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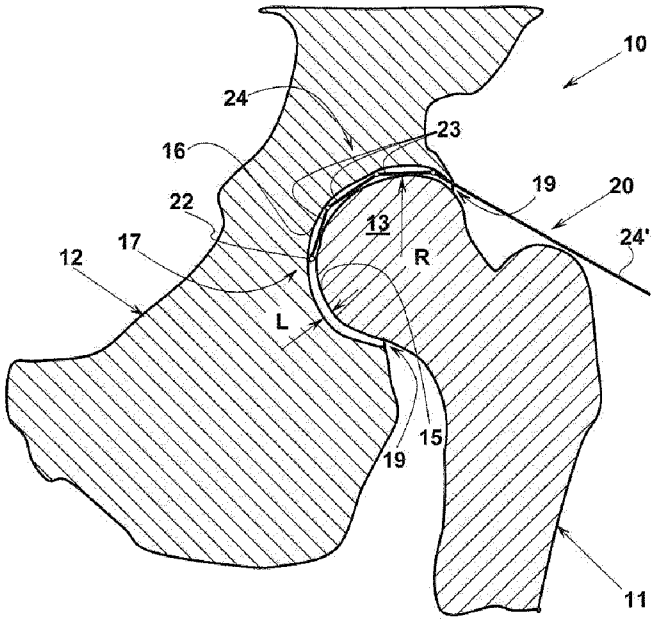
(54) Title: NON-INVASIVE ARTICULAR SURGERY DEVICE

Fig. 1



(57) Abstract: An articular surgical device (20) comprising a surgical tool (22) for modifying a connective tissue of one or both articular surfaces (15, 16) of a bone joint (10), in particular to carry out a treatment such as removal of connective tissue, e.g. damaged cartilage, removal or smoothing of bone tissues. The device comprises a deformable linear element, wherein a positioning means (24) is provided for the tool (22), said positioning means comprising linear or curved elongated elements (23) connected to each other by hinges (25), such that the device (20) is adapted to move through an intra-articular passageway (19) to reach the surgical treatment site (17) between two articular surfaces, said passageway (19) having a determined width (L) and a determined curvature radius (R). The tool (22', 22") can be a mechanical tool such as a barrel-shaped milling cutter (22') or a spherical milling cutter (22"), which may be provided with a pneumatic actuation means or with a turbine hydraulic actuation means. In alternative, The tool may be a laser or an ultrasound tool. A positioning means (24) is provided comprising, for instance, a plurality of tendons (27, 27'), and an actuation means arranged at a proximal portion (21 ') of positioning means (24), which is arranged around bone joint (10). The tendons (27, 27') are at least the same number of the elongated elements (23), in order to actuate a respective degree of freedom of each tendon. In particular, a couple of tie-members is provided for each elongated element, which comprises an extension tie-member (27) and a flexion tie-member (37), in order to bilaterally actuate respective opposite extension and flexion movements.

WO 2012/110528 A2

TITLE

NON-INVASIVE ARTICULAR SURGERY DEVICE

DESCRIPTION

Scope of the invention

The present invention relates to a device for non-invasive articular surgery, and also to a device for remodeling articular surfaces. In particular, the device is useful for implanting an articular lining and for partially or totally replacing metal and not metal articular prosthesis. The device is, furthermore, useful for ablation, suture, reconstruction surgery of soft parts of the articulations. Such surgical treatments can involve the main joints of body limbs and, in particular, the hip, the knee, the shoulder, the elbow and the ankle.

Background of the invention

Articular surgery techniques are known for ablative treatments and replacement of soft tissues and for remodeling and replacing articular surfaces. Most of traditional techniques provide invasive open surgery of the bone joint.

Mini-invasive endoscopic (arthroscopic) techniques have been developed recently, capable of reducing at most collateral damages due to the surgery on the bone joint, even in case of particularly complex treatments.

The drawbacks of mini-invasive arthroscopic techniques are the stiffness of the tools, their relative mechanical weakness and the impossibility to reach all the articular recesses which require a surgical treatment.

Summary of the invention

It is therefore a feature of the present invention to provide a semi-automatic manipulator, i.e. a device that an operator can control by a remote control interface, with the aid of virtual reality with feedback force.

It is also a feature of the present invention to provide such a device for performing an articular surgery treatment in a minimally invasive way, in particular a treatment of relatively impervious bone joints, typically arthrodies, and enarthrosis, such as the hip joint.

It is, furthermore, a feature of the present invention to provide a minimally invasive bone joint surgery device which is easier to use, and more precise than the prior art devices.

It is a particular feature of the invention to provide a relatively narrow and relatively long device, in order to reach the inner zones of a wide variety of joints, with minimum trauma for the joints.

It is another particular feature of the present invention to provide a bone joint surgery device that has a higher mechanical resistance than prior art devices.

These and other objects are achieved by a bone joint surgery device, the device comprising:

— a surgical tool adapted to surgically modify a bone joint tissue at a surgical site of a bone joint surface of the bone joint;

— a positioning means of the surgical tool, the positioning means having a proximal actuation end portion and a distal end portion, the surgical tool connected to the distal end portion;

the main feature of the device being that the positioning means comprises a plurality of elongated elements, the elongated elements mutually linked by means of hinges, such that the positioning means can be deformed and adapted to pass through an intra-articular passageway to the surgical site, the passageway defined between two bone joint surfaces of the bone joint, the intra-articular passageway having a prefixed width and a prefixed curvature.

This way, it is possible to position the surgical tool in relatively impervious joints, since the succession of a plurality of elongated elements makes it possible to limit the radial size of the positioning means, and the use of the hinges allows a deformation of the positioning means in order to reach inner positions i.e. inner surgical sites of extended joints and/or having relevant curvature, in particular arthrodies, and enarthrosis. The device allows to extend the application of minimally invasive articular surgery to surgical sites treatment of difficult accessibility, reducing the use of open surgery.

Advantageously, at least one of the elongated elements has a curved shape, assisting the passage through the access of the positioning means. The curvature of the elongated elements of the device allows, in particular to

approach intra-articular spaces of relevant curvature, and to limit that the device can be blocked against the articular surfaces.

Preferably, the positioning means comprises a motion actuation mechanism including a plurality of tendons, and an actuation means is provided for operating the tendons. Preferably, the actuation means is arranged at a manoeuvre unit at the proximal end portion, the manoeuvre unit in use arranged outside of the bone joint.

