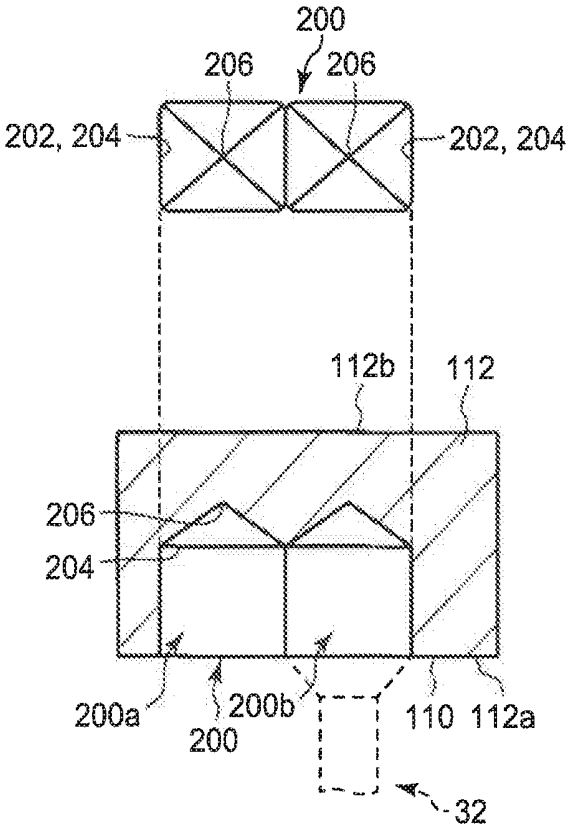
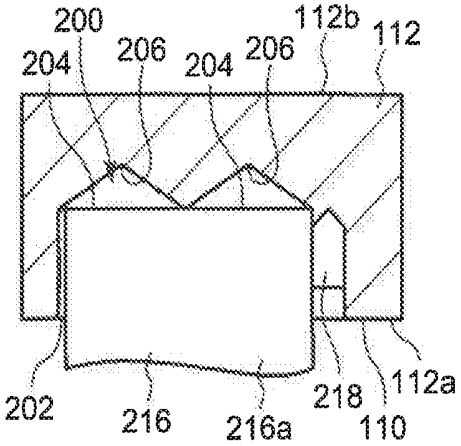


FIG.11C



ULTRASOUND PROBE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of International Application No. PCT/JP2016/082183, filed on Oct. 28, 2016, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] The present disclosure relates to an ultrasound probe.

[0003] A typical ultrasound probe can have treatmentsection in a distal portion of the probe with a cutting blade that determines a contour of the hole that is formed in the bone. A plurality of cutting elements of the cutting blade can be radially disposed with respect to a center axis of the probe. debris resulting from cutting the bone can be discharged from a passage formed between the cutting elements on an outer periphery of the treatment section. The passage can be formed as an inclined surface that is separated from the center axis along the treatment section from a distal side toward a proximal side of thereof. Hence, when forming a through-hole in the bone, the treatment section can form a through-hole having a substantially circular contour with substantially the same inner diameter from one end to the other end of the through-hole.

[0004] Since the plurality of cutting elements of the cutting blade of the treatment section of the probe are radially disposed with respect to the center axis of the probe, an outer edge approaches or is separated from the center axis when the outer edge of the treatment section of the probe is viewed along a peripheral direction of the center axis. In addition, the outer edge of the treatment section changes in shape toward the proximal side from a distal end. Therefore, when a recessed hole that does not penetrate the bone is to be formed by using the probe, the hole has a specific geometrical contour as it is closer to a back side of the hole.

[0005] For example, in a case where a hamstring (semitendinosus muscle) is used in an anterior cruciate ligament reconstructive surgery of a knee joint, a tendon transplant is formed so that a cross section thereof has a rectangular outline or an outline similar thereto. Therefore, even in the case of the through-hole, there are needs of forming a polygonal hole such as a rectangular hole or a hole having an appropriate shape such as an ellipse similar thereto, not a circular hole.

[0006] In addition, in a case where a patellar muscle tendon is used, there is a demand that a substantially rectangular parallelepiped-shaped bone on an end portion of the tendon transplant be inserted and fixed into the recessed hole. Therefore, there is a demand that the contour of the bone hole have the same or substantially the same shape on a back side and on an entrance side in a range of the bone hole in which the tendon transplant is inserted into the bone hole, and the bone hole be formed to have a desired simple shape such as a polygon or an ellipse.

SUMMARY

[0007] An ultrasound probe that has a treatment section having a distal end and a proximal end. The treatment section includes a cutting portion that defines a columnar portion. The columnar portion has a projection shape of a polygon, a substantially polygonal shape, an elliptical shape, or a substantially elliptical shape when viewed from the distal end. The probe also has a discharge portion that discharges cutting debris of the bone cut by the cutting portion toward the proximal end from the cutting portion, the discharge portion including a recessed portion with grooves inclined with respect to the longitudinal axis of the treatment section.

[0008] The above and other features, advantages and technical and industrial significance of this disclosure will be better understood by reading the following detailed description of presently preferred embodiments of the disclosure, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic view illustrating a treatment system according to an exemplary embodiment;

[0010] FIG. **2** is a schematic view illustrating a treatment unit according to an exemplary embodiment;

[0011] FIG. **3**A is a schematic view illustrating an ultrasound probe of a treatment instrument of the treatment unit according to an exemplary embodiment;

[0012] FIG. **3**B is a sectional view illustrating a state in which the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment is cut along line **3**B-**3**B orthogonal to a longitudinal axis in FIG. **3**A;

[0013] FIG. **3**C is a schematic view illustrating a state of the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment when viewed from a direction represented by arrow **3**C in FIG. **3**A;

[0014] FIG. **3**D is a sectional view illustrating a state in which an ultrasound probe of a treatment instrument of a treatment unit according to an exemplary embodiment is cut along line **3**B-**3**B orthogonal to the longitudinal axis in FIG. **3**A;

[0015] FIG. **3**E is a schematic view illustrating a state of the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment when viewed from the direction represented by arrow **3**C in FIG. **3**A;

[0016] FIG. **4**A is a partial sectional view schematically illustrating a state in which a hole is formed in a bone by the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment;

[0017] FIG. **4**B is a prospective view schematically illustrating a recessed hole in the bone, which is formed by the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment;

[0018] FIG. **5**A is a schematic view illustrating an ultrasound probe of a treatment instrument of a treatment unit according to an exemplary embodiment;

[0019] FIG. **5**B is a sectional view illustrating a state in which the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment is cut along line **5**B-**5**B orthogonal to the longitudinal axis in FIG. **5**A;

[0020] FIG. **5**C is a schematic view illustrating an ultrasound probe of a treatment instrument of a treatment unit according to an exemplary embodiment;

[0021] FIG. **5**D is a sectional view illustrating a state in which the ultrasound probe of the treatment instrument of

the treatment unit according to an exemplary embodiment is cut along line **5**D-**5**D orthogonal to the longitudinal axis in FIG. **5**C;

[0022] FIG. **6**A is a schematic view illustrating a relationship between a columnar portion of a cutting portion and a recessed portion of a discharge portion of a treatment section of the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment;

[0023] FIG. **6**B is a schematic view illustrating a state of the columnar portion of the cutting portion and the recessed portion of the discharge portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit according to an exemplary embodiment when viewed from a direction represented by arrow **6**B in FIG. **6**A;

[0024] FIG. **7**A is a schematic view illustrating a relationship between a columnar portion of a cutting portion and a recessed portion of a discharge portion of a treatment section of an ultrasound probe of a treatment instrument of a treatment unit according to an exemplary embodiment;

[0025] FIG. **7**B is a schematic view illustrating a state of the columnar portion of the cutting portion and the recessed portion of the discharge portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit when viewed from a direction represented by arrow **7**B in FIG. **7**A;

[0026] FIG. **8**A is a schematic view illustrating a relationship between a columnar portion of a cutting portion and a recessed portion of a discharge portion of a treatment section of an ultrasound probe of a treatment instrument of a treatment unit;

[0027] FIG. **8**B is a schematic view illustrating a state of the columnar portion of the cutting portion and the recessed portion of the discharge portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit when viewed from a direction represented by arrow **8**B in FIG. **8**A;

[0028] FIG. **9**A is a schematic view illustrating a state in which a through-hole is formed from an intercondylar fossa of a femur toward an outer side of the femur by using a drill;

[0029] FIG. **9**B is a schematic view illustrating a state in which a recessed hole is formed from the intercondylar fossa of the femur toward the outer side of the femur with respect to a drill hole illustrated in FIG. **9**A;

[0030] FIG. **9**C is a schematic view illustrating a state in which an STG-type tendon transplant instead of an anterior cruciate ligament is disposed into the hole illustrated in FIG. **9**B, and the tendon transplant is fixed to an outer site of the femur by a fixing instrument;

