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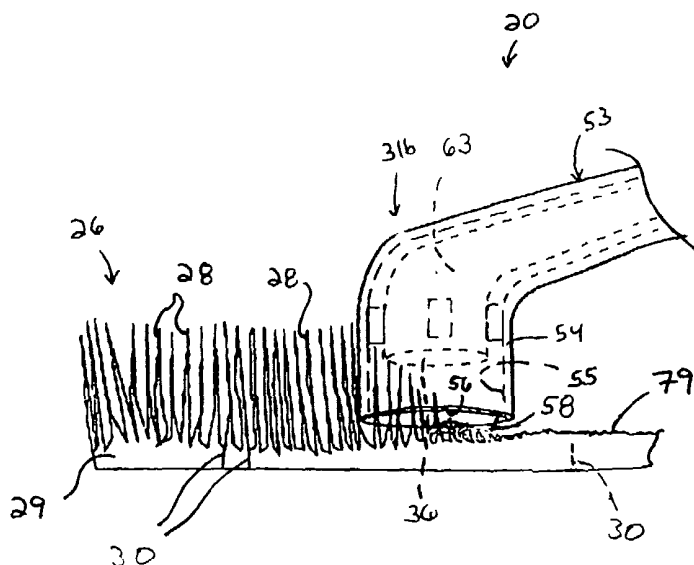
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(54) Title: METHOD AND APPARATUS FOR TREATMENT OF DISRUPTED ARTICULAR CARTILAGE



(57) Abstract: An apparatus (20) for treating disrupted articular cartilage comprising an elongate probe member (31) having proximal and distal extremities (31a, 31b) and a handle (34) coupled to the proximal extremity of the elongate probe member. The distal extremity has a peripheral wall (54) defining a cavity (55) and a distal opening (58) communicating with the cavity. A controllable environment is created within the cavity when the distal extremity is placed substantially flush against the disrupted articular cartilage. An electrode (36) is positioned within the cavity at a distance spaced inwardly of the distal opening. The disrupted articular cartilage is sealed to form a substantially continuous surface when energy is supplied to the electrode. A method of using the apparatus is provided.

WO 02/062247 A1

METHOD AND APPARATUS FOR TREATMENT OF DISRUPTED ARTICULAR CARTILAGE

Background of the Invention

Field of the Invention

This invention relates generally to the use of electrosurgical methods and apparatuses for the treatment of damaged tissues and, more particularly, to the treatment of disrupted articular cartilage in the joint of a mammalian body.

Description of Related Art

The normal function of joints in humans depends on the distribution of relatively large forces across the body surfaces. In diarthrodial joints, the magnitude of the joint forces reaches levels four to seven times body weight. These forces are dispersed by articular cartilage in the joint. Proper cartilage function occurs via a highly organized extracellular matrix maintaining a fixed charge density and possessing a high affinity for water.

Chondromalacia occurs when cartilage beds in joints become worn and degenerate into strands of cartilage which extend away from their respective cartilage beds and into the joint cavity. The cartilage surface becomes visibly disrupted, fissured and fibrillated. The damaged cartilage has deleterious effects on the mechanical properties and normal function of articular surface. The fibrillated cartilage may breakdown and break off to form particulate matter. It is the particulate matter (broken fibrils) and various proteins and enzymes released when the normally smooth layered architecture of cartilage is undermined and frayed, which causes pain by irritating the synovial lining of the joint.

Treatment to date has included surgical intervention. In one arthroscopic procedure, a shaver is introduced through an arthroscope and is used to mechanically remove the strands of disrupted and fibrillated cartilage. However, this treatment can disrupt and remove part of the normal healthy cartilage bed and does not restore a smooth surface nor improve the mechanical function. Another modality for the repair and treatment of the damaged cartilage includes open procedures which can lead to increased recovery time and a possible increase in pain and further dysfunction of the joint.

Another exemplary device for treating fibrillated cartilage joint surfaces or irregular cartilage joint surfaces in an arthroscopic procedure delivers sufficient thermal energy to reduce the level of fibrillation of the cartilage joint surface. See U.S. Patent No. 6,068,628 to Fanton *et al.* Particular care is used to minimize any undesired thermal effect on non-targeted tissue and thereby prevent necrosis below the surface of the cartilage joint surface into the healthy layer since cartilage does not grow and regenerate after being damaged. In view of the foregoing, it would be desirable to provide a thermal treatment device to coagulate the fibrillated cartilage strands together and closely monitor the ambient temperature in the immediate or surgical environment of the fibrillated cartilage so as to minimize undesirable cartilage damage and necrosis of underlying subchondral bone.

Summary of the Invention

An apparatus for treating disrupted articular cartilage comprising an elongate probe member having proximal and distal extremities and a handle coupled to the proximal extremity of the elongate probe member is provided. The distal extremity has a peripheral wall defining a cavity and a distal opening communicating with the cavity. A controllable environment is created within the cavity when the distal extremity is placed substantially flush against the disrupted articular cartilage. An electrode is positioned within the cavity at a distance spaced inwardly of the distal opening. The disrupted articular cartilage is sealed to form a substantially continuous surface when energy is supplied to the electrode. A method of using the apparatus is provided.

In general, one advantage of the present invention is to provide a minimally invasive apparatus for delivering energy within a controllable environment to articular cartilage and particularly fibrillated articular cartilage, for treatment thereof, while minimizing collateral thermal effect on non-targeted tissue.

A further advantage of the present invention is to provide an electrosurgical probe which can more accurately monitor temperature of articular cartilage being treated within a controllable environment for a more precise feedback control of thermal energy delivered to tissue.

Another advantage of the present invention is to provide an apparatus of the above character in which sufficient thermal energy can be delivered to coagulate cartilage fibrils in predictable and reproducible levels thereby minimizing collateral damage.

Yet another advantage of the present invention is to provide an apparatus of the above character which can be used for treating chondromalacia and other articular cartilage defects.

The accompanying drawings, which are incorporated in, and form a part of this specification, illustrate embodiments of the invention and, together with the following description, serve to explain the principles of the invention.

Brief Description of the Drawings

FIG. 1 is schematic view of a system incorporating an apparatus for treatment of fibrillated tissue in use on a knee of a human body.

FIG. 2 is an enlarged schematic view of a knee capsule being treated by the system shown in FIG. 1.