The manoeuvre unit may be is adapted to be operated according to a surgical treatment mode selected among a manual operating mode and a tele-operation treatment mode. This way, The manoeuvre unit can be operated by the surgeon either directly, or tele-operation mode.

Advantageously, the elongated elements define channels or elongated recesses that extend for all the length of such elongated elements, said recesses having openings at the end portions of the elongated elements, for passage the tendons.

In particular, the positioning means comprises extension and flexion tendons.

Furthermore, at least one of the hinges may be adapted to maintain in one plane a rotation of two elongated elements with respect to each other.

In particular, said hinges comprise abutments in order to impede a hyperextension of said elongated elements beyond a position of alignment of said elongated elements, according to a predetermined straight line line or curve.

Preferably, the positioning means comprises three elongated elements.

This way, the positioning means is made according to an anthropomorphic model of a finger of a hand, of which it maintains the following features:

— the finger of a hand is stiff and strong in a position of full extension with a few degrees of hyper-extension: the extension and flexion tendons contract together stiffening and stabilizing the end link;

— the finger cannot be hyper-extended to obtain a mechanical resistance and stability;

— the finger has at least three segments movable with respect to each other only in a plane of the space, the “bone joints”, the joints of half-spherical type are constrained at the respective ends and rotate about a single axis.

Advantageously, the tendons are at least the same number as the elongated elements, and each of the elongated elements has at least one connection point with a tendon. This way, it is possible to actuate each degree of freedom of the device, in particular remotely, in favour of the precision of positioning the surgical tool or of other instruments and of the precision of the surgical treatment.

Preferably, for one or for each elongated element one pair of tendons is provided comprising an extension tendon and a flexion tendon, wherein the extension and flexion tendons are adapted to actuate respective opposite extension and flexion movements of the elongated element with respect to an adjacent elongated element. This way, each degree of freedom of the device can be bilaterally actuated. In other words, it is possible to carry out a bilateral surgical treatment exploiting all the degrees of freedom of the device; like the finger of a hand, the device can be bent by pulling flexion elements and can be stabilized i.e. blocked at whichever bending degree, owing to the contemporaneous contraction of flexion tendons and of extension tendons.

In particular, each elongated element has at least two connection points with respective tendons of the couple of corresponding tendons.

The device can comprise effectors i.e. instruments adapted to carry out at the surgical site a treatment selected from the group comprised of::

– connective tissue removal, in particular damaged cartilaginous tissue removal;
– bone tissue removal;
– joint smoothing;
– a combination thereof.

In an exemplary embodiment, the surgical effector is a surgical mechanical tool. In particular, a turbine surgical tool. In particular, the surgical mechanical tool is a pneumatically and/or hydraulically actuated turbine surgical tool.

In particular, the surgical mechanical tool is a barrel-shaped milling cutter, the barrel-shaped milling cutter having a curved cutting profile whose radius of

curvature is shorter or of the same length as a local curvature of the joint surface at the surgical site. This solution of the shape of the turbine, and, in particular, of the radius of curvature of the generatrix, assists the surgical treatment on the articular surfaces of the concave articular ends of the bone joints, for example on the surface of the pelvis acetabulum, in case of the coxofemoral enarthrosis, and of the glenoid fossa, in scapulo-omeral enarthrosis. More in detail, the barrel-shaped cutter assists the surgical treatment at the same time on convex and concave bone ends of joints like those above cited.

Alternatively, but not in an exclusive way, the surgical mechanical tool is a spherical milling cutter.

Advantageously, the effector of mechanical type or of other kind, is configured for surgically modifying both a convex joint surface and a concave joint surface of the bone joint.

In another exemplary embodiment, the surgical tool comprises a laser surgical tool.

Preferably, the device comprises a display means which is adapted to make an image of the articular surfaces and to make available the image to an operator the device, and the hydraulic operation is configured to provide irrigation means associated with the display means. Most of the display means requires preferably the presence of a rinsing liquid optical means consisting of water or of a physiological solution, which can advantageously be the liquid used for operating the turbine.

Preferably, the irrigation means comprises a plurality of channels arranged within the elongated elements of the connection means, in order not to enlarge the radial size of the connection means, of the connection elements provided between the inner channel of each element and the channel of an element neighbouring, in order to provide hydraulic continuity between the channels that form a passageway for an irrigation fluid.

Brief description of the drawings

The invention will be now shown with the description of an exemplary embodiment thereof, exemplifying but not limitative, with reference to the attached drawings, wherein:

– Fig. 1 is a diagrammatical cross sectional view of an coxofemoral bone joint with a passageway between a hip and a femur, said passageway engaged by a minimally invasive articular surgery device according to the invention;

– Fig. 2 is a diagrammatical cross sectional view of a bone joint and of a passageway as shown in Fig. 1, wherein the elements of the connection means are curved elements;

– Fig. 3 is a perspective view of the articular surgery device and of an element of the bone joint according to Fig. 1;

– Fig. 4 is another perspective view of the articular surgery device and of an element of the bone joint according to Fig. 1;

– Fig. 5 is a diagrammatical cross sectional view of the articular surgery device that is provided with a barrel-shaped milling cutter surgical tool;

– Fig. 6 is a partial diagrammatical view of a device according to an exemplary embodiment of the invention, comprising a barrel-shaped milling cutter surgical tool;

– Fig. 7 is a partial diagrammatical view of a device according to an exemplary embodiment of the invention, comprising a spherical milling cutter surgical tool;

– Fig. 8 is a diagrammatical view of a device according to an exemplary embodiment of the invention, in which the positioning means comprises a plurality of tendons;

– Fig. 9 is a diagrammatical view of a device according to an exemplary embodiment of the invention, in which the positioning means comprises a plurality of couples of extension and flexion tendons.

Description of a preferred exemplary embodiment

With reference to Fig. 1, a device 20 is described for minimally invasive articular surgery according to an exemplary embodiment of the invention. Device 20 is shown arranged within a passageway 19, i.e. within a passageway for accessing a surgical site 17 between two articular surfaces 15 and 16 of two respective articular ends 13 and 14 of a bone joint. Passageway 19 has typically an anatomic width L and a curvature radius R. The dimensions L and R depend mainly upon the type of bone joint and upon the size of the

subject. In this case, the proximal epiphysis 13 of a femur 11 is diagrammatically shown, as well as the corresponding acetabular recess 14 of a hip 12, which form a coxofemoral joint 10.