[0031] FIG. **10**A is a schematic view illustrating a state in which a through-hole is formed from an intercondylar fossa of a femur toward an outer side of the femur by using a drill;

[0032] FIG. **10**B is a schematic view illustrating a state in which a longitudinal axis of the cutting portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit is disposed at a position displaced from a center axis of the drill hole, and a first recessed hole communicating with the drill hole illustrated in FIG. **10**A is formed from the intercondylar fossa of the femur toward the outer side of the femur;

[0033] FIG. **10**C is a schematic view illustrating a state in which the longitudinal axis of the cutting portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit is disposed at a position displaced from the center axis of the drill hole toward an opposite side of the position illustrated in FIG. **10**B, and a second recessed hole communicating with the drill hole and the first recessed hole illustrated in FIG. **10**B is formed from the intercondylar fossa of the femur toward the outer side of the femur;

[0034] FIG. **10**D is a schematic view illustrating a state in which a BTB-type tendon transplant instead of the anterior cruciate ligament is disposed into the first recessed hole and the second recessed hole illustrated in FIG. **10**C, and the tendon transplant is fixed to the outer site of the femur by the fixing instrument;

[0035] FIG. **11**A is a schematic view illustrating a state in which the first recessed hole is formed from the intercondylar fossa of the femur toward the outer side of the femur by the cutting portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit;

[0036] FIG. **11**B is a schematic view illustrating a state in which the longitudinal axis of the cutting portion of the treatment section of the ultrasound probe of the treatment instrument of the treatment unit is disposed at a position displaced from the first recessed hole illustrated in FIG. **11**A, and the second recessed hole communicating with the first recessed hole illustrated in FIG. **11**A is formed from the intercondylar fossa of the femur toward the outer side of the femur; and

[0037] FIG. **11**C is a schematic view illustrating a state in which the BTB-type tendon transplant instead of the anterior cruciate ligament is disposed into the first recessed hole and the second recessed hole illustrated in FIG. **11**B, and the tendon transplant is fixed at a position adjacent to at least one of the first recessed hole and the second recessed hole by a screw.

DETAILED DESCRIPTION

[0038] Embodiments are described with reference to the drawings.

[0039] In a case where a treatment is performed on a knee joint **100**, a treatment system **10** illustrated in FIG. **1** is used, for example. The treatment system **10** includes an arthroscopic device **12**, a treatment device **14**, and a perfusion device **16**.

[0040] The arthroscopic device **12** includes an arthroscope **22** that observes an inside of the knee joint **100**, that is, an inside of a joint cavity **110**, of a patient, an arthroscope controller **24** that performs an image process based on an object image captured by the arthroscope **22**, and a monitor **26** that projects a video generated by the image process by the arthroscope controller **24**. The arthroscope **22** is inserted into the joint cavity **110** of the knee joint **100** by a first portal **102** through which the inside of the knee joint **100** and an outside of skin of the patient communicate with each other. A position of the first portal **102** is not fixed but is appropriately determined depending on a condition of the patient. In general, an antero-internal portal and/or antero-external portal is formed as the first portal **102**. A cannula (not illustrated) may be provided to the first portal **102**, and the arthroscope **22** may be inserted into the joint cavity **110** of the knee joint **100** via the cannula. Incidentally, the arthroscope **22** and a treatment instrument **52** to be described below of the treatment device **14** are delineated in a state in which both are opposite to each other in FIG. **1**; however,

both are disposed to have an appropriate positional relationship depending on a position or the like of a treatment target.

[0041] The treatment device **14** includes a treatment unit **32**, a controller **34**, and a switch **36**. The switch **36** is illustrated as a hand switch in FIG. **1**; however, the switch may be a foot switch.

[0042] The controller **34** supplies appropriate energy (electric power) to an ultrasound transducer unit **54** to be described below of the treatment unit **32** in response to an operation of the switch **36** and transmits ultrasonic vibration to a treatment section **74** of a probe **66** to be described below of the treatment unit **32**. The treatment section **74** of the probe **66** is inserted into the joint cavity **110** of the knee joint **100** by a second portal **104** through which the inside of the joint **100** and the outside of skin of the patient communicate with each other. A position of the second portal **104** is not fixed but is appropriately determined depending on a condition of the patient. Preferably, a cannula (not illustrated) is provided to the second portal **104**, and the treatment section **74** of the probe **66** is inserted into the joint cavity **110** of the knee joint **100** via the cannula. For example, the switch **36** maintains a state in which an ultrasound transducer **56***b* to be described below is driven in a state of a press operation on the switch, and a state in which the ultrasound transducer **56***b* is driven is canceled when a press on the switch is canceled.

[0043] Here, description is provided, in which one switch **36** is used; however, a plurality of switches **36** may be used. The controller **34** is capable of appropriately setting an amplitude of the ultrasound transducer **56***b*. Therefore, the operation of the switch **36** may change a frequency of ultrasonic vibration which is output from the ultrasound transducer **56***b* to be described below or may change the amplitude thereof. In addition, the operation of the switch **36** may change both the frequency and the amplitude of ultrasonic vibration which are output from the ultrasound transducer **56***b*. Hence, preferably, the switch **36** is capable of switching between a plurality of states such as two high and low amplitudes of the ultrasound transducer **56***b*.

[0044] The perfusion device **16** includes a liquid source **42** that contains a perfusate such as a physiological salt solution, a perfusion pump unit **44**, a liquid feed tube **46** having one end connected to the liquid source **42**, a liquid discharge tube **48**, and a suction bottle **50** to which one end of the liquid discharge tube **48** is connected. The suction bottle **50** is connected to the suction source attached to a wall of an operating room. The perfusion pump unit **44** is capable of feeding out the perfusate from the liquid source **42** by a liquid feed pump **44***a*. In addition, opening and closing of a pinch valve **44***b* as a liquid discharge valve can cause the perfusion pump unit **44** to switch between suction and suction stop of the perfusate in the joint cavity **110** of the knee joint **100** with respect to the suction bottle **50**.

[0045] The other end of the liquid feed tube **46** which is a liquid feed tube line is connected to the arthroscope **22**. Therefore, it is possible to feed out the perfusate in the joint cavity **110** of the joint **100** via the arthroscope **22**. The other end of the liquid discharge tube **48** which is a liquid discharge tube line is connected to the arthroscope **22**. Therefore, it is possible to discharge the perfusate from the joint cavity **110** of the joint **100** via the arthroscope **22**. Incidentally, it is needless to say that the other end of the liquid discharge tube **48** may be connected to the treatment instrument **52** such that the perfusate can be discharged from the joint **100**. Incidentally, the perfusate may be fed and discharged from another portal.

[0046] As illustrated in FIG. **2**, the treatment unit **32** includes the ultrasound treatment instrument **52** and the ultrasound transducer unit **54**. Preferably, the ultrasound transducer unit **54** is attachable to and detachable from the ultrasound treatment instrument **52**; however, both may be integrated. The ultrasound transducer unit **54** includes a housing (transducer case) **56***a*, a bolt-clamped Langevin-type transducer **56***b*, and a connection portion **56***c* connected to a proximal end of the ultrasound probe **66** to be described below. The connection portion **56***c* is formed on a distal end of the transducer **56***b*. Preferably, the connection portion **56***c* projects toward a distal side of the housing **56***a* along a center axis C of the ultrasound transducer unit **54**. A cable **56***d* is extended from a proximal end of the housing **56***a* of the ultrasound transducer unit **54**, the cable having one end that is connected to the transducer **56***b* and the other end that is connected to the controller **34**. The transducer **56***b* and the connection portion **56***c* form an integrated vibrating body **58**.

[0047] The housing **56***a* supports a support target portion **58***a* of the vibrating body **58**. The ultrasound transducer unit **54** is already known, and thus the detailed description thereof is omitted. In a state in which the transducer **56***b* generates vibration, the connection portion **56***c* and a proximal end of the transducer **56***b* is an antinode of vibration. Incidentally, although not illustrated in FIG. **2**, preferably, the switch **36** is provided in the housing **56***a* of the ultrasound transducer unit **54** or in a housing **62** to be described below of the ultrasound treatment instrument **52**.

[0048] The ultrasound treatment instrument **52** includes the housing (handle) **62**, a cylindrical body (outer cylinder) **64** extended from the housing **62** along the center axis C, and the ultrasound probe **66** inserted into the cylindrical body **64**. Here, in the ultrasound treatment instrument **52**, a side on which the housing **62** is positioned with respect to the cylindrical body **64** is set to a proximal side (arrow C**1** side), and an opposite side of the proximal side is set to a distal side (arrow C**2** side). The cylindrical body **64** is attached to the housing **62** from the distal side. In addition, the ultrasound treatment instrument **52** includes the treatment section **74** to be described below at a part on the distal side with respect to the cylindrical body **64**.