FIG. 3 is an enlarged perspective view of an end of the apparatus shown in FIG. 1 treating a section of fibrillated tissue.

FIG. 4 is an enlarged perspective view, partially cut away of the end of the apparatus shown in FIG. 3.

FIG. 5 is a cross-sectional view of the apparatus shown in FIG. 4 taken along line 5-5 of FIG. 4.

FIG. 6 is a perspective view, partially cut away of the apparatus shown in FIG. 4,

illustrating an energy current pathway therefor.

FIG. 7 is a perspective view, partially cut away and similar to FIG. 6, illustrating an energy current pathway of a further embodiment of the apparatus for treatment of fibrillated tissue of the present invention.

FIG. 8 is a perspective view, similar to FIG. 6, illustrating an energy current pathway of a further embodiment of the apparatus for treatment of fibrillated tissue of the present invention.

FIG. 9 is a schematic side elevational view of the end of the apparatus shown in FIG. 4.

FIG. 10 is a schematic side elevational view, similar to FIG. 9, of an end of another embodiment of the apparatus for treatment of fibrillated tissue of the present invention.

FIG. 11 is an enlarged perspective view of the end of the apparatus of FIG. 10 treating a section of fibrillated tissue.

FIG. 12 is a schematic side elevational view, similar to FIG. 9, of an end of yet another embodiment of the apparatus for treatment of fibrillated tissue of the present invention.

Description of the Preferred Embodiments

Reference will now be made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the preferred embodiments, it will be understood that they are not intended to limit the invention to those embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims.

Turning now to the drawings, wherein like components are designated by like reference numerals throughout the various figures, attention is directed to FIGS. 1 and 2 which illustrate a system 15 incorporating an irrigant source 16, an irrigant collection 17, a cathode ray tube or video display unit 18, and an apparatus 20 for treating a joint of a mammalian body. An exemplary knee joint 21 connecting thigh 22 and shin 23 is shown in FIGS. 1 and 2. Knee joint 21 is the junction of three bones, namely a thigh bone or femur 24, a shin bone or tibia 25, and a kneecap or patella (not shown). The ends of femur 24, tibia 25, and the patella are covered with articular cartilage 26 and are located within a joint capsule 27. Cartilage or cartilage fibrils 28 may extend from a respective cartilage bed 29 for a length of approximately one to ten millimeters and often extend approximately four to seven millimeters. Disrupted articular cartilage 26 can further include fissures 30 (see FIG. 3) and fragmented, avulsed or frayed cartilage. Hence, for purposes of the disclosure, disrupted articular cartilage 26 is broad enough to include cartilage that is fibrillated, fragmented and/or fissured.

Referring to FIGS. 1 and 2, apparatus 20 generally includes an elongate probe member 31 having a proximal extremity 31a and a distal extremity 31b and an energy source 33. A probe handle 34 is mounted to proximal extremity 31a and an active electrode 36 (shown in FIGS. 3 and 4) is provided on distal extremity 31b.

- 4 -

The apparatus of the present invention is preferably used in combination with other standard arthroscopic implements such as an irrigating system, a viewing system and a positioning system in addition to the otherwise conventional equipment utilized in a minimally invasive procedure conducted on a mammal under general anesthesia. For example, a standard arthroscopic system such as the one described in U.S. Patent No. 6,068,628, the entire contents of which is incorporated herein by this reference, is preferably utilized for access to joint capsule 27. The irrigating system includes irrigant source 21 and irrigant collection 22. Any suitable irrigant source can be utilized, such as solution bags (not shown) of normal or isotonic saline.

An irrigating connection tube 39 includes tubing clamps or other suitable means for mechanically inhibiting and controlling the flow of the irrigating solution. A first percutaneous cannula 41 provides a portal for introducing irrigant into joint capsule 27 adjacent articular cartilage 26, as illustrated in FIGS 1 and 2. A second cannula 45 provides a second portal or outflow port allowing irrigating fluid to exit joint capsule 27. Cannula 45 optionally includes a diversion tube 46 to direct the outflow of the irrigant away from an operator. One should appreciate that the irrigating system optionally may include a pump system that senses intra-articular pressure and maintains a desired pressure within joint capsule 27 to insure distraction of the joint and adequate hemostasis. Alternatively, intra-articular pressure can be generated in a well known manner by elevating the solution bags above the level of the patient making use of a simple gravity supply.

Either one or both of cannulas 41 and 45 may be incorporated into a cannula system allowing the introduction of an arthroscopic scope 49 for viewing the interior of joint capsule 27 and distal extremity 31b of probe member 31, as well as other interventional tools including other probes, cutting tools, electrosurgical instruments and electrothermal instruments which may be introduced into joint capsule 27. Arthroscopic scope 49 generally includes an optical rod lens which optionally is operably connected to a video camera that provides a video signal to a suitable display unit 18, such as a cathode ray tube, a liquid crystal display or a plasma monitor, for viewing by the operator.

Probe member 31 includes an elongated and hollow outer shaft 53, as shown in FIGS. 3-5. A peripheral wall 54 is formed by a distal extremity of outer shaft 53. Peripheral wall 54 defines a cavity 55. A lower edge 56 of peripheral wall 54 defines a distal opening 58 communicating with cavity 55. Although the illustrated peripheral wall 54 is tubular, one should appreciate that it may take other forms. For example, the peripheral wall may be oval or polygonal in shape.

Active electrode 36 is made from any suitable conductive material such as stainless steel, platinum, iridium, titanium, silver and their alloys or any other medical grade metal. The electrode 36 is cup-shaped, as shown in profile in FIG. 5, and has a distally-oriented end wall 37 provided with an outer or distal surface 38 and a tubular side wall 39 extending proximally from

- 5 -

the distal opening 58. Outer surface 38 is shown as being convex with an outwardly bowed shape. It should be appreciated, however, that the outer surface 38 of electrode end wall 37 can be planar or of any other suitable shape and be within the scope of the present invention.