Articular surgery device 20 has an effector, at an own distal end 21" (Fig. 3), i.e. a surgical tool 22 that is arranged to carry out a surgical treatment of a connective tissue of a bone surface, in the present case a surgical treatment of the bone joint convex surface 15 of the femur and/or of the concave bone joint surface 16 of the hip. Surgical device 20 further comprises a positioning means 24 for moving surgical tool 22 in passageway 19, and for positioning surgical tool 22 at least at one surgical site 17 on the bone joint surface of epiphysis 13 of femur 11 and/or of acetabular recess 14 of hip 12. Positioning means 24 comprises a plurality of elongated elements 23, 23', 23" that are connected to one another by means of hinges 25 (Figs. 3 and 4). In an exemplary embodiment shown in the figures, elongated elements 23, 23", 23' are connected to each other by means of hinges 25 that are arranged at the end of elongated elements 23, 23", 23'. Elongated elements 23, 23", 23', along with hinges 25 form therefore a deformable linear element that can move along passageway 19 between articular surfaces 15 and 16, fitting the shape of passageway 19, in particular of curvature radius R;

Fig. 2 shows a device 20', according to another exemplary embodiment of the invention, which is similar to device 20 of Fig. 1. However, elongated elements 23 of device 20' are substantially curved to assist movement of device 20' through passageway 19, which is defined between articular surfaces 15 and 16, even if curvature radius R is particularly small, as in the case of young and/or of small-size patients.

Both device 20 of Fig. 1, and device 20' of Fig. 2 have three elongated elements 23 of substantially the same length. In any case, the device may also have a different number of elongated elements, which do not need to have the same length; the number, the shape and the length of elongated elements 23 depend upon the bone joint that has to be surgically treated, in particular upon curvature radius R, upon the extension of the articular surfaces and upon the shape of the bone joint.

An exemplary embodiment of device 20, according to the invention, is shown more in detail in Figs. 3 and 4. Here, for the sake of clarity, only the

articular end 13 of femur 11 is shown, i.e. only the articular member that has a convex bone joint surface like bone surface 15. More in detail, connection hinges 25 are shown for connecting each elongated element 23 with adjacent elongated elements 23. In this case, elongated elements are all linear. Each hinge 25 is arranged to limit the relative rotation between elongated elements 23, 23" and 23", 23', which it connects along a plane, for instance, along a plane that is defined by longitudinal axis 28", 28' of two adjacent elements 23", 23'. In other words, each elongated element 23, 23', 23" has one rotational degree of freedom, with respect to the preceding elongated element, or with respect to a proximal portion of gripping end 24'. At any rate, even the case of more than one relative degree of freedom between adjacent elongated elements 23 falls within the scope of this invention.

As shown in Fig. 4, the plane along which the relative rotating between elongated elements 23" and 23' occurs is not preferably the same plane along which the relative rotating between elongated elements 23' and 23 occurs.

Furthermore, hinges 25 advantageously comprise abutment members, not shown, for instance conventional abutment members, which limit relative rotation α between two adjacent elongated elements, such as elongated elements 23', 23", in order to avoid a hyperextension, i.e. in order to prevent two adjacent elongated elements from spacing apart with respect to each other beyond a prefixed relative position, for example beyond a relative alignment position, in which α is about zero. In case of curved elongated elements, the rotation angle α between two adjacent elongated elements may be defined as one of the angles comprised between two lines, each of these lines passing through a rotation centre of one of two hinges 25 that are located at the end of each elongated element.

Figs. 3 and 4 refer to an exemplary embodiment of the device in which effector 22, i.e. surgical tool 22, is a mechanical tool, for example a spherical milling cutter, that is arranged to rotate about a rotation axis coinciding with the longitudinal axis 28' of elongated end element 23'.

Even if an articular surgery device of the invention has been shown with reference to a limited number of human bone joints, in particular with reference to bone joints that have narrow passageways and/or small curvature articular surfaces, the device can advantageously be used in any human or vertebrate

bone joint.

In Fig. 5 a more enlarged diagrammatical view is shown of an articular surgery device 20 according to an exemplary embodiment of the invention, in which the surgical tool for carrying out the surgical treatment of the articular surfaces is a barrel-shaped milling cutter 22'. This is shown more in detail in Fig. 6. The barrel-shaped milling cutter 22' is pivotally arranged about a rotation axis coinciding with longitudinal axis 28' of terminal elongated element 23' of device 20, which is small in size, such that the barrel-shaped milling cutter 22' has at least one rotational degree of freedom with respect to positioning means 24, for example about a hinge 25'. The barrel-shaped milling cutter 22' has a cut surface 26 that is defined by a generatrix that has a curvature radius r slightly shorter than curvature radius R' of concave bone joint surface 16 that, in this case, is the surface of a pelvis acetabulum 12, in the region where the surgical treatment has to be carried out.

Fig. 7 is a partial diagrammatical view of a device 20 according to another exemplary embodiment of the invention, in which a spherical milling cutter surgical tool 22" is provided, which is pivotally arranged about a rotation axis 28 coinciding with the longitudinal axis of the terminal elongated element 23' of positioning means 24. In this case, the size of terminal elongated element 23' is small enough to provide at least one rotational degree of freedom of the barrel-shaped milling cutter 22' with respect to positioning means 24, for instance about a hinge 25'.

Alternatively to the milling cutter tool 22', 22", or to any other mechanical surgical tool, a laser or an ultrasound surgical tool can be provided, not shown, or any other surgical tool or effector adapted to treat a bone joint surface in a minimally invasive way, for example a treatment of removal of damaged connective tissue, a treatment of removal of bone tissue, a bone smoothing treatment, i.e. a treatment to change such surface features as the roughness of the bone tissue.

The rotation of the mechanical tools 22, 22', 22" of Figs. 3 to 7, and the connection and support means of the milling cutter with respect to the terminal elongated element 23' can be made according to well-known actuation and support systems, for example as normally used to make microsurgical and/or dental tools.