[0049] The housing **62** and the cylindrical body **64** of the ultrasound treatment instrument **52** are formed by a material having an electrical insulation property. The housing **56***a* of the ultrasound transducer unit **54** is detachably connected to the housing **62** of the ultrasound treatment instrument **52**. Preferably, the housing **62** of the ultrasound treatment instrument **52** and the housing **56***a* of the ultrasound transducer unit **54** are integrated.

[0050] Incidentally, a rotating knob (not illustrated) which is a rotation operating member may be attached to the housing **62** of the treatment instrument **52**. The rotating knob can rotate around a center axis of the cylindrical body **64** with respect to the housing **62**. Rotation of the rotating knob causes the housing **56***a* of the ultrasound transducer unit **54**, the cylindrical body **64**, and the treatment section **74** and a probe main body section **72** to be described below to rotate together around the center axis C of the probe main body section **72** with respect to the housing **62**.

[0051] The housing **62** of the ultrasound treatment instrument **52** and an outer peripheral surface of the cylindrical

body **64** have an insulation property. For example, the ultrasound probe **66** is formed by a material by which the ultrasonic vibration can be transmitted, that is, a metal material such as a titanium alloy material. The connection portion **56***c* of the ultrasound transducer unit **54** fixed to the housing **62** is fixed to the proximal end of the probe **66**. Preferably, the entire length of the probe **66** is an integer multiple of a half wavelength based on a resonance frequency of the transducer **56***b*, for example. The entire length of the probe **66** is not limited to the integer multiple of the half wavelength based on the resonance frequency of the transducer **56***b* but is appropriately adjusted depending on a material, an amplitude magnification factor, or the like. Therefore, the entire length of the probe **66** may be substantially the integer multiple of the half wavelength based on the resonance frequency of the transducer **56***b*. Materials or lengths of the vibrating body **58** and the probe **66** are appropriately set such that, as a whole, the vibrating body and the probe vibrate with the resonance frequency of the transducer **56***b* and a frequency in an output of the controller **34**.

[0052] As illustrated in FIGS. **2** and **3**A, the ultrasound probe **66** includes the probe main body section **72** and the treatment section **74** that is provided on the distal side of the probe main body section **72** and is capable of forming a hole in a bone which is a treatment target with the ultrasonic vibration. The ultrasonic vibration generated by the ultrasound transducer **56***b* is transmitted to the probe main body section **72** via the connection portion **56***c* of the vibrating body **58**. The ultrasonic vibration generated by the ultrasound transducer **56***b* is transmitted to the treatment section **74** via the connection portion **56***c* and the probe main body section **72**.

[0053] Preferably, the probe main body section **72** is straightly formed. Preferably, the treatment section **74** is straightly extended from a distal end of the probe main body section **72** toward the distal side; however, the treatment section may be appropriately curved with consideration for visual recognition of the treatment section **74** by the arthroscope **22**. Therefore, the center axis C of the probe main body section **72** and a longitudinal axis L of the treatment section **74** may or may not be coincident with each other.

[0054] The treatment section **74** includes a cutting portion **82**. The cutting portion **82** has a projection shape of a polygon such as a rectangular shape illustrated in FIGS. **3**B and **3**C when the proximal side of the cutting portion is viewed from the distal side along the longitudinal axis L of the treatment section **74** or a projection shape of an elliptical shape (including a substantially elliptical shape) illustrated in FIGS. **3**D and **3**E. The projection shape may be a substantially polygonal shape similar to the elliptical shape. The polygon may be a regular polygon. The projection shape may be a rectangle with rounded corners, which is a substantially polygonal shape, a track shape of an athletics stadium, which is a substantially elliptical shape, or the like. Therefore, the projection shape is formed into an appropriate shape such as the polygonal shape, the substantially polygonal shape, an elliptical shape, or a substantially elliptical shape.

[0055] As illustrated in FIG. **4**A, the cutting portion **82** of the treatment section **74** is moved such that the treatment section **74** applies a force F to a bone B toward the distal side along the longitudinal axis L, in a state in which the ultrasonic vibration is transmitted to the probe main body section **72**. Therefore, the probe **66** is straightly or substantially straightly moved toward the distal side along the center axis C. In this case, the bone is cut by the treatment section **74**.

[0056] The cutting portion **82** has a block body **86** on a distal portion of the treatment section **74**. The block body **86** is formed into a block shape that determines an outline (contour of a hole) when the bone B is cut. The block body **86** is provided with a columnar portion **86***a* and a projecting portion **86***b* that projects from the columnar portion **86***a* toward the distal side along the longitudinal axis L. The columnar portion **86***a* is formed into a columnar shape such as a polygonal columnar shape or an elliptical columnar shape. The columnar portion **86***a* and the projecting portion **86***b* are integrally formed by cutting work or the like.

[0057] The columnar portion **86***a* of the block body **86** of the cutting portion **82** is formed to have a cross section of the same shape or substantially the same shape from a distal end **87***a* to a proximal end **87***b* along the longitudinal axis L, the cross section being orthogonal to the longitudinal axis L. An outer peripheral surface of the columnar portion **86***a* is continuous to the proximal side of the distal end **87***a* of the columnar portion **86***a* along the longitudinal axis L. Therefore, the columnar portion **86***a* is formed to have the cross section with the same area or substantially the same area from the distal end **87***a* to the proximal end **87***b*, the cross section being orthogonal to the longitudinal axis L. The distal end **87***a* of the columnar portion **86***a* determines the maximum outline portion (contour of the hole) when the bone B is cut. The outer peripheral surface of the columnar portion **86***a* has the same projection shape as the projection shape of the cutting portion **82** when the proximal side is viewed from the distal side along the longitudinal axis L of the treatment section **74**. In this manner, an outline of the cutting portion **82** of the treatment section **74** is formed depending on a shape of the hole (refer to FIG. **4**B) which is to be formed when the bone B is cut. Hence, the cutting portion **82** forms a hole in the bone B based on the projection shape.

[0058] Incidentally, as a polygonal column of the columnar portion **86***a*, a triangular column, a quadrangular column, a pentagonal column, a hexagonal column, or the like is formed to have an appropriate shape or a shape similar thereto. The columnar portion **86***a* does not need to be formed to absolutely have a distinct corner. In addition, the columnar portion **86***a* does not need to have a regular polygonal shape and is preferably formed in a flat state. Therefore, a use of the probe **66** according to the embodiment enables a hole with a desired shape to be formed in the bone B.

[0059] Preferably, the projection shape of the cutting portion **82** is a polygonal shape such as a substantially rectangular shape illustrated in FIGS. **3**B and **3**C or an elliptical shape illustrated in FIGS. **3**D and **3**E, for example. In a case where an anterior cruciate ligament reconstructive surgery is performed by using an STG tendon to be described below, an outline of a cross section of a tendon transplant is formed into a substantially rectangular shape having a size of about 4 mm×5 mm, the cross section being orthogonal to the longitudinal axis. Therefore, in a case where the cutting portion **82** has the projection shape of the substantially rectangular shape, as an example, preferably, the outline of the cross section orthogonal to the longitudinal axis L is formed to have a size of about 4 mm×5 mm, for example.

[0060] The projecting portion **86***b* is formed on the distal side of the columnar portion **86***a*. The projecting portion **86***b* projects from the distal end **87***a* of the columnar portion **86***a* toward the distal side along the longitudinal axis L and is formed to have a cone shape or a substantial cone shape based on the projection shape of the cutting portion **82**. A vertex **86***c* of the projecting portion **86***b* of the cutting portion **82** is formed at an appropriate position on the distal side along the longitudinal axis L with respect to the columnar portion **86***a*. The vertex **86***c* of the projecting portion **86***b* of the cutting portion **82** is formed within a range of the projection shape of a boundary (distal end **87***a* of the columnar portion **86***a*) between the projecting portion **86***b* and the columnar portion **86***a* of the cutting portion **82**, when the proximal side is viewed from the distal side along the longitudinal axis L. The projecting portion **86***b* of the cutting portion **82** may be formed to have a straight or curved line formed by connecting the vertex **86***c* and one point on the boundary between the projecting portion and the columnar portion **86***a* of the cutting portion **82**. Therefore, the shape of the projecting portion **86***b* of the cutting portion **82** is not limited to the cone shape but may have the substantial cone shape. In addition, the vertex **86***c* does not need to be formed to have a sharp shape and may have a blunt shape.

[0061] Here, the projecting portion **86***b* of the cutting portion **82** is set to be formed as a quadrangular cone illustrated in FIG. **3**C. A contact area between the vertex **86***c* of the projecting portion **86***b* of the cutting portion **82** and the bone is small in an initial state when the bone is cut. Therefore, it is possible to start cutting the bone in a state in which friction between the cutting portion **82** and the bone is low.