Distal extremity 31*b* of probe member 31 includes an inner shaft 63 which is affixed to outer shaft 53 by a plurality of brackets or spacers 67, as shown in FIGS. 5 and 6. Conductive lead means is included with inner shaft 63 for providing energy to active electrode 36. Such conductive lead means can be in the form of a tubular member or tube 64 made from any suitable conductive material and preferably a suitable medical grade conductor such as stainless steel 304 or any other stainless steel, MP35N, alloy metals, noble metals, any other suitable conductive carbon material or imbedded plastics or polymers. The distal end of tube 64 is secured to active electrode 36 by any suitable means and, as shown, the tube 64 is press fit about the circumferentially-extending side wall 39 of the active electrode so as to be electrically coupled to the active electrode. An additional tubular member or outer side wall, preferably in the form of a sleeve 68, is shrunk about or otherwise suitably disposed around the outside of tube 64 and thus side wall 39 of the active electrode 36. Sleeve 68, which is preferably formed from a thermally-insulating material and is more preferably formed from teflon (PTFE), polyolefin or nylon (PFA) or other plastics or polymers, serves to thermally insulate electrode side wall 39 and conductive tube 64 disposed thereabout.

Inner shaft 63 and active electrode 36 carried thereby are supported within peripheral wall 54 by the one or more spacers 67. More specifically, spacers 67 are circumferentially disposed about the inner shaft 63 and serve to space active electrode 36 and the inner shaft 63 radially within outer shaft 53. The spacers 67 can be made from any suitable material such as glass, ceramic or any nonconductive electrical and/or thermal material. Active electrode 36 is spaced inwardly or proximally from opening 58 a distance of approximately two to ten millimeters and preferably approximately two to five millimeters so as to be recessed within distal extremity 31*b*.

A temperature or heat sensor 69 is preferentially carried by distal extremity and preferably by inner shaft 63 for measuring and monitoring the temperature of active electrode 36 within cavity 55. Heat sensor 69 is of a conventional design and may consist of a thermocouple, a thermistor, a resistive wire, an integrated circuit (IC) or any other suitable sensor. The sensor 69 is electrically coupled to active electrode 36. In this regard, a heat sink 71 is disposed within the proximal recess formed by end wall 37 and side wall 39 of electrode 36. The heat sink is made from any suitable thermally-conductive material such as a heat sink paste and is secured to the proximal surface of end wall 37. Sensor 69 is encapsulated by heat sink 71 and located in close proximity to electrode end wall 37. The heat sink 71 is not in contact with side wall 39 and is preferably spaced radially inwardly from the side wall 39. Although the heat sink can be of any suitable shape, it is preferably conical in shape so as to ensure contact with the entire proximal surface of end wall 37 and yet remain separated from side

- 6 -

wall 39. An optional insulator 72 made from any suitable thermally insulating material is disposed between heat sink 71 and side wall 39 for further minimizing any effect on temperature sensor 69 from the side wall.

System 15 of the present invention is an electrothermal system which includes probe apparatus 20 and energy source 33 to thermally coagulate disrupted articular cartilage, for example a fibrillated articular surface typically present in Grades I, II and III chondromalacia. Energy source 33 is preferably a radiofrequency generator and controller hereinafter referred to as radiofrequency generator 33. Radiofrequency generator 33 includes a feedback controller which is dependent upon temperature and/or impedance. Active electrode 36 is electrically connected to radiofrequency generator 33 by means of conductive tube 64 and a suitable connecting cable 75, which extends from the energy source 33 to probe handle 34 to electrically couple to the proximal end of tube 64. As shown in FIG. 1, connecting cable 75 may be integrated to the probe handle 34 to form a one-piece unit between apparatus 20 and probe handle 34. This provides a fluid resistant environment within electrosurgical probe handle 34 to prevent electrical disconnects and shorting between apparatus 20 and energy source 33. It will also be appreciated that probe handle 34 and connecting cable 75 may also be separate units utilizing a keyed and/or electrically insulated connection at a proximal end of probe handle 34.

In one embodiment, a grounding pad 76 is provided on thigh 22 of the patient's body as shown in FIG. 1. The grounding pad 76 may also be placed on any electrically suitable location of the body to complete the circuit. Grounding pad 76 is electrically connected to radio frequency generator 33 via a second return connecting cable 77 to complete the electrical circuit. Radiofrequency generator 33 can deliver high frequency (RF) voltage in the range of one to 350 watts.

Optionally, impedance is monitored by energy source 33 along the electrical circuit between power output and return input of the energy source 33. The energy source 33 monitors the impedance of the electrical circuit by measuring the difference between the output power and the input return as a function of voltage over current. In a typical monopolar system the impedance level is about 100 ohms and in a typical bipolar system the impedance level is about 60 ohms.

The feedback controller of radiofrequency generator 33 monitors the temperature of the tissue or cartilage being treated by monitoring the temperature experienced by sensor 69 located in the proximity of the active electrode. The feedback controller compares such temperature to a programmed temperature profile. The feedback control can also directly monitor system impedance of the electrical circuit. If the measured impedance exceeds a predetermined level, energy delivery to active electrode 36 is disabled or adjusted thus ceasing or adjusting delivery of thermal energy to active electrode 36. If the temperature within cavity 55 measured by sensor 69 exceeds a predetermined desired temperature, energy delivery to active electrode 36 is

- 7 -

disabled or adjusted thus ceasing or adjusting delivery of thermal energy to active electrode 36 and thereby controlling the temperature within the microenvironment created by cavity 55.

Optionally, apparatus 20 may be used in combination with a suction source. For example, the probe member includes a lumen 78, as shown in FIGS. 4-6, which extends from cavity 55 towards proximal extremity 31a (not shown in FIGS. 4-6) of the probe member and through probe handle 34. In the illustrated embodiment, lumen 78 is annular in cross section at distal extremity 31b where the lumen communicates with cavity 55. Specifically, such annular lumen 78 is formed at its outside by peripheral wall 54 and at its inside by inner shaft 63. Lumen 78 fluidly connects with the suction source via a suitable fluid coupling adjacent proximal extremity 31a in a conventional manner. In such configuration, the suction source can be activated to produce a suction effect within lumen 78 and cavity 55, as is indicated by arrows S in FIG. 6. The suction source can be activated by a physician to aspirate the joint cavity as desired by the physician. When the suction source is activated, fluid, particulates and other matter within the surgical field is aspirated into a collection vessel. One should appreciate, however, that apparatus 20 may be used with or without a suction source.

In operation and use, a suitable positioning system can be used to immobilize joint 25 to facilitate the operator's or physician's access to joint capsule 27. The positioning system is selected based upon the specific anatomy to be addressed with the procedure in accordance with the present invention.