With reference to Fig. 8, a positioning means 24 of a device 20" is described according to an exemplary embodiment of the invention. Positioning means 24 comprises at least one tie-member 27, 27' for changing the position of a respective elongated element 23, 23' with respect to the elongated element that the precedes it and/or with respect to a proximal end portion 24', typically a grip portion or manipulator, of device 20", which in use is arranged outside of passageway 19 of bone joint 10 (Fig. 1). In other words, each tie-member 27, 27' makes it possible to actuate a specific degree of freedom of device 20". Each tie-member 27, 27' has a first end that is connected to a connection point 29, 29' of a respective elongated element 23, 23', and an opposite end that is connected to an actuation means. The actuation means comprises a manoeuvre unit 30, and is arranged at proximal end 21' of device 20", in particular the actuation means is integrally arranged at proximal portion 24' of device 20". Furthermore, at least so many tendons 27 are provided as elongated elements 23, which serve, for instance, for changing rotation angles α, α' that are formed between longitudinal axis 28 of two consecutive elongated elements 23, 23'.

The manoeuvre unit 30 can be a unit that is adapted to be locally, i.e. manually operated by an operator, according to a manual or local operating mode. In alternative, the manoeuvre unit 30 may comprise a tele-surgery means, not shown, for instance a well-known tele-surgery means, according to a remote operating mode.

In an exemplary embodiment, as diagrammatically shown in Fig. 9, for each degree of freedom, e.g. for each angle α, a couple of tie-members is provided which consist of an extension tie-member 27 and a flexion tie-member 37 that are configured for bilaterally actuating this degree of freedom, i.e. for actuating opposite movements, in this case movement of bending and of extending the links, wherein, respectively, the angle α increases and decreases.

Tendons 27, 27', 37 of the devices shown in Figs. 8 and 9 are housed within channels or elongated recesses 33 that extend longitudinally within elongated elements 23. Channels 33 are open at least at one end of each element 33, which allows introducing and preferably also extracting tendons 27, 27', 37.

At tool 33, device 20 may comprise a display means to provide to an operator an image of articular surfaces 15, 16 and of surgical treatment site 17. The display means is preferably associated with a local irrigation means arranged to deliver a liquid such as water or a physiological solution to ensure visibility of the surgical treatment site 17. This item is required by most well-known display means. Further channels may be provided to allow the flow of the irrigation liquid passage, as well as for to allow electric and/or optical connection means to reach the display means. These channels are not shown, but they may be similar to longitudinal channels 33 for tendons 27, 27', 33 of Fig. 8 and 9. Moreover, connection elements may be provided between the longitudinal channel of each elongated element 23 and the channel of a neighbouring elongated element 23.

The foregoing description of exemplary embodiments will so fully reveal the invention according to the conceptual point of view, so that others, by applying current knowledge, will be able to modify and/or adapt for various applications such embodiment without further research and without parting from the invention, and, then it is therefore to be understood that such adaptations and modifications will have to be considered as equivalent to the specific embodiment. The means and the materials to realise the different functions described herein could have a different nature without, for this reason, departing from the field of the invention. It is to be understood that the phraseology or terminology the is employed herein is for the purpose of description and not of limitation.

CLAIMS

1. A bone joint surgery device (20,20',20"), said device comprising:

— a surgical tool (22,22',22") adapted to surgically modify a bone joint (10) tissue at a surgical site (17) of a bone joint surface (15,16) of said bone joint (10);

— a positioning means (24) of said surgical tool, said positioning means (24) having a proximal actuation end portion (21') and a distal end portion (21"), said surgical tool connected to said distal end portion;

characterised in that said positioning means comprises a plurality of elongated elements (23,23',23"), said elongated elements mutually linked by means of hinges (25), such that said positioning means can be deformed and adapted to pass through an intra-articular passageway (19) to reach said surgical site, said passageway defined between two bone joint surfaces (15,16) of said bone joint, said intra-articular passageway having a prefixed width (L) and a prefixed curvature (R).

2. A surgery device (20') according to claim 1, wherein at least one of said elongated elements (23) has a curved shape.

3. A surgery device (20,20') according to claim 1, wherein said positioning means comprises three elongated elements (23).

4. A surgery device (20") according to claim 1, wherein said positioning means (24) comprises a motion actuation mechanism including a plurality of tendons (27',27"), and an actuation means is provided for operating said tendons,

5. A surgery device (20") according to claim 1, said actuation means arranged at a manoeuvre unit (30) at said proximal end portion (21'), said manoeuvre unit in use arranged outside of said bone joint (10),

6. A surgery device (20") according to claim 1,, wherein said manoeuvre unit (30) is adapted to be operated according to a surgical treatment mode selected among a manual operating mode and a teleoperation mode.

7. A surgery device (20") according to claim 4, wherein said tendons (27',27") are at least the same number as said elongated elements (23,23'), and each of said elongated elements has at least one

connection point (29,29') with a tendon, such that each degree of freedom (α,α') of said device can be actuated,

8. A surgery device (20") according to claim 1, wherein for one or for each elongated element (23,23') one pair of tendons (27,37) is provided comprising an extension tendon (27) and a flexion tendon (37), wherein said extension and flexion tendons are adapted to actuate respective opposite extension and flexion movements of said elongated element with respect to an adjacent elongated element (23,23'), such that each degree of freedom (α) of said device can be bilaterally actuated.

9. A surgery device (20") according to claim 1, wherein at least one of said hinges (25) is adapted to maintain in one plane a rotation (α) of two elongated elements (23,23') with respect to each other,

10. A surgery device (20") according to claim 1, wherein said hinges (25) comprise a rotation limiting means for limiting said rotation of said two adjacent elongated elements (23,23') with respect to each other, in such a way to prevent an extension movement of said adjacent elongated elements beyond an aligned reciprocal position along a determined straight or curved line.

11. A surgery device (20,20',20") according to claim 1, wherein said surgical tool (22,22',22") is adapted to carry out at said surgical site (17) a treatment selected from the group comprised of:

- connective tissue removal, in particular damaged cartilaginous tissue removal;
- bone tissue removal;
- joint smoothing;
- a combination thereof.

12. A surgery device according to claim 1, wherein said surgical tool (22',22") is a mechanical surgical tool,

13. A surgery device (20") according to claim 1, comprising a pneumatically and/or hydraulically actuated turbine surgical tool.

14. A surgery device according to claim 8, wherein said mechanical surgical tool (22',22") is selected from the group comprised of:

– a barrel-shaped milling cutter (22'), said barrel-shaped milling cutter having a curved cutting profile whose radius of curvature (r) is shorter or it has the same length as a local curvature (R') of said joint surface at said surgical site.

– a spherical milling cutter (22"),

15. A surgery device (20") according to claim 1, wherein said mechanical surgical tool (22',22") is configured for surgically modifying both a convex joint surface (15) and a concave joint surface (16) of said bone joint (10).