[0062] Here, the vertex **86***c* of the most distal end of the projecting portion **86***b* of the cutting portion **82** is moderately sharp. When the vertex **86***c* abuts or comes into press contact with the bone B with an appropriate force, it is more difficult for the vertex **86***c* to slide with respect to the bone B, compared with the blunt shape of the vertex. Therefore, when the ultrasonic vibration is transmitted to the probe **66** in a state in which the vertex **86***c* abuts or comes into press contact with the bone B with the appropriate force, it is difficult for the vertex **86***c* to slide with respect to the bone B or be displaced when a hole **200** (refer to FIGS. **4**A and **4**B) starts to be opened. Hence, when the vertex **86***c* is moderately sharp, it is difficult to shift the position of the vertex **86***c* of the most distal end of the projecting portion **86***b* of the cutting portion **82** with respect to the bone B, and it is easy to position a location where the hole **200** is formed.

[0063] As illustrated in FIGS. **3**A to **3**C, the treatment section **74** has a discharge portion **84** that discharges cutting debris of the bone cut by the cutting portion **82** toward the proximal side from the cutting portion **82**. A part of the discharge portion **84** is provided in the cutting portion **82**. The discharge portion **84** is provided with a recessed portion **92** formed on an outer peripheral surface of the cutting portion **82** and a shaft portion **94** provided on the proximal side from the cutting portion **82**.

[0064] As illustrated in FIG. **3**B, the outer peripheral surface of the columnar portion **86***a* is provided with the recessed portion **92** of the discharge portion **84**, which decreases a contact area between the treatment section **74** and the bone and becomes a discharge path of the cutting debris. Here, the recessed portion **92** is formed into a wavy shape with a bottom at a position recessed from outer peripheral surfaces of the columnar portion **86***a* and the projecting portion **86***b*. The bottom of the recessed portion **92** is close to the center axis C (longitudinal axis L) than the columnar portion **86***a*. As will be described below, the recessed portion **92** does not absolutely need to be formed in the projecting portion **86***b* (refer to FIG. **5**A).

[0065] The shaft portion **94** is extended more toward the proximal side along the longitudinal axis L than the block body **86** of the cutting portion **82**. The shaft portion **94** is provided between the distal end of the probe main body section **72** and the proximal end **87***b* of the block body **86** of the cutting portion **82**. The shaft portion **94** has a projection shape within a range of a projection shape of the block body **86** of the cutting portion **82** when the proximal side is viewed from the distal side along the longitudinal axis L.

[0066] The shaft portion **94** is provided with a distal portion **94***a* that is continuous to the proximal end of the block body **86**. The distal portion **94***a* of the shaft portion **94** has a cross section that decreases in sectional area from the distal side toward the proximal side along the longitudinal axis L, the cross section being orthogonal to the longitudinal axis L. In addition, the shaft portion **94** has a part in which the sectional area of the cross section increases or is maintained to be constant from the distal side toward the proximal side in a part closer to proximal side than the distal portion **94***a*, the cross section being orthogonal to the longitudinal axis L. In other words, the shaft portion **94** has a narrow portion between a distal end and a proximal end of the shaft portion. A boundary between the distal portion **94***a* of the shaft portion **94** and the proximal end (proximal end **87***b* of the columnar portion **86***a*) of the block body **86** has a shape that prevents stress concentration in a state in which the ultrasonic vibration is transmitted. Therefore, the boundary between the distal portion **94***a* of the shaft portion **94** and the proximal end **87***b* of the columnar portion **86***a* of the block body **86** is smoothly continuous to each other. Incidentally, when the treatment section **74** is viewed from the distal side toward the proximal side along the longitudinal axis L, the shaft portion **94** is hidden by the block body **86**, and thus it is not possible to observe the shaft portion **94**. Therefore, the shaft portion **94** that is continuous to the proximal side of the block body **86** can be a part of the discharge portion **84** that discharges cutting debris of a bone or a liquid such as a perfusate toward the proximal side along the longitudinal axis L.

[0067] When the treatment section **74** is viewed in a direction represented by arrow **3**C in FIG. **3**A, that is, the proximal side is viewed from the distal side along the longitudinal axis L, an outline of the treatment section **74** is observed as outlines of the projecting portion **86***b* and the columnar portion **86***a* of the cutting portion **82**, as illustrated in FIG. **3**C. In this case, the columnar portion **86***a* is provided with the recessed portion **92** of the discharge portion **84**; however, the outer peripheral surface of the columnar portion **86***a* appears at least once between the distal end **87***a* and the proximal end **87***b* of the columnar portion **86***a* on an outer edge of the treatment section **74** in FIG. **3**C. Therefore, the cutting portion **82** determines the maximum outline portion. Hence, when the proximal side is viewed from the distal side along the longitudinal axis L, the projection shape of the cutting portion **82** becomes a shape of a hole when the bone B is cut by using the treatment instrument **52**.

[0068] Here, the recessed hole **200** having a desired shape is provided with an opening edge **202** having the same shape and size as those of the projection shape of the cutting portion **82** of the treatment section **74** when the proximal side is viewed from the distal side along the longitudinal axis L, and the recessed portion is straightly recessed toward a back side with the same shape as the shape of the opening edge **202**. Therefore, an example of the desired shape of the hole **200** is a rectangular shape having an appropriate depth.

[0069] In order to form the recessed hole **200** having the desired shape, the cutting portion **82** of the treatment section **74** needs to have the maximum outline portion such that projection when the proximal side is viewed from the distal side along the longitudinal axis L becomes the shape of the opening edge **202** of the desired hole. The distal end **87***a* of the columnar portion **86***a* of the cutting portion **82** of the treatment section **74** is formed into the same shape as the shape of the opening edge **202** of the desired hole **200**. Therefore, the distal end **87***a* of the columnar portion **86***a* of the cutting portion **82** of the treatment section **74** of the probe **66** of the embodiment allows the recessed hole **200** provided with the desired opening edge **202** to be formed.

[0070] On the other hand, from a viewpoint of a decrease in friction between the bone B and the cutting portion **82** of the treatment section **74** and from a viewpoint of discharge of the cutting debris from the bone B, the shorter the length of the maximum outline portion of the cutting portion **82** in a direction (ultrasonic vibration direction) along the longitudinal axis L, the better. Therefore, a configuration in which the columnar portion **86***a* does not have the same shape and the same sectional area but have a sectional area that gradually decreases from the distal end **87***a* of the columnar portion **86***a*, which is the maximum outline portion, toward the proximal side.

[0071] Preferably, the probe **66** is straightly moved along the longitudinal axis L, and the hole **200** is straightly formed along the longitudinal axis L by the columnar portion **86***a* of the cutting portion **82**. Therefore, in order to prevent the cutting portion **82** from being unstable and form the hole **200** straightly, the outline of the columnar portion **86***a* from the distal end **87***a* toward the proximal end needs to have a certain length by which the columnar portion is parallel to the longitudinal axis L.

[0072] In addition, while the ultrasonic vibration having an appropriate amplitude is transmitted to the probe **66**, the treatment section **74** cuts the bone B. Therefore, the columnar portion **86***a* of the cutting portion **82** of the treatment section **74** needs to have an appropriate strength. When the sectional area gradually decreases from the distal end **87***a* of the columnar portion **86***a* toward the proximal side, there is a possibility that it is difficult to form the treatment section **74** that has a strength to the extent that the treatment section **74** cuts the bone B, while the ultrasonic vibration having the appropriate amplitude is transmitted to the probe **66**, depending on a decrease rate of the sectional area.

[0073] The columnar portion **86***a* of the cutting portion **82** of the probe **66** of the embodiment has a part, which configures the maximum outline portion and is continuous from the distal end **87***a* to the proximal end **87***b*, and a certain length along the longitudinal axis L. In the embodiment, the columnar portion **86***a* of the cutting portion **82** has the cross section that is the same or substantially the same from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a*, the cross section being orthogonal to the longitudinal axis L. In this manner, the cutting portion **82** of the treatment section **74** has the columnar portion **86***a*, and thereby it is possible to the straight hole **200** that has the same shape as the shape of the maximum outline portion of the columnar portion **86***a* when the bone B is cut, while the strength of the treatment section **74** when the probe **66** is straightly moved toward the distal side along the longitudinal axis L is maintained.

[0074] Incidentally, in a case where the columnar portion **86***a* has the appropriate length in the longitudinal axis L and is not provided with the recessed portion **92** of the discharge portion **84**, friction between the bone B and the outer peripheral surface of the columnar portion **86***a* increases. The columnar portion **86***a* has the maximum outline portion from the distal end **87***a* to the proximal end **87***b* along the longitudinal axis L, and thus outlines of parts orthogonal to the longitudinal axis L are the same at any position from the distal end **87***a* to the proximal end **87***b*. Therefore, in a case where the recessed portion **92** of the discharge portion **84** is not present, cutting debris from the bone B cut on the distal end **87***a* of the columnar portion **86***a* is pinched between the bone B and the outer peripheral surface of the columnar portion **86***a* and is unlikely to be discharged.