After the patient has been appropriately sedated or anesthetized, joint capsule 27 is pressurized by a suitable irrigant to create a work area within the joint space 27, as shown in FIG. 2. For example, fluid inflow from irrigant source 21 by means of pump and/or gravity introduces pressurized irrigant fluid into joint capsule 27 so as to create a workspace within joint capsule 27 and provide a flushing and cooling action. The irrigating solutions are commonly stored in the operating room and are then used at room temperature. The saline or other irrigating fluid from irrigant source 21 further serves to cool cartilage bed 29 outside of the treatment zone defined by cavity 55. Such cooling minimizes the thermal heating of the deeper layers of cartilage bed 29 and thus inhibits the undesirable thermal damage of such deeper tissues.

Probe handle 34 is grasped by the physician to introduce distal extremity 31b of probe member 31 through cannula 45 and into the joint capsule of the patient and thereafter to position lower edge 56 of distal extremity 31b substantially flush against the disrupted articular cartilage 26. Scope 49 allows the physician to view distal extremity 31b within joint capsule 27 and thus facilitates movement of distal extremity relative to articular cartilage bed 29 by the physician. In particular, the physician can manipulate probe member 31 such that opening 58 is substantially flush against disrupted articular cartilage 26 as shown in FIG. 3. A controllable environment, that is an environment or area separate from the remainder of joint capsule 27 outside of cavity 55, is created within cavity 55 when lower edge 56 is placed substantially flush

against disrupted articular cartilage 26.

Probe member 31 temporarily confines a volume of fluid and the disrupted articular cartilage 26 within the controllable environment of cavity 55 as distal extremity 31a is swept across the surface of articular cartilage bed 29. The physician activates radiofrequency generator 33 and radio frequency energy is supplied to the controllable fluid-filled environment within cavity 55. The saline and/or other conductive irrigants present within joint capsule 27 serve to transmit such radio frequency energy and, together with other tissue of the mammalian body, transmit the radio frequency energy to grounding pad 76. The resulting monopolar current path is shown schematically by arrow M in FIG. 6. The passing of such radio frequency through the fluid within cavity heats such fluid to a temperature that can be monitored by temperature sensor 69. The amount of energy supplied to electrode 36 controls the temperature of the electrode and the fluid within the environment of cavity 55.

The disrupted articular cartilage over which cavity 55 rests, for example the fibrillated articular cartilage fibrils or strands 28 extending from cartilage bed 29, are thermally treated by the heated fluid within cavity 55 so as to become coagulated cartilage. Fibrillated strands 28 which contact distal surface 38 of active electrode 36 are similarly coagulated or melded and thus treated. Subjecting the fibrillated articular cartilage strands 28 to temperatures in the range of approximately 50°C to 100°C, and preferably in the range of approximately 55°C to 85°C, causes the fibrillated articular cartilage strands 28 to meld into cartilage bed 29 and thus form a substantially smooth coagulated mass on the surface of the cartilage bed 29 as indicated by numeral 79 in FIG. 3. In this manner, the cartilage bed 29 is sealed into a coagulated mass 79. The treatment of disrupted articular cartilage 26 by apparatus 20 in the foregoing manner can also result in the sealing of fissures 30, one of such sealed fissures 30 being shown by a dashed line in FIG. 3, and the sealing of any fragmented, avulsed or otherwise disrupted cartilage into a coagulated mass 79.

Active electrode 36 is spaced or recessed inwardly from opening 58 so as to minimize direct contact between the active electrode and cartilage bed 29 when apparatus 20 is utilized for treating fibrillated articular cartilage strands 28. Active electrode 36 is recessed within opening 58 a distance that allows for the targeted fibrillated articular cartilage strands 28 to extend into the cavity or space created by the extension of peripheral wall 54 beyond distal surface 38 of the active electrode. The distance between the active electrode and the surface of the articular cartilage bed 29 is preferably such that the delivery of energy from radiofrequency generator 33 coagulates the fibrillated articular cartilage strands into a coalesced and singular mass to form a contiguous articular cartilage surface. Such distance reduces the delivery of thermal energy to underlying subchondral bone thus preventing avascular necrosis (AVN). The movement of apparatus 20 by the operating physician across the disrupted articular cartilage 26 limits the time of exposure of such cartilage to thermal heating, which is also a factor in preventing AVN.

- 9 -

As thermal energy is so delivered to active electrode 36, the physician advances or sweeps probe member 31 continuously across cartilage bed 29 at a speed that allows for sufficient coagulation of fibrillated articular cartilage strands 28 to occur and form a coagulated mass 79, as shown in FIG. 3, but without excessive thermal exposure to deeper viable tissues including cartilage bed 29 and subchondral bone such as tibia 25 (FIG. 2). The sweeping motion of the probe member along cartilage bed 29 results in a convective thermal effect that follows the path of the probe.

One should appreciate that tissues do not immediately heat up when exposed to thermal energy. The exposure time of thermal energy upon an area of cartilage bed 29 is a factor in treatment effectiveness. The phenomena known as thermal latency of tissues determines the thermal response time, or thermal conduction time of the targeted tissue being treated. The apparatus of the present invention is particularly suited for providing locally high temperatures confined to a small area or controllable environment that is moveable across the surface of the fibrillated cartilage. Peripheral wall 54 substantially isolates the targeted tissue, that is the fibrillated cartilage extending into cavity 55, from adjacent non-targeted tissue, in this case all tissue located outside peripheral wall 54. Accordingly, the apparatus of the present invention can be employed to coagulate tissues safely within this controllable thermal environment while minimizing the thermal exposure of adjacent tissue. By creating a controllable thermal environment within the confines of cavity 55, the physician can progressively coagulate an entire degenerative area of fibrillated cartilage regardless of a particular patients' individual pathology and characteristics. Because the thermal energy is confined to a select area within the electrosurgical probe at any moment in time, that is the area confined the outline of peripheral wall 54 and exposed to cavity 55, unwanted damage and effect to other non-targeted tissue is minimized and/or prevented.