16. A surgery device according to claim 1, wherein said surgical tool (22) comprises a laser surgical tool.

Fig. 1

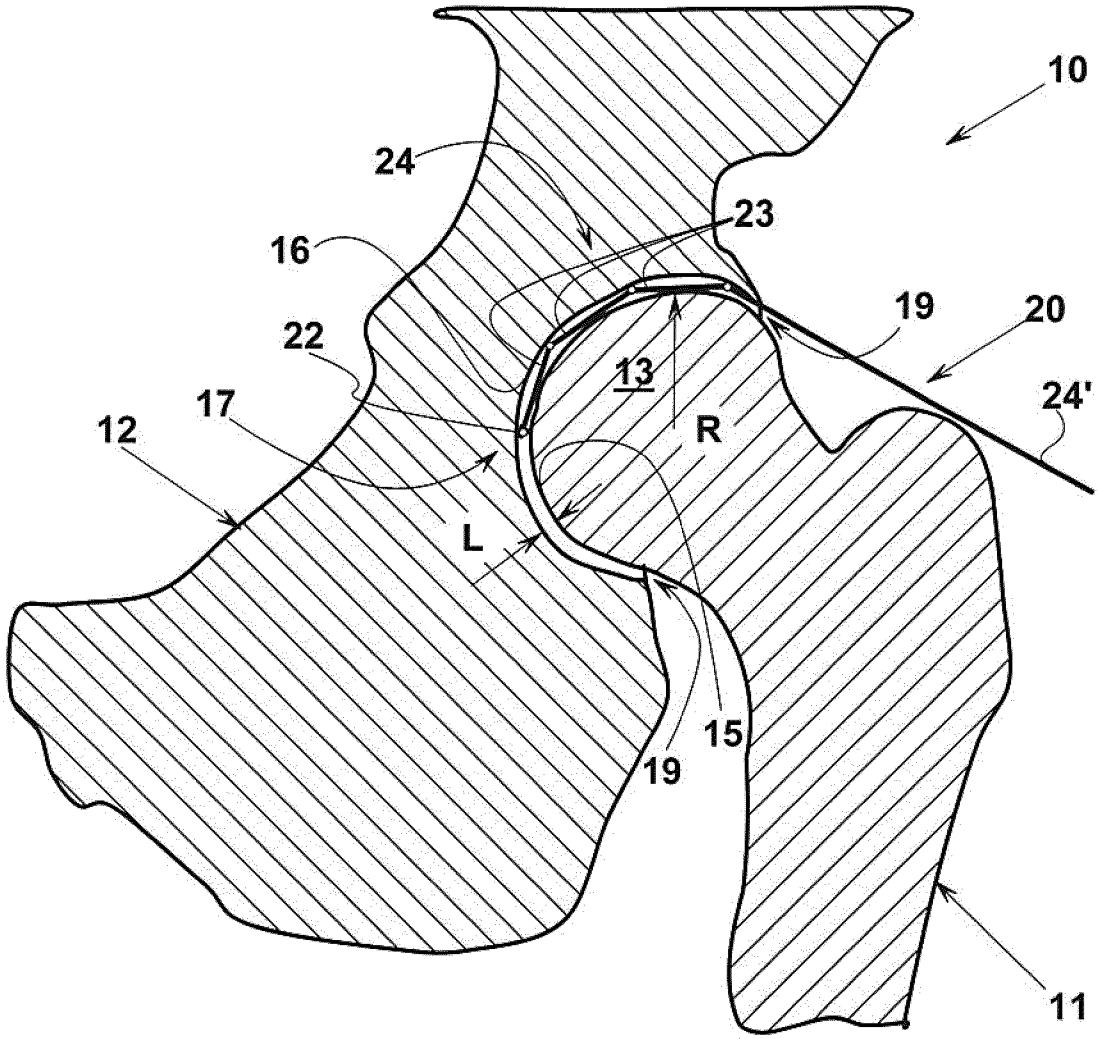


Fig. 2