[0075] The recessed portion **92** of the discharge portion **84** of the probe **66** according to the embodiment is formed in the columnar portion **86***a*. The recessed portion **92** of the discharge portion **84** does not change the projection shape of the maximum outline portion of the columnar portion **86***a* when the treatment section **74** is viewed from the distal side toward the proximal side along the longitudinal axis L. Further, the recessed portion **92** is continuous from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a*. Therefore, once the cutting debris enters the recessed portion **92**, the cutting debris moves along the recessed portion **92** toward the proximal side from the treatment section **74**, as the probe **66** moves forward along the longitudinal axis L. Hence, the treatment section **74** of the probe **66** according to the embodiment solves problems of friction between the bone B and the cutting portion **82**, discharge of the cutting debris cut by the cutting portion **82**, and strength of the cutting portion **82**.

[0076] The distal portion **94***a* of the shaft portion **94** of the discharge portion **84** has a sectional area that decreases from the distal side toward the proximal side. Hence, the probe **66** is provided with a narrow portion formed in cooperation between the proximal end of the shaft portion **94** and the distal end of the probe main body section **72**. Therefore, the shaft portion **94** of the discharge portion **84** of the embodiment can form a space for discharging the cutting debris between an inner wall of the recessed hole **200** of the bone B and the shaft portion **94**.

[0077] Next, an operation of the treatment system **10** according to the embodiment will be described. Here, mainly regarding an operation of the ultrasound probe **66** of the treatment unit **32**, the case of forming the recessed hole **200** in the bone B is described.

[0078] The ultrasound transducer unit **54** is attached to the ultrasound treatment instrument **52**, and the treatment unit **32** is formed. In this case, the proximal end of the ultrasound probe **66** and the connection portion **56***c* of the ultrasound transducer unit **54** are connected to each other. Incidentally, here, in order to simplify the description, the center axis C of the probe main body section **72** is coincident with the longitudinal axis L of the treatment section **74**.

[0079] When the switch **36** is operated, energy is supplied from the controller **34** to the ultrasound transducer **56***b* of the vibrating body **58** fixed to the proximal end of the ultrasound probe **66**, and the ultrasound transducer **56***b* generates the ultrasonic vibration. Therefore, the ultrasonic vibration is transmitted to the ultrasound probe **66** via the vibrating body **58**. The vibration is transmitted from the proximal end of the ultrasound probe **66** toward the distal side. In this case, the connection portion **56***c* on a distal end of the vibrating body **58** and a proximal end of the vibrating body **58** become an antinode of vibration. One point on the center axis C on an inner side of a support target portion **58***a* becomes a node of vibration. The proximal end of the ultrasound probe **66**, which is connected to the connection portion **56***c* of the vibrating body **58** becomes the antinode of vibration, and thus the cutting portion **82** of the treatment section **74** becomes the antinode of vibration.

[0080] The cutting portion **82** of the treatment section **74** becomes the antinode of vibration, and thus the cutting portion is displaced along the longitudinal axis L at a speed (for example, thousands of m/s) based on a resonance frequency of the transducer **56***b*. Therefore, when the treatment instrument **52** is moved toward the distal side along the longitudinal axis L (center axis C) such that the treatment section **74** comes into press contact with the bone B in a state in which the vibration is transmitted, a portion of the bone B, with which the treatment section **74** comes into contact, is crushed by an action of the ultrasonic vibration. Hence, as the treatment instrument **52**, that is, the probe **66**, is moved toward the distal side along the longitudinal axis L (center axis C), the recessed hole **200** is formed in the bone B along the longitudinal axis L of the treatment section **74** of the ultrasound probe **66**.

[0081] Incidentally, in a case where the bone B is present beneath a cartilage, and the treatment section **74** of the ultrasound probe **66** comes into press contact with the cartilage toward the distal side along the longitudinal axis L, a portion of the cartilage, with which the treatment section **74** comes into contact, is resected, and a recessed hole is formed in the cartilage by the action of the ultrasonic vibration.

[0082] The projecting portion **86***b* and the columnar portion **86***a* of the treatment section **74** of the ultrasound probe **66** are each provided with the recessed portion **92** of the discharge portion **84**. The recessed portion **92** of the discharge portion **84** is formed, and thereby a contact area between the cutting portion **82** and the bone B is smaller than a contact area in a case where the recessed portion **92** is not formed, when the recessed hole **200** is formed in the bone B. Therefore, friction between the cutting portion **82** and the bone B is reduced. In addition, the recessed portion **92** is present in the cutting portion **82**, and thereby a surface area is larger than that in a case where the recessed portion **92** is not formed. Since a joint fluid or a perfusate is present in the joint **100**, heat dissipation capacity of the treatment section **74** improves, and the treatment section is smoothly cooled due to the presence of the recessed portion **92**. Hence, cutting debris of the bone B is placed in the recessed portion **92**. Therefore, the treatment section **74** of the treatment unit **32** can form the recessed hole **200** at an appropriate speed.

[0083] Hence, when the treatment section **74** is viewed from the distal side toward the proximal side along the longitudinal axis L, it is not possible to observe the shaft portion **94** of the discharge portion **84** due to the presence of the columnar portion **86***a* of the cutting portion **82**. Therefore, when the recessed hole **200** is formed, a space is formed between the proximal end **87***b* of the columnar portion **86***a*, the shaft portion **94**, and a side of the bone hole **200**. Therefore, the cutting debris of the bone B is discharged to the space between the shaft portion **94** and the side of the bone hole **200** from the proximal end **87***b* of the columnar portion **86***a*.

[0084] In this manner, the cutting debris of a site of the bone B, on which a treatment is performed by the treatment section **74**, is discharged toward the proximal side through the recessed portion **92** of the discharge portion **84** along the longitudinal axis L. In particular, the joint **100** is filled with the joint fluid. In addition, the perfusate circulates in the joint **100**. Therefore, the joint fluid or the perfusate acts as a lubricant such that it is easy for the cutting debris of the bone B to be discharged toward the proximal side from the cutting portion **82** along the longitudinal axis L. In a case where forming of the recessed hole **200** having a desired depth in the bone B is completed, a press on the switch **36** is canceled such that the generation of the ultrasonic vibration is stopped. Hence, the ultrasound probe **66** is moved toward the proximal side along the longitudinal axis L.

[0085] As illustrated in FIG. **4**B, the recessed hole **200** formed in the bone B is formed into the same shape as an outer edge of the columnar portion **86***a* of the cutting portion **82** from the entrance **202** to a back-side site **204**. A deepest position **206** of the recessed hole **200** is formed into the same shape as an outline of the projecting portion **86***b* including the vertex **86***c*. In other words, as illustrated in FIG. **4**A, in a case where the ultrasonic vibration is transmitted to the probe **66** of the ultrasound treatment instrument **52** such that the recessed hole **200** is formed in the bone B, it is possible to copy the shape of the cutting portion **82** of the treatment section **74** as it is.

[0086] The ultrasonic vibration is transmitted to the probe **66** of the treatment unit **32** according to the embodiment, and the ultrasonic vibration is applied to a site of the bone B, to which a hole needs to be formed. In this manner, the site, with which the treatment section **74** on the distal end of the probe **66** comes into contact, is finely crushed and cut. The distal portion of the treatment section **74** has a projecting shape, and the cutting portion **82** is further provided with the recessed portion **92** of the discharge portion **84** through which the cutting debris of the bone B is discharged. Therefore, the projecting portion **86***b* or the recessed portion **92** of the discharge portion **84** is provided rather than the cutting portion **82** that is not provided with the projecting portion **86***b* and has the same shape of the projection shape of the columnar portion **86***a* in an axial direction without change, and thereby opening work of opening a hole more rapidly can progress.

[0087] The cutting portion **82** is moved along the longitudinal axis L, and thereby the shape of the distal end **87***a* of the columnar portion **86***a* as it is can be formed as the opening edge of the recessed hole **200** when the treatment section **74** is viewed from the distal side along the longitudinal axis L. Therefore, the projection shape of the cutting portion **82** along the longitudinal axis L is the same as the shape of the desired recessed hole **200**. Hence, the cutting portion **82** digs a hole in the bone B, and thereby it is possible to open the recessed hole **200** having a desired shape with a desired depth in the bone B.

[0088] In addition, the treatment section **74** has a projecting shape on the distal portion, and the contact area between the bone B and the cutting portion **82** is decreased by the recessed portion **92** of the discharge portion **84**. In this manner, it is further easy to discharge the cutting debris. Therefore, when the bone B is cut, it is possible to limit generation of friction between the treatment section **74** and the bone B, and it is possible to increase a work speed.

[0089] FIGS. **5**A and **5**B illustrate a first modification example of the ultrasound probe **66**.