One should also appreciate that peripheral wall 54 substantially isolates the targeted tissue from the flushing and cooling action, as discussed above, of the saline and other irrigants within joint capsule 27. In this regard, peripheral wall 54 defines a controllable environment within cavity 55 which minimizes the flow of ambient cooling and irrigating fluids past active electrode 36 and cartilage tissue within cavity 55 and thus inhibits convective cooling of the active electrode 36 and such tissues and undesired temperature fluctuations in the treatment area. The controllable environment defined by peripheral wall 54 further serves to minimize the risk of contact between the active electrode and nearby anatomical structures, thus also minimizing unwanted temperature fluctuations in the treatment area and preventing non-targeted tissue damage. The confined and controllable thermal environment, substantially free from the flushing and cooling actions within joint capsule 27, also permits more accurate temperature measurement for the feedback control in radiofrequency generator 33 such that a precise energy delivery may be effected.

- 10 -

In the event that apparatus 20 is used in combination with a suction source, insulating sleeve 68 insulates active electrode 36 from convective cooling of the saline and other irrigating fluids which flow through lumen 78 during irrigation of cavity 55. Advantageously, insulating sleeve 68 further minimizes temperature fluctuations in the treatment area because sleeve 68 minimizes convective cooling of active electrode 36.

Temperature sensor 69 located within cavity 55 permits the ambient temperature of the controlled environment to be accurately monitored. Insulating sleeve 68 inhibits convective cooling of active electrode 36 from fluid traveling through suction lumen 78 when apparatus 30 is used in combination with a suction source. Accordingly, the temperature of electrode 36 and the fluid within cavity 55 can be accurately monitored and regulated thereby minimizing the possibility of thermal damage to non-targeted tissue as well as to apparatus 20. For example, because the temperature within cavity 55 is accurately monitored, predictable and reproducible levels of energy can be delivered in order to effectively meld fibrillated articular cartilage strands 28 and minimize collateral thermal effect on non-targeted tissue including underlying cartilage bed 29 and subchondral bone 25. The coupling of sensor 69 only to end wall 37 of active electrode 36, and not side wall 39 thereof, further ensures accurate temperature measurements by sensor 69. The utilization of insulator 72 is also beneficial in this regard.

The disposition of electrode 34 inhibits damage to probe member 31. As is known in the art, arcing and sparking may occur in the event that an electrode contacts metal surfaces, for example, cannulas within surgical environments. Because active electrode 36 of the present invention is located within peripheral wall 54 and cavity 55 a distance from opening 58, contact of the active electrode 36 with other items within joint capsule 27, as well as the resulting arcing and sparks, are minimized and/or prevented. The configuration of the present invention thus protects scope 49, cannulas 41, 45 and other instruments present in the joint capsule because direct contact of such items with active electrode 36 is prevented.

The structure of the apparatus and probe member may vary widely and fall within the scope of the present invention. For example, the active electrode may have a variety of different geometric configurations. Although active electrode 36 is shown as being convex in FIG. 5, one should appreciate that other geometries may be used. For example, the electrode may be spherical, flat, asymmetric or concave. In addition, it should be appreciated that the energy source, apparatus and method of the present invention can utilize other suitable frequencies along the electromagnetic spectrum, including infrared, coherent light, sonic and microwave, for heating the controllable environment created by cavity 55 and the disrupted articular cartilage 26 exposed thereto and be within the scope of the present invention.

In another embodiment, as shown in FIG. 7, apparatus 80 therein is substantially similar to apparatus 20 and like reference numerals have been used to describe like components of the various embodiments. Apparatus 80 is bipolar and includes an annular external return electrode

- 11 -

84 provided on an external surface of peripheral wall 54 for permitting the energy source to operate in a sesquipolar mode. Return electrode 84 is electrically connected to the radiofrequency generator 33 and completes the electrical circuit therewith instead of a grounding pad. The bipolar current path extending from active electrode 36 to return electrode 84 is shown schematically in FIG. 7 by arrow B. Although return electrode 84 is shown having a tubular or cylindrical configuration in FIG. 7, one should appreciate that other geometries may be used. For example, the return electrode may be conical or toroidal in shape, segmented, or be located on just one side of peripheral wall 54 and still fall within the scope of the present invention. In use and operation, apparatus 80 is used in the same manner as apparatus 30 except that a grounding pad on the patient's body is not necessary to complete the electrical circuit and is thus not used.

In another embodiment, shown in FIG. 8, apparatus 90 therein is bipolar and includes an internal return electrode 91 provided on an internal surface of peripheral wall 54. Similar to apparatus 80, internal return electrode 91 of apparatus 90 is electrically connected to the radiofrequency generator 33 and completes the electrical circuit therewith instead of a grounding pad. The bipolar current path extending from active electrode 36 to return electrode 91 is shown schematically in FIG. 8 by arrow B'. In use and operation, apparatus 90 is used in substantially the same manner as apparatus 80.

The geometry of the peripheral wall may also vary widely and fall within the scope of the present invention, as shown in FIGS. 9, 10, and 12. For example, peripheral wall 54 of apparatus 20 has a lower edge 56 that is substantially planar, as is shown in FIGS. 4-6 and 9. In another embodiment shown in FIGS. 10 and 11, apparatus 100 includes a tubular peripheral wall 101 having a lower edge 102 which is scalloped with a plurality of semicircular segments or scallops 103 separated by a plurality of respective recesses 104. Again it is noted that like reference numerals have been used to describe like components of the various embodiments. An electrode 105, substantially similar to electrode 36, is carried within outer shaft 53 and has an end wall 106 having an outer or distal surface 107 of any suitable shape and, as shown, is substantially planar (see FIG. 10). Distal surface 107 of the electrode 105 is spaced inwardly or proximally from the base of recesses 104 a distance ranging from one to twelve millimeters and preferably approximately six millimeters.

The shape of lower edge 102 in FIG. 11 facilitates raking individual fibrillated articular cartilage strands 28 into the cavity as a physician sweeps the probe member of apparatus 100 along cartilage bed 29. In particular, the scalloped lower edge 102 inhibits matting of fibrillated cartilage as the probe member of apparatus 100 is swept along bed 29. This phenomena is similar to individual blades of grass returning to their substantially vertical position after a rake passes over them. In addition, the semicircular segments 103 groom the fibrillated cartilage and thus enhance the sealing effect of the lower edge against the cartilage strands 28, thereby

- 12 -

minimizing undesirable convective inflow of the exterior irrigant into the controllable environment within cavity 55.