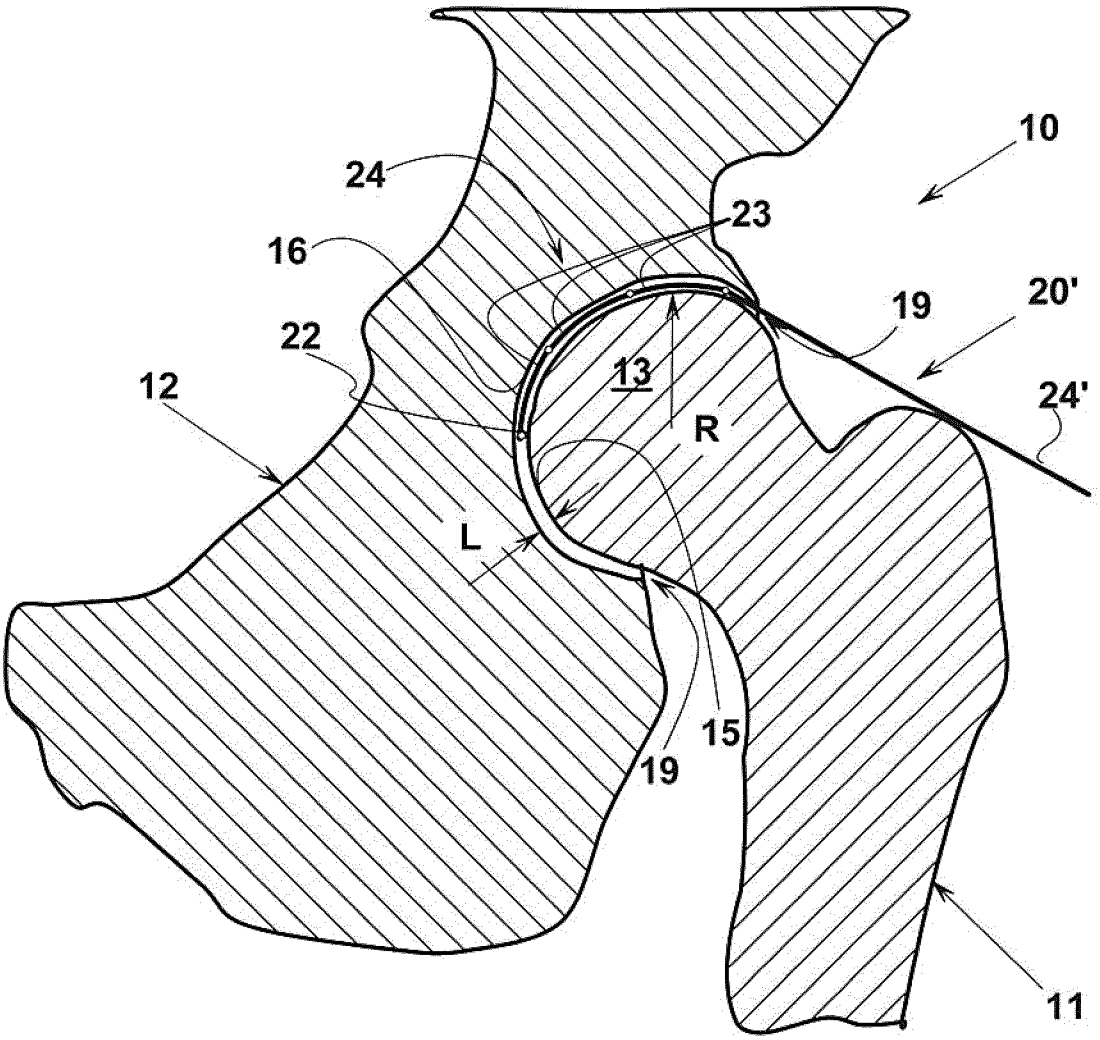


Fig. 3

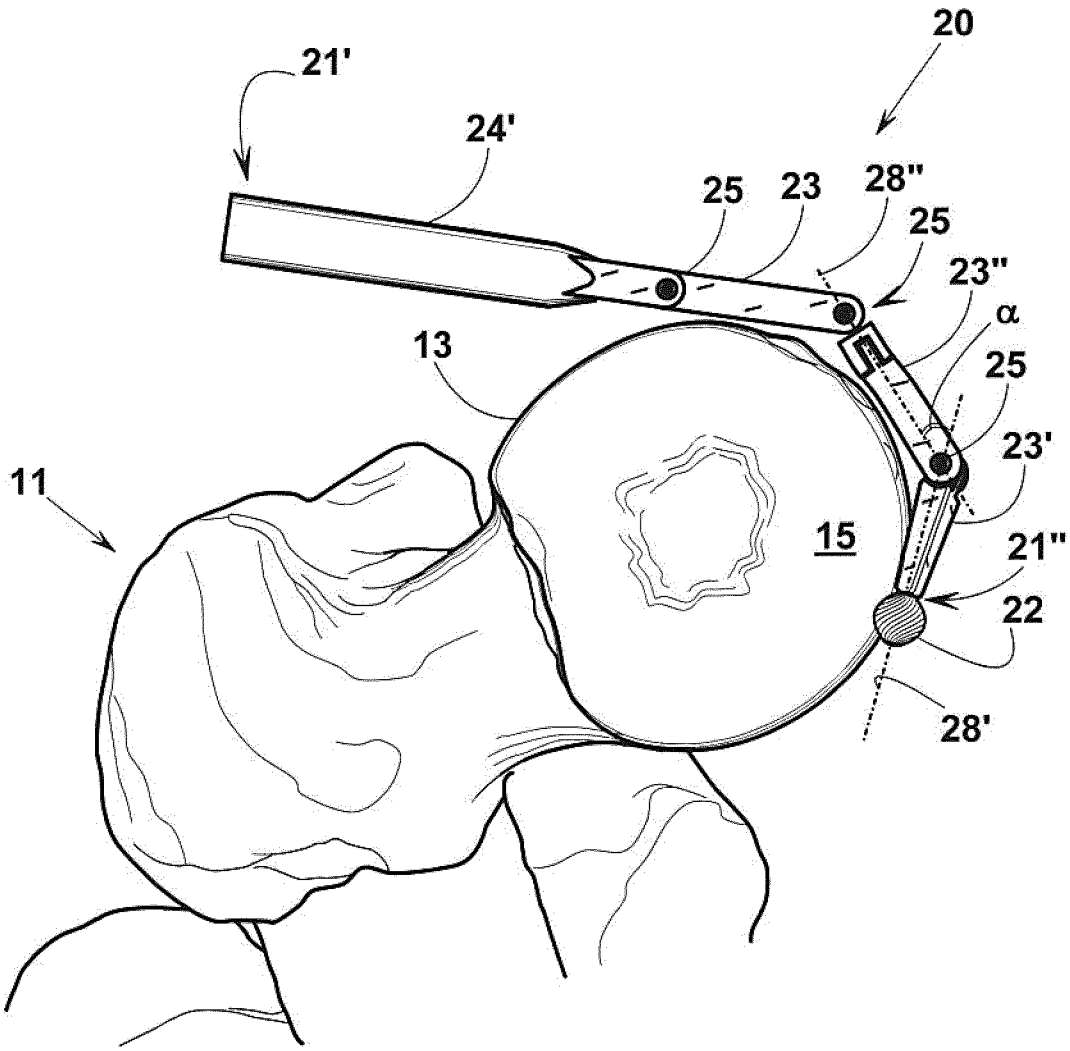


Fig. 4

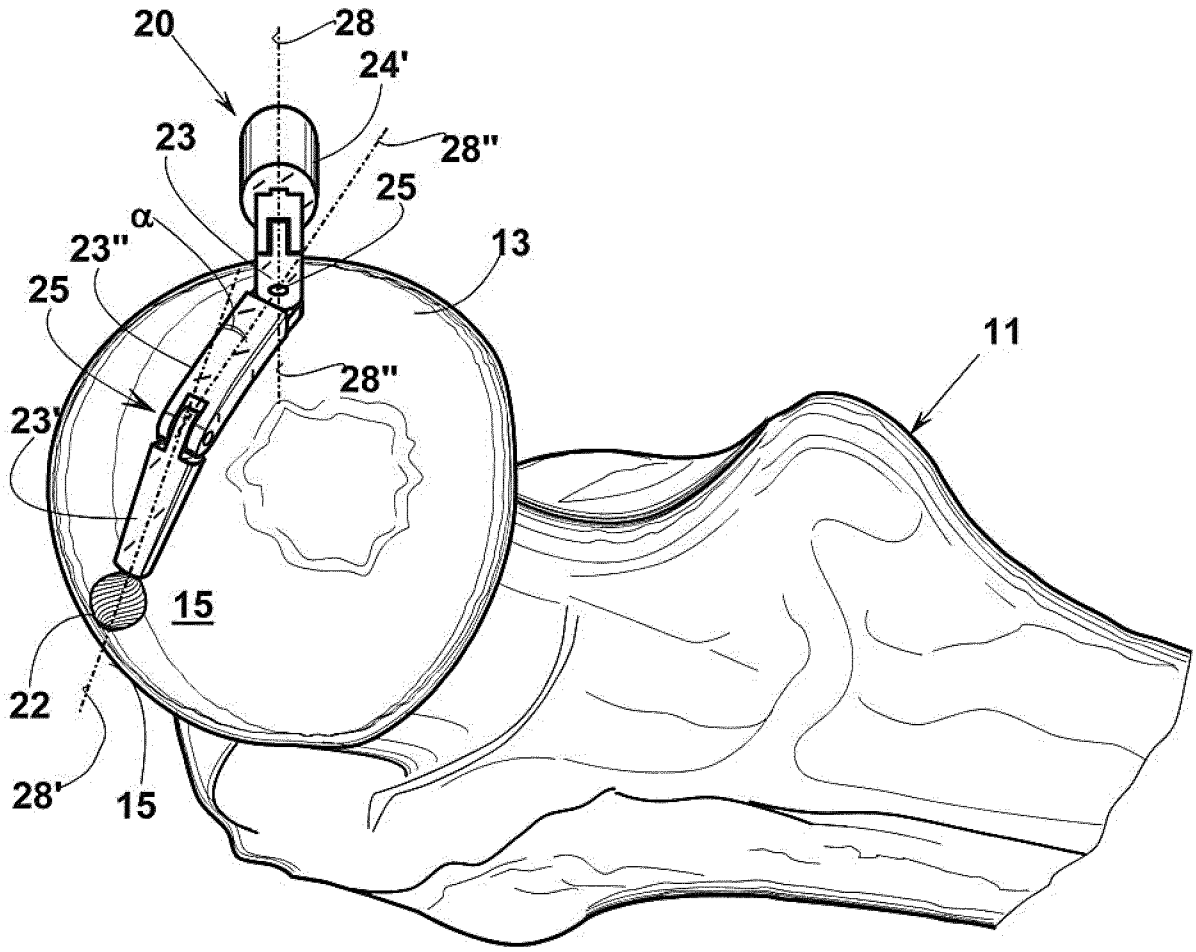


Fig. 5