[0090] As illustrated in FIG. **5**B, the cross section of the columnar portion **86***a* of the treatment section **74** of the ultrasound probe **66** has a substantially elliptical shape, the cross section being orthogonal to the longitudinal axis L. Incidentally, the columnar portion **86***a* has the same shape between the distal end **87***a* and the proximal end **87***b* and has the projection shape of the substantially elliptical shape when the proximal side is viewed from the distal side along the longitudinal axis L of the treatment section **74**.

[0091] Here, the discharge portion **84** is formed in the columnar portion **86***a* of the cutting portion **82** of the treatment section **74**. On the other hand, the discharge portion **84** is formed in the projecting portion **86***b* of the cutting portion **82** of the treatment section **74**.

[0092] In this case, the cutting debris of the cartilage or the bone B cut by the projecting portion **86***b* of the cutting portion **82** is placed between the projecting portion **86***b* and the cartilage or the bone B. The cutting debris is moved toward the columnar portion **86***a* from an inclined surface of the projecting portion **86***b*, as the recessed hole **200** is formed deeply. Hence, the cutting debris is discharged toward the proximal side along the longitudinal axis L from the recessed portion **92** of the discharge portion **84** between the distal end **87***a* and the proximal end **87***b* of the columnar portion **86***a*. In this case, a discharge amount of the cutting debris from the projecting portion **86***b* toward the proximal side is more decreased, compared to a case where the discharge portion **84** is present in the projecting portion **86***b*. Incidentally, an amount of the cutting debris is adjusted by a shape or the like of the recessed portion **92**.

[0093] The projecting portion **86***b* of the cutting portion **82** of the ultrasound probe **66** illustrated in FIG. **5**A can more decrease the cutting speed, but it is possible to cut the bone B, compared to the projecting portion **86***b* of the cutting portion **82** of the ultrasound probe **66** illustrated in FIG. **3**A. Therefore, the recessed portion **92** of the discharge portion **84** does not absolutely need to be formed in the projecting portion **86***b*. When the recessed portion **92** of the discharge portion **84** is formed in the projecting portion **86***b* of the cutting portion **82**, the discharge of the cutting debris is more promoted, and the work speed can be increased. After the columnar portion **86***a* of the cutting portion **82** reaches the bone B, the cutting debris is discharged toward the proximal side along the longitudinal axis L by the recessed portion **92** of the discharge portion **84** which is formed in the columnar portion **86***a*.

[0094] As illustrated in FIG. **5**B, a groove (bottom) **92***a* having a cross-hatched shape is formed, as the recessed portion **92** of the discharge portion **84** in the columnar portion **86***a* of the cutting portion **82** of the treatment section **74**. The groove **92***a* is continuous from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a*. The recessed portion **92** of the discharge portion **84** is provided in the columnar portion **86***a*; however, the outer edge of the columnar portion **86***a* does not change as illustrated in FIG. **5**B when the treatment section **74** is viewed from the distal side toward the proximal side along the longitudinal axis L. Therefore, the distal end **87***a* of the columnar portion **86***a* of the cutting portion **82** can form the recessed hole **200** without a change in outline (contour).

[0095] Incidentally, as described above, the groove **92***a* is continuous from the distal end **87***a* toward the proximal end **87***b* of the columnar portion **86***a*. Therefore, since the cutting debris of the bone B, which enters the groove **92***a* once, moves along the groove **92***a* that is continuous from the distal end **87***a* and the proximal end **87***b*, and thus the cutting debris is easily discharged from the distal end **87***a* through the proximal end **87***b* of the columnar portion **86***a* toward the proximal side of the treatment section **74**.

[0096] FIGS. **5**C and **5**D illustrate a second modification example of the ultrasound probe **66**.

[0097] The vertex **86***c* of the ultrasound probe **66** illustrated in FIG. **5**C has an edge extended in a direction orthogonal to the longitudinal axis L. The vertex (edge) **86***c* is parallel to the distal end **87***a* of the columnar portion **86***a*. In other words, the projecting portion **86***b* is not limited to the cone shape. The projecting portion **86***b* of the cutting portion **82** has a shape in which a sectional area of a cross section orthogonal to the longitudinal axis L decreases from the distal end **87***a* of the columnar portion **86***a* of the cutting portion **82** toward the distal side along the longitudinal axis L.

[0098] As illustrated in FIGS. **5**C and **5**D, the recessed portion **92** of the discharge portion **84** is formed in the columnar portion **86***a*. The recessed portion **92** is provided with the recessed bottom **92***a* resulted from a sandblast process. Here, as illustrated in FIG. **5**D, the projection shape of the treatment section is a rectangular shape when the proximal side is viewed from the distal side along the longitudinal axis L of the treatment section **74**. The distal end **87***a* of the columnar portion **86***a* determines the maximum outline portion when the bone B is cut, and a cross section of the columnar portion has the same shape or substantially the same shape as the projection shape of the rectangular shape from the distal end **87***a* to the proximal end **87***b* along the longitudinal axis L, the cross section being orthogonal to the longitudinal axis L. Hence, when the proximal side is viewed from the distal side of the treatment section **74** along the longitudinal axis L, a proximal end of the recessed portion **92** cannot be visually recognized and is entirely hidden by the columnar portion **86***a*.

[0099] The recessed portion **92** processed by sandblast is provided with an enormous number of bottoms **92***a*. An enormous number of vertices are formed by the enormous number of bottoms **92***a* in the maximum outline portion between the distal end **87***a* and the proximal end **87***b* of the columnar portion **86***a* of the cutting portion **82**.

[0100] Incidentally, the bottom **92***a* is continuous from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a*. An enormous inter-vertex distances of the maximum outline portion of the columnar portion **86***a* of the cutting portion **82** are formed to be larger than the cutting debris of the bone B. Therefore, the cutting debris enters a space between the enormous number of vertices of the maximum outline portions of the columnar portion **86***a* of the cutting portion **82**. Hence, the cutting debris of the bone B, which enters the bottom **92***a* once, is easily discharged on

the proximal side of the treatment section **74** from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a*.

[0101] Otherwise, the recessed portion **92** of the discharge portion **84** illustrated in FIG. **5**C is preferably a bottom **92***a* having a recessed spiral groove shape (refer to FIGS. **3**B and **3**D), a bottom **92***a* having a recessed cross-hatched shape (refer to FIG. **5**B), or the like.

[0102] Here, FIGS. **6**A and **6**B illustrate an example of the recessed portion **92** of the discharge portion **84** formed in the columnar portion **86***a*. Here, drawing of the projecting portion **86***b* is omitted. FIGS. **7**A and **7**B illustrate a reference example of an undesirable recessed portion **92** of the discharge portion **84** formed in the columnar portion **86***a*. Here, drawing of the projecting portion **86***b* is omitted. FIGS. **8**A and **8**B illustrate another reference example of an undesirable recessed portion **92** of the discharge portion **84** formed in the columnar portion **86***a*. Here, drawing of the projecting portion **86***b* is omitted.

[0103] As illustrated in FIGS. **6**A and **6**B, the recessed portion **92** of the discharge portion **84** from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a* of the cutting portion **82** is inclined such that a proximal end of the bottom **92***a* of the recessed portion **92** is not observed when the proximal side is viewed from the distal side of the treatment section **74** along the longitudinal axis L. In a case where a part of the proximal end of the bottom **92***a* of the recessed portion **92** is observed as in the reference example illustrated in FIGS. **7**A and **7**B, the bone is likely to be uncut straightly along the longitudinal axis L by a groove **92***b* along the longitudinal axis L.

[0104] In the reference example illustrated in FIG. **8**A, the recessed portion **92** has the same inclination as that in FIG. **6**A. However, a width of the recessed portion **92** is larger than that in FIG. **6**A, the width being orthogonal to the longitudinal axis L. Hence, when the proximal side is viewed from the distal side of the treatment section **74** along the longitudinal axis L, a part of the proximal end of the bottom **92***a* of the recessed portion **92** is observed. In this case, as illustrated in FIG. **8**B, the bone has a portion that does not abut the columnar portion **86***a*, from the distal end **87***a* to the proximal end **87***b* of the columnar portion **86***a*. Therefore, an uncut portion of the bone is straightly formed along the longitudinal axis L. There is a concern that a tendon transplant **212** or **216** (refer to FIGS. **9**C, **10**D, and **11**C) to be described below is caught on the uncut portion. In this manner, it is not preferable that the recessed portion **92** have a shape illustrated in FIGS. **8**A and **8**B. Therefore, the projection shape of the maximum outline portion is not broken, and an angle and a width of the recessed portion **92** is formed as illustrated in FIG. **6**A. In addition, only one recessed portion **92** illustrated in FIG. **6**A is not formed, but a plurality of recessed portions are preferably formed.

[0105] Here, there is provided the simple description of an operation example performed on a side of a femur **112** in a case where the anterior cruciate ligament reconstructive surgery in the knee joint **100** is performed.