Yet another embodiment is shown in FIG. 12 in which apparatus 110 includes a peripheral wall 111 having a lower edge 112 which is scalloped with a plurality of stepped segments 113, each of which is shown as being rectangular in shape. Apparatus 110 has similarities to apparatus 20 and 100 and like reference numerals have been used to describe like components of apparatus 20, 100 and 110. Each pair of stepped segments is separated by a recess 114, which is also rectangular in shape. Distal surface 107 of the electrode 105 is spaced inwardly or proximally from the base of recesses 114 a distance ranging from one to twelve millimeters and preferably approximately six millimeters.

The steps or tooth-like segments 113 advantageously seal the articular cartilage in a deep fibril environment, that is a dense field of cartilage strands 28, by allowing the fibrillated articular cartilage strands that are being advanced upon to enter the cavity or chamber in the distal extremity of apparatus 110. Convection is less of a concern in such a deep fibril environment because slots are filled by the entering fibrillated articular cartilage in the same manner as discussed above with respect to apparatus 100.

As can be seen from the foregoing, the present invention provides a minimally invasive apparatus for delivering energy to disrupted articular cartilage and particularly cartilage fibrils extending outwardly from a cartilage bed for treatment thereof while minimizing collateral thermal effect on non-targeted tissue. The present invention creates a controlled environment for the purpose of melding cartilage fibrils extending from the cartilage bed. The present invention delivers sufficient thermal energy to coagulate fibrillated articular cartilage to form a more normal and sealed articular cartilage surface in predictable and reproducible levels thereby minimizing collateral damage to nearby non-target and healthy tissue. The present invention can be used for treating chondromalacia and other articular cartilage defects.

The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

- 13 -

WHAT IS CLAIMED IS:

1. An apparatus for treating disrupted articular cartilage comprising:
an elongate probe member having:
proximal and distal extremities, the distal extremity having a peripheral wall defining a cavity and a distal opening communicating with the cavity whereby a controllable environment is created within the cavity when the distal extremity is placed substantially flush against the disrupted articular cartilage; and
an electrode positioned within the cavity at a distance spaced inwardly of the distal opening whereby the disrupted articular cartilage is sealed to form a substantially continuous surface when energy is supplied to the electrode; and
and a handle coupled to the proximal extremity of the elongate probe member.
2. The apparatus of Claim 1 wherein the disrupted articular cartilage is formed by fibrillated strands and wherein the electrode is spaced inwardly from the distal opening a depth sufficient to seal the fibrillated strands into a coagulated mass so as to form the substantially continuous surface when the distal extremity is placed substantially flush against the fibrillated strands.
3. The apparatus of Claim 1 wherein the disrupted articular cartilage is formed by fissures within the disrupted articular cartilage and wherein the electrode is spaced inwardly from the distal opening a depth sufficient to seal the fissures so as to form the substantially continuous surface when the distal extremity is placed substantially flush against the fissures in the disrupted articular cartilage.
4. The apparatus of Claim 1 wherein the peripheral wall is serrated at a distal portion of the peripheral wall around the distal opening to facilitate raking of the peripheral wall over the disrupted articular cartilage.
5. The apparatus of Claim 1 further comprising a temperature sensor within the distal extremity for monitoring the ambient temperature within the controllable environment.
6. The apparatus of Claim 5 further comprising a controller electrically coupled to the temperature sensor for modulating the amount of energy supplied to the electrode in response to the monitored ambient temperature.
7. The apparatus of Claim 5 wherein the electrode has a distally-oriented wall and a circumferentially-extending side wall extending proximally from the distal opening, the temperature sensor being disposed behind the distally-oriented wall within a thermally-conductive fill material adhered to the distally-oriented wall for monitoring of the temperature of the distally-oriented wall.
8. The apparatus of Claim 7 wherein the thermally-conductive fill material is spaced inwardly from the side wall for enhancing accuracy in the monitoring of the temperature of the distally-oriented wall.

- 14 -

9. The apparatus of Claim 8 further comprising an insulating material disposed between the thermally-conductive fill material and the side wall.

10. The apparatus of Claim 1 wherein the elongate probe member is provided with a lumen extending longitudinally therethrough and communicating with the cavity for providing suction to the cavity.

11. The apparatus of Claim 1 further comprising a grounding pad electrically coupled to the electrode and adapted for attachment to the body.

12. The apparatus of Claim 1 further comprising a return electrode carried by the distal extremity of the elongate probe member.

13. An apparatus for treating a fluid-filled joint of a mammalian body having disrupted articular cartilage comprising an elongate probe member having proximal and distal extremities, the distal extremity having a peripheral wall defining a cavity and a distal opening communicating with the cavity whereby a controllable fluid-filled environment is created in the cavity when the distal extremity is placed substantially flush against the disrupted articular cartilage, and an electrode carried by the distal extremity within the cavity in a position spaced inwardly of the opening whereby the disrupted articular cartilage is melded together when energy is supplied to the electrode to heat the controllable fluid environment.

14. The apparatus of Claim 13 wherein the disrupted articular cartilage includes cartilage fibrils extending from a cartilage bed and wherein the electrode is spaced inwardly from the opening a depth that is sufficient to avoid the electrode contacting the cartilage bed during treatment.

15. The apparatus of Claim 14 wherein the peripheral wall is serrated around the opening to facilitate raking of the peripheral wall over the cartilage fibrils.

16. The apparatus of Claim 13 further comprising a temperature sensor carried by the distal extremity within the cavity for monitoring the ambient temperature within the controllable fluid-filled environment.

17. The apparatus of Claim 16 wherein the electrode is cup-shaped and has an end wall facing the distal opening and a side wall extending proximally from the distal opening, the electrode temperature sensor being disposed behind the end wall, an outer side wall of an insulating material surrounding the side wall of the electrode for enhancing accuracy in the monitoring of the ambient temperature.

18. The apparatus of Claim 17 wherein the elongate probe member is provided with a lumen extending longitudinally therethrough, the additional side wall being spaced inwardly from the peripheral wall for forming an annular opening for the lumen.

19. A method for treating disrupted articular cartilage in a body with an elongate probe member having a distal extremity provided with a cavity and an energy source comprising the steps of:

- 15 -

introducing the distal extremity into the body;

placing the distal extremity substantially flush against the disrupted articular cartilage so that a controllable fluid-filled environment encompassing the disrupted articular cartilage is formed by the cavity; and

delivering energy from the energy source to controllable environment so as to seal the disrupted articular cartilage.