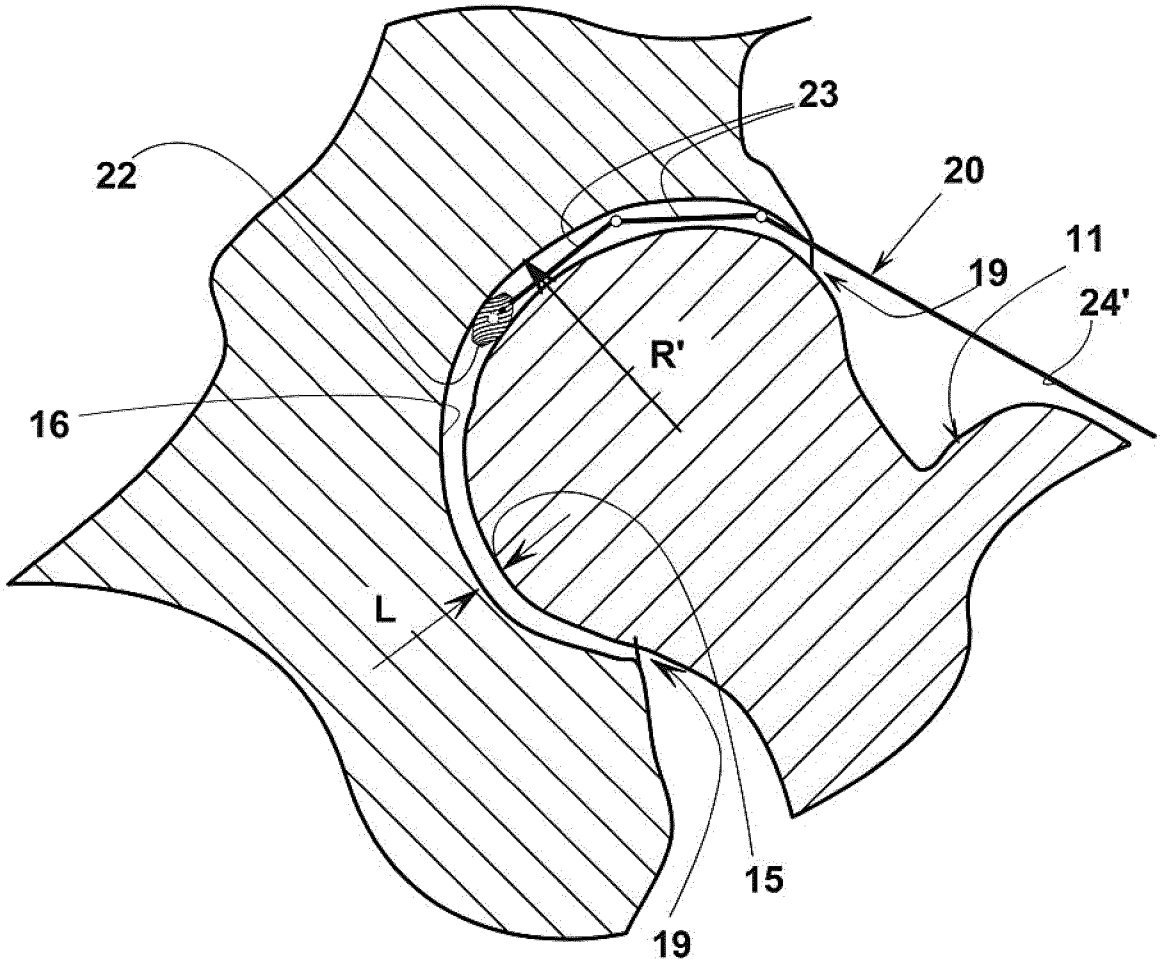


Fig. 6

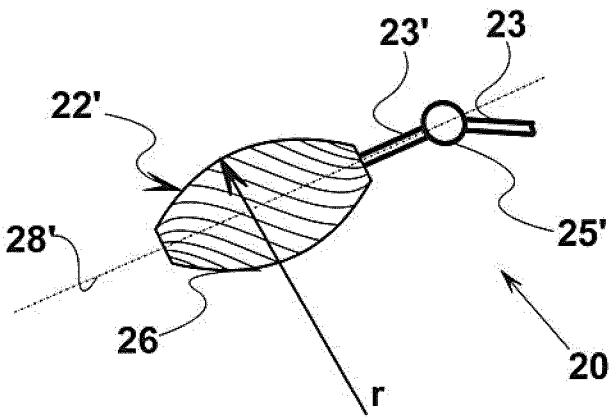


Fig. 7

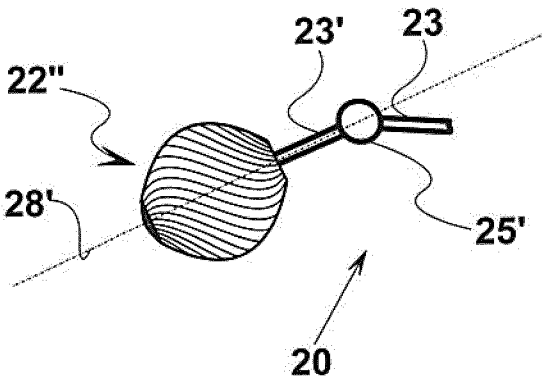


Fig. 8

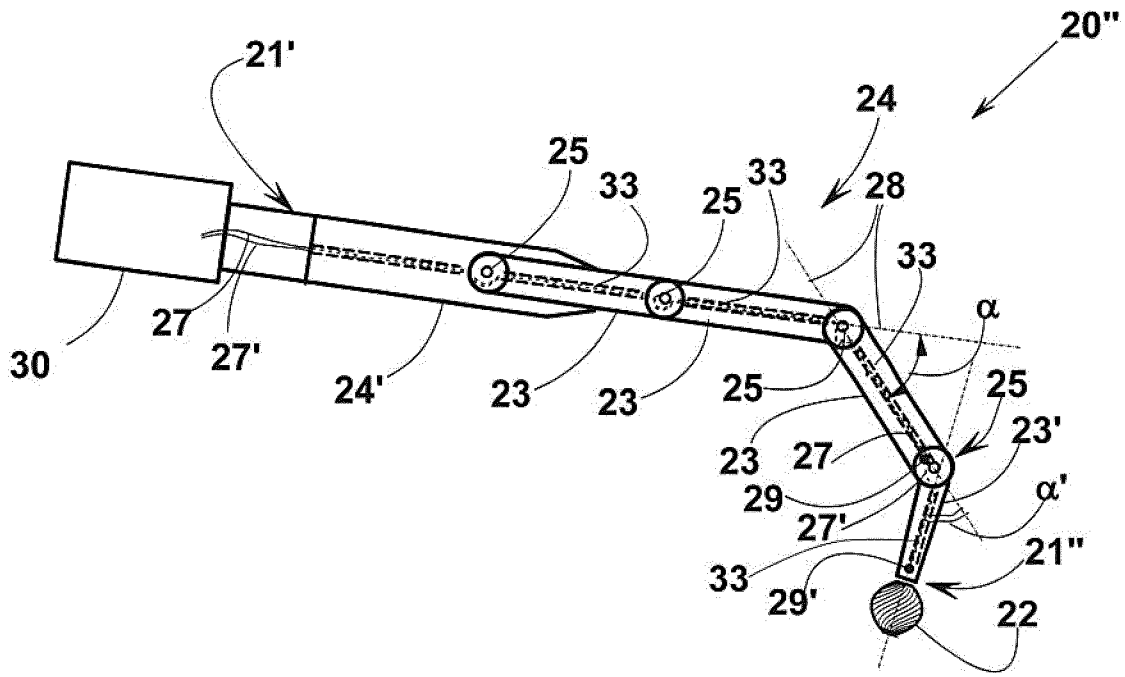