[0106] It is possible to divide an operation method into two methods depending on a material of a tendon transplant of a ligament to be reconstructed. One is a method in which a semitendinosus muscle tendon or a gracilis muscle tendon present inside a knee is used as the tendon transplant (STG tendon) **212**. The other is a method in which a patellar tendon is used as the tendon transplant (BTB tendon) **216**. Incidentally, here, in both the methods, the bone hole **200** is formed by an inside-out method from an inside of the joint cavity **110** toward an outer side of the femur **112**.

[0107] First, an example of using the tendon transplant (STG tendon) **212** is simply described with reference to FIGS. **9**A to **9**C.

[0108] By appropriately using the treatment system **10** illustrated in FIG. **1**, the semitendinosus muscle tendon or the gracilis tendon present inside the knee is collected as the tendon transplant **212**. In this case, a length of the tendon is substantially about 250 mm to 300 mm. Hence, the collected tendon is bent a plurality of times such as four times to six times, and thereby the tendon transplant **212** having an outline of a cross section of a substantially rectangular shape is formed, the cross section being orthogonal to the longitudinal axis, for example. In this case, an outline of the tendon transplant **212** is 4 mm×5 mm, as an example. Hence, a string **213** illustrated in FIG. **9**C is caused to pass to one end of the tendon transplant **212**, and a suspended fixing instrument **214** is fixed to the string **213**.

[0109] A treatment instrument (not illustrated) is put into an inner side of the joint cavity **110** of the knee joint **100** through the second portal (skin incision site) **104** of the knee joint **100**. Then, while a footprint of the anterior cruciate ligament on a side of the femur **112** is checked by using the arthroscope **22**, the cut anterior cruciate ligament is dissected to expose the footprint (portion to which the anterior cruciate ligament is attached). Incidentally, although not illustrated clearly, the footprint is present in a rear part of an outer wall of an intercondylar fossa of the femur **112**. In addition, the footprint on a side of a tibia **114** is present on an inner side of an anterior intercondylar area of the tibia **114**. A position of the footprint on the side of the femur **112** is a position, at which one end of a bone hole (tunnel) **201** on the side of the femur **112** is placed, or the vicinity of the position. Here, an example of forming the bone hole **201** and the recessed hole **200** having a desired shape in the footprint is described.

[0110] As illustrated in FIG. **9**A, a drill **38** is inserted into the joint cavity **110** through the second portal **104** of the knee joint **100**. While the footprint of the anterior cruciate ligament on the side of the femur **112** is checked by using the arthroscope **22**, the penetrating bone hole (tunnel) **201** that has an end portion in the footprint and is used for the tendon transplant **212** to pass through the femur **112** is opened by using the drill **38**. In other words, the bone hole **201** is formed from a site **112***a* of the femur **112** in the joint **100** to an outer site **112***b* of the femur **112**. In this case, the through-hole **201** has a circular shape.

[0111] Then, the drill **38** is removed from the inside of the joint **100**, and the treatment section **74** of the probe **66** of the ultrasound treatment instrument **52** is inserted from the same second portal **104**, for example. Hence, a state in which the projecting portion **86***b* of the cutting portion **82** of the treatment section **74** abuts the entrance **202** of the bone hole **201** is checked by using the arthroscope **22**. Hence, the ultrasonic vibration is generated by the transducer **56***b* such that the treatment section **74** is moved forward along the longitudinal axis L. Therefore, as illustrated in FIG. **9**B, the recessed hole **200** having a substantially rectangular parallelepiped shape with an appropriate depth is formed in the site **112***a* of the femur **112** in the joint **100**. In this case, the drill hole **201** by the drill **38** and the recessed hole **200** communicate with each other.

[0112] As illustrated in FIG. **9**C, the tendon transplant **212** is placed in the recessed hole **200**. In this case, the recessed hole **200** has a rectangular shape of about 4 mm×5 mm, and the tendon transplant **212** has a rectangular shape of about 4 mm×5 mm. Therefore, the tendon transplant **212** is prevented from rotating around a longitudinal axis of the recessed hole **200** and the drill hole **201**. Hence, the fixing instrument **214** is supported by the outer site **112***b* of the femur **112** through the drill hole **201**. In this manner, the tendon transplant **212** is fixed on the side of the femur **112**.

[0113] Incidentally, since the anterior cruciate ligament is anatomically known as two fiber bundles, it is preferable that two holes be opened at each of the femur **112** and the tibia **114**, and the tendon transplants **212** pass through the holes, respectively.

[0114] Then, the other end of the tendon transplant **212** is fixed in the vicinity of a front surface of the tibia **114**, with a string (not illustrated) passing through the bone hole (not illustrated) formed in the tibia **114** (refer to FIG. **1**).

[0115] Next, an example of using the tendon transplant (BTB tendon) **216** will be simply described.

[0116] A first example of using the BTB-type tendon transplant **216** is described with reference to FIGS. **10**A to **10**D.

[0117] By using the treatment system **10**, the patellar tendon is collected as the tendon transplant **216**. In this case, an outline of a bone piece **216***a* of the tendon transplant **216** is 10 mm×5 mm, as an example. Hence, the string **213** illustrated in FIG. **10**D is caused to pass through the tendon transplant **216**, and the suspended fixing instrument **214** is fixed to the string **213**.

[0118] As illustrated in FIG. **10**A, similarly to the description provided above, the bone hole (drill hole) **201** is formed in the footprint by using the drill **38**. The bone hole **201** is formed from the site **112***a* of the femur **112** in the joint **100** to the outer site **112***b* of the femur **112**. In this case, the through-hole **201** has a circular shape.

[0119] Then, the drill **38** is removed from the inside of the joint **100**, and the treatment section **74** of the probe **66** of the ultrasound treatment instrument **52** is inserted from the same second portal **104**. Hence, a state in which the projecting portion **86***b* of the cutting portion **82** of the treatment section **74** abuts the entrance **202** of the bone hole **201** is checked by using the arthroscope **22**. Hence, the ultrasonic vibration is generated by the transducer **56***b* such that the treatment section **74** is moved forward along the longitudinal axis L. Therefore, as illustrated in FIG. **10**B, a first recessed hole **200***a* having an appropriate depth is formed. In this case, the first recessed hole **200***a* communicates with the drill hole **201** by the drill **38**. In this case, the first recessed hole **200***a* having a substantially rectangular parallelepiped shape is formed in the site **112***a* of the femur **112** in the joint **100**.

[0120] The treatment section **74** of the same probe **66** is moved back along the longitudinal axis L such that the treatment section **74** is removed from the first recessed hole **200***a*. Hence, the position of the treatment section **74** is shifted to a position that is continuously adjacent to the first recessed hole **200***a* such that the treatment section **74** abuts the bone B. The ultrasonic vibration is generated by the transducer **56***b* such that the treatment section **74** is moved forward along the longitudinal axis L. Therefore, as illustrated in FIG. **10**C, a second recessed hole **200***b* having an appropriate depth is formed. In this case, the second recessed hole **200***b* communicates with the drill hole **201** by the drill **38**. In this case, the first recessed hole **200***a* and the second recessed hole **200***b* which have a substantially rectangular parallelepiped shape are formed in the site **112***a* of the femur **112** in the joint **100**. Hence, the first recessed hole **200***a* and the second recessed hole **200***b* are continuous to each other as illustrated in FIG. **10**C and both form one continuous recessed hole **200**.

[0121] Incidentally, the bone piece **216***a* of the tendon transplant **216** has a rectangular shape of about 10 mm×5 mm. In a case where the recessed hole **200** does not reach the size of the bone piece and the bone piece **216***a* cannot enter the recessed hole **200**, the recessed hole **200** is more widened by using the ultrasound treatment instrument **52**.

[0122] As illustrated in FIG. **10**D, the bone piece **216***a* of the tendon transplant **216** is placed in the recessed hole **200**. In this case, the bone piece **216***a* of the tendon transplant **216** has a rectangular shape of about 10 mm×5 mm. The recessed hole **200** is formed to have a rectangular shape that is slightly larger than the bone piece **216***a* of the tendon transplant **216**. Therefore, the recessed hole **200** prevents he tendon transplant **216** from rotating around the longitudinal axis of the recessed hole. Hence, the fixing instrument **214** is supported by the outer site **112***b* of the femur **112**. In this manner, the tendon transplant **216** is fixed on the side of the femur **112**.

[0123] Then, the other end of the tendon transplant **216** is fixed in the vicinity of the front surface of the tibia **114**, with a string (not illustrated) passing through the bone hole (not illustrated) formed in the tibia **114** (refer to FIG. **1**). Alternatively, the other end of the tendon transplant **216** is fixed by using a screw (not illustrated).

[0124] A second example of using the BTB-type tendon transplant **216** is described with reference to FIGS. **11**A to **11**C.

[0125] Here, an example of using a screw **218** as a fixing instrument is described.