20. The method of claim 19 wherein the disrupted articular cartilage includes fibrillated articular cartilage.

21. The method of claim 19 wherein the disrupted articular cartilage includes fissured cartilage.

22. The method of claim 19 wherein the energy is radio frequency energy.

23. The method of claim 22 further comprising the step of electrically coupling a grounding pad to the body for serving as a return for the radio frequency energy.

24. The method of claim 22 further comprising the step of providing a return electrode at the distal extremity of the elongate probe for returning energy to the energy source in a sesquipolar mode.

25. A method for treating a fluid-filled joint of a mammalian body having disrupted cartilage strands extending from a cartilage bed with an elongate probe member having a distal extremity provided with a cavity comprising the steps of introducing the distal extremity into the joint of the body, placing the distal extremity against the disrupted cartilage strands so that a controllable fluid-filled environment is created in the cavity around the disrupted cartilage strands and heating the controllable fluid-filled environment to meld the disrupted cartilage strands into the cartilage bed.

26. The method of Claim 25 wherein the energy is radio frequency energy.

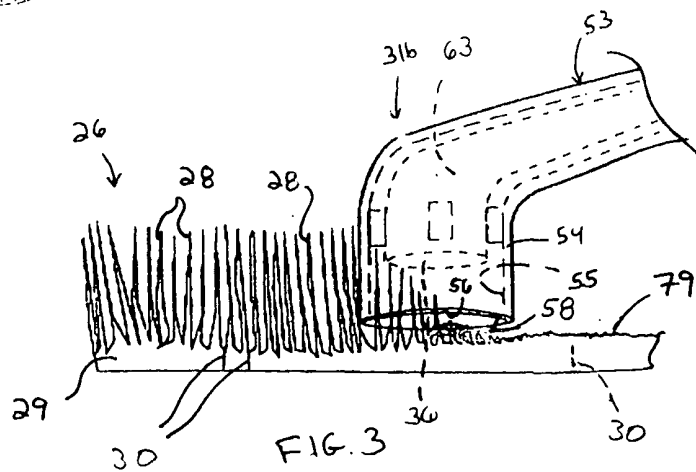
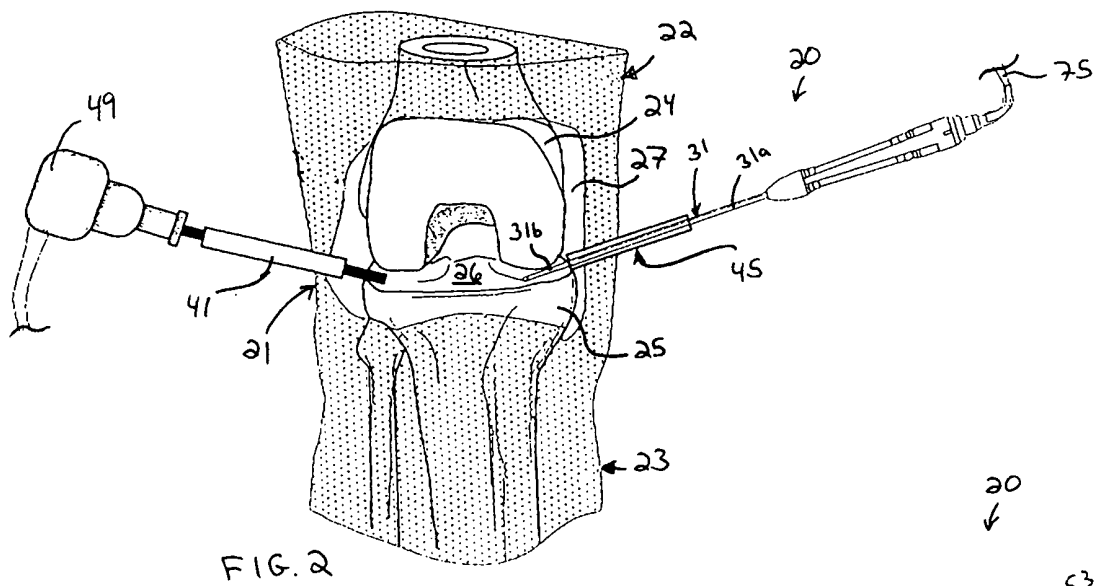
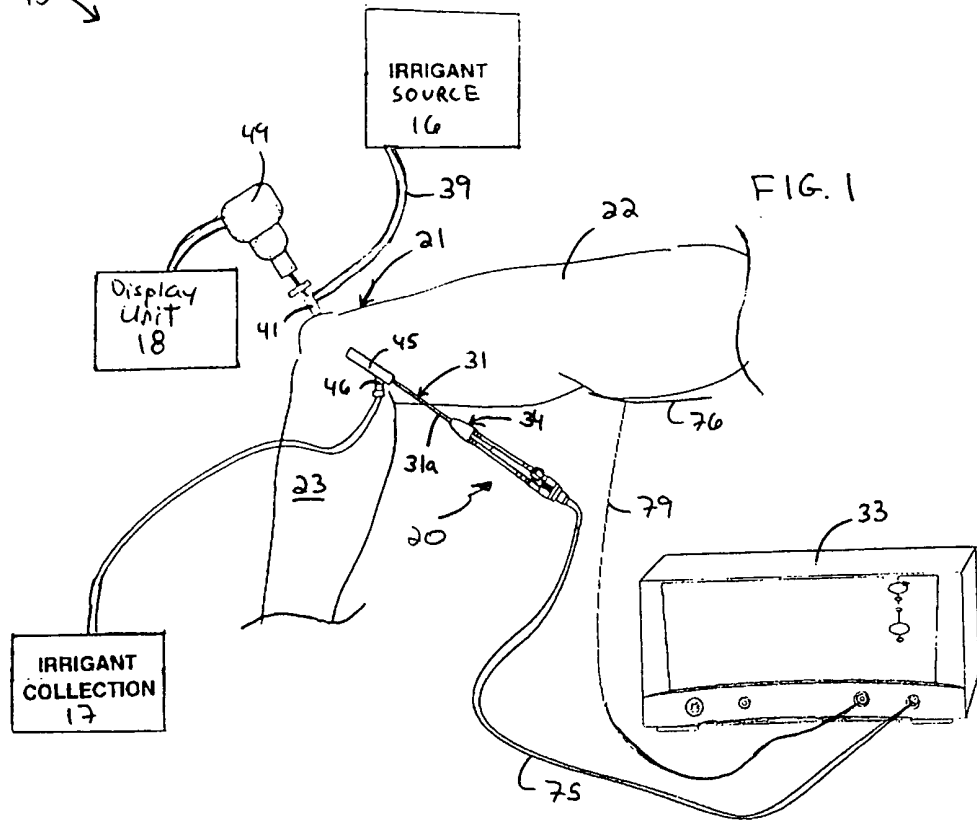
27. The method of Claim 25 wherein an electrode is carried by the distal extremity within the cavity for heating the controllable fluid-filled environment.