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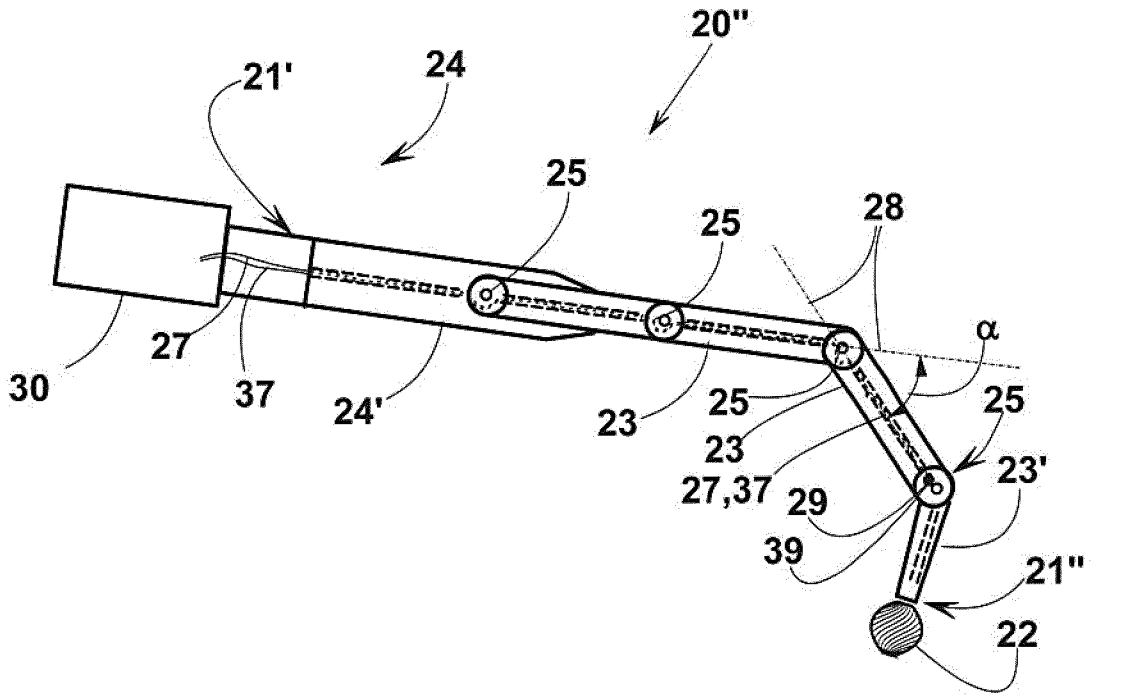
Fig. 9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