[0126] As illustrated in FIG. **11**A, the treatment section **74** of the probe **66** of the ultrasound treatment instrument **52** is inserted from the second portal **104**. Hence, a state in which the projecting portion **86***b* of the cutting portion **82** of the treatment section **74** abuts the footprint is checked by using the arthroscope **22**. In this manner, the ultrasonic vibration is generated by the transducer **56***b* such that the treatment section **74** is moved forward along the longitudinal axis L. In this case, the first recessed hole **200***a* having the substantially rectangular parallelepiped shape with an appropriate depth is formed in the site **112***a* of the femur **112** in the joint **100**.

[0127] Hence, the position of the treatment section **74** of the same probe **66** is shifted such that the projecting portion **86***b* of the cutting portion **82** of the treatment section **74** abuts the entrance **202** of the bone hole **201**. The ultrasonic vibration is generated by the transducer **56***b* such that the treatment section **74** is moved forward along the longitudinal axis L. Therefore, as illustrated in FIG. **11**B, the second recessed hole **200***b* having the appropriate depth is formed. The first recessed hole **200***a* and the second recessed hole **200***b* which have the substantially rectangular parallelepiped shape are formed in the site **112***a* of the femur **112** in the joint **100**. Hence, the first recessed hole **200***a* and the second recessed hole **200***b* are continuous to each other as illustrated in FIG. **11**B and both form one continuous recessed hole **200**.

[0128] As illustrated in FIG. **11**C, the bone piece **216***a* of the tendon transplant **216** is placed in the recessed hole **200**. In this case, the recessed hole **200** prevents he tendon transplant **216** from rotating around the longitudinal axis of the recessed hole. In addition, the screw **218** presses the bone piece **216***a* of the tendon transplant **216** to a wall surface of the recessed hole **200**.

[0129] In this manner, the tendon transplant **216** is fixed on the side of the femur **112**.

[0130] As described above, the probe **66** of the treatment instrument **52** according to the embodiment is described as follows.

[0131] The footprint of the anterior cruciate ligament takes a narrow area. On the other hand, an outline of an end portion of the tendon transplants **212** and **216** has the rectangular shape or the substantially rectangular shape different from a circle. For example, when the BTB-type tendon transplant **216** of 5 mm×10 mm=50 mm^2 enters a circular hole formed by a drill, the circular hole needs to have a diameter of about 11 mm. In this case, a sectional area of the circular hole is about 95 mm^2, and substantially a half of the sectional area is a space. The joint fluid can enter the space, and ligamentation of the tendon transplant **216** can be delayed. The same is true of the case of the STG-type tendon transplant **212**.

[0132] Therefore, when the recessed hole **200** is formed according to the outline of the tendon transplant **212** or **216**, it is possible to reduce a space quantity between the recessed hole **200** and the tendon transplant **212** or **216** and reduce a cutting amount of the bone B. In the embodiment, it is possible to form the recessed hole **200** by using the ultrasound treatment instrument **52** including the treatment section **74** provided with the columnar portion **86***a* having a cross section of the rectangular shape, the substantially rectangular shape, the elliptical shape, or the substantially elliptical shape. In other words, it is possible to form the recessed hole **200** having the same shape or substantially the same shape as the outline of the tendon transplant **212** or **216** which is buried in the bone B. Therefore, it is possible to form the bone hole **200**, in which the end portion of the tendon transplant **212** or **216** is placed without projecting as much as possible with respect to the footprint of the anterior cruciate ligament. Therefore, the tendon transplant is prevented from invading into peripheral tissue of the footprint of the anterior cruciate ligament of the site **112***a* of the femur **112** in the joint **100**. In addition, it is possible to make the ligamentation of the tendon transplants **212** and **216** earlier by the recessed hole **200** having a space quantity to the smallest extent in a state in which the tendon transplant **212** or **216** is placed.

[0133] In addition, a treatment of forming the recessed hole **200** in the bone B by the ultrasound treatment instrument **52** is different from a treatment of dilating a hole by a dilator or the like. Therefore, it is possible to perform the treatment on a target of medical treatment, even when the target is a woman, an aged person, or the like who has low bone density and is excluded from the operation target in related art.

[0134] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the disclosure in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. An ultrasound probe comprising:

a probe main body section that receives ultrasonic vibration generated from an ultrasound transducer;

a controller that is connected to the ultrasound transducer and is configured to control generation of the ultrasonic vibration; and

a treatment section that is provided on a distal side of the probe main body section and is configured to form a hole in a treatment target, with the ultrasonic vibration, the treatment section having a distal end and a proximal end and including:

a cutting portion that is configured to cut the treatment target to form the hole while the cutting portion is moved in a direction along a longitudinal axis of the treatment section in a state in which the ultrasonic vibration is transmitted to the probe main body section, the cutting portion including:

a columnar portion having a distal end and a proximal end, and when viewed from the distal end of the treatment section, the columnar portion has a projection shape that is one of the following: a polygon shape; a substantially polygonal shape; an elliptical shape; and a substantially elliptical shape.

2. The ultrasound probe according to claim **1**, wherein the treatment section further comprises a discharge portion that is configured to discharge cutting debris of the treatment target cut by the cutting portion toward the proximal end of the treatment section from the cutting portion, the discharge portion including a recessed portion formed in a groove shape, the recessed portion being inclined with respect to the longitudinal axis of the treatment section.

3. The ultrasound probe according to claim **2**, wherein a proximal end of the recessed portion is not visible when the proximal end of the treatment section is viewed from the distal end of the treatment section along the longitudinal axis.

4. The ultrasound probe according to claim **2**, wherein the recessed portion is provided with a recessed spiral groove-shaped bottom.

5. The ultrasound probe according to claim **2**, wherein the recessed portion is provided with a recessed crosshatch-shaped bottom.

6. The ultrasound probe according to claim **1**, wherein a cross-section of the columnar portion has a shape that is the same as the projection shape of the columnar portion when viewed from the distal end of the treatment section along the longitudinal axis, the cross-section of the columnar portion being orthogonal to the longitudinal axis.

7. The ultrasound probe according to claim **6**, wherein the distal end of the columnar portion defines a maximum outline of a cut section of the treatment target.

8. The ultrasound probe according to claim **2**, wherein:

the cutting portion further includes a projecting portion that projects distally from the columnar portion toward along the longitudinal axis; and

the recessed portion of the discharge portion is configured to decrease a contact area between the treatment section and the treatment target such that the recessed portion is a discharge path of the cutting debris.

9. The ultrasound probe according to claim **1**, wherein:

the cutting portion further includes a projecting portion that projects distally from the columnar portion along the longitudinal axis; and

the projecting portion of the cutting portion has a cross-sectional area that decreases from the distal end of the columnar portion of the cutting portion toward a distal end of the projecting portion.

10. The ultrasound probe according to claim **2**, further comprising a shaft portion that abuts the discharge portion, the shaft portion being provided between the probe main body section and the columnar portion and extends proximally from the columnar portion along the longitudinal axis, the shaft having a dimension that is covered by the projection shape of the cutting portion when viewed from a distal side along the longitudinal axis.

11. The ultrasound probe according to claim **10**, wherein:

the shaft portion is provided with a distal portion that is continuous to a proximal end of the columnar portion along the longitudinal axis; and

the distal portion of the shaft portion has a cross section that decreases from a distal side of the shaft portion toward a proximal side of the shaft portion along the longitudinal axis, the cross section being orthogonal to the longitudinal axis.

12. The ultrasound probe according to claim **11**, wherein a boundary between the distal portion of the shaft portion and the proximal end of the columnar portion has a shape that prevents stress concentration in a state in which the ultrasonic vibration is transmitted.

13. The ultrasound probe according to claim **1**, wherein the columnar portion has a predetermined length from the distal end of the columnar portion to the proximal end of the columnar portion.

14. The ultrasound probe according to claim **1**, wherein the columnar portion is a block shape.

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[标]申请(专利权)人(译)	奥林巴斯株式会社		
申请(专利权)人(译)	OLYMPUS CORPORATION		
当前申请(专利权)人(译)	OLYMPUS CORPORATION		
[标]发明人	FUJISAKI KEN SAWADA KIICHIRO TANIGAMI YASUO YOSHIMINE HIDETO YOKOYAMA KEN MIYASAKA RYO		
发明人	FUJISAKI, KEN SAWADA, KIICHIRO TANIGAMI, YASUO YOSHIMINE, HIDETO YOKOYAMA, KEN MIYASAKA, RYO		
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摘要(译)

超声波探头包括：探头主体部分，超声波换能器产生的超声波振动被传输到探头主体部分;控制器，连接到超声波换能器并控制超声波振动的产生;以及处理部，其设置在探头主体部的远端侧，并且利用超声波振动在作为治疗目标的骨中形成孔。治疗部分具有远端和近端，并且包括柱状部分，通过用超声波振动压碎骨头来切割骨骼并形成孔的切割部分，以及排出切割的骨头的切割碎屑的排出部分。切割部分从切割部分朝向近端，排出部分包括形成为相对于纵向轴线倾斜的凹槽形状的凹入部分。