28. The method of Claim 25 wherein the controllable fluid-filled environment in the cavity is heated to a temperature between 50°C and 100°C.

29. The method of Claim 25 wherein the controllable fluid-filled environment in the cavity is heated to a temperature between 55°C and 85°C.

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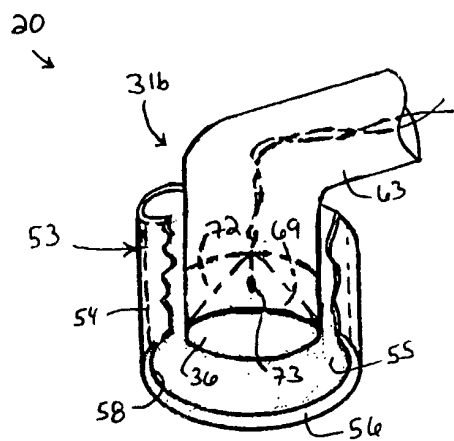


FIG. 4

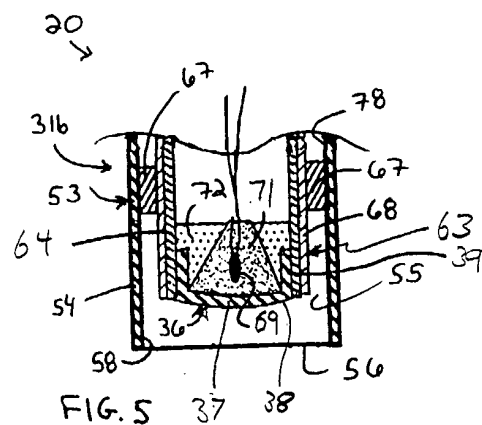


FIG. 5

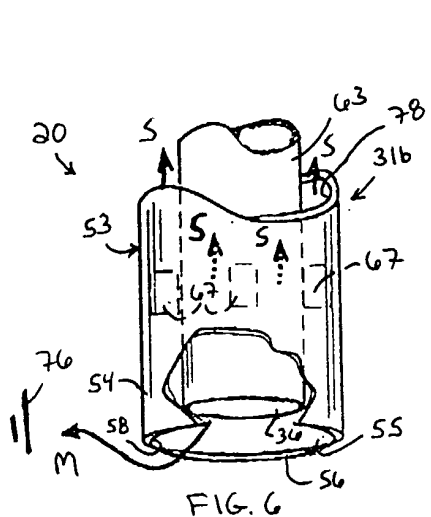


FIG. 6

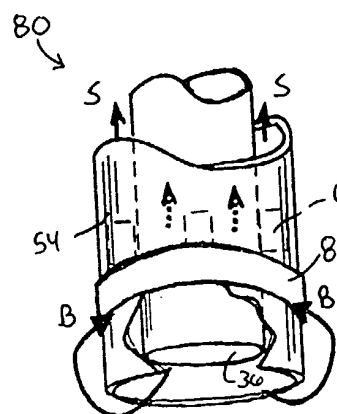


FIG. 7

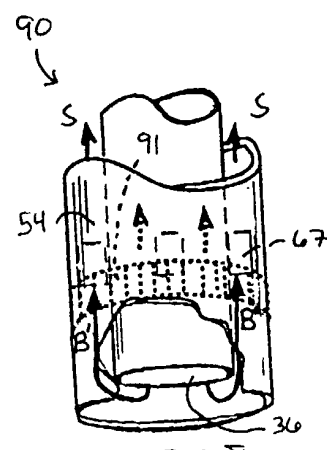


FIG. 8

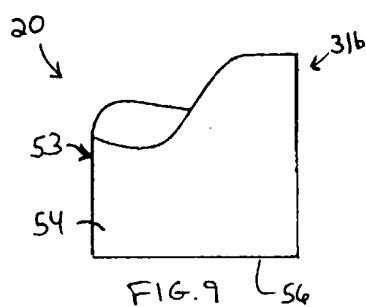


FIG. 9

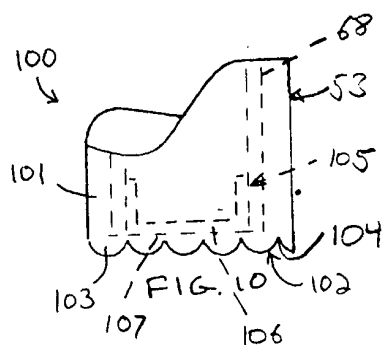


FIG. 10

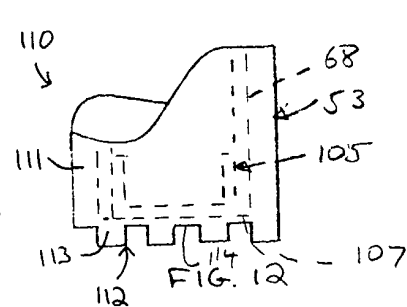


FIG. 12

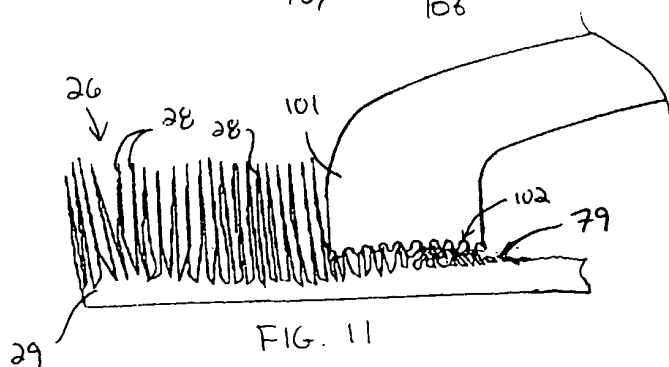


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/03511

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : A61B 18/18

US CL : 606/049

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 606/049, 041, 047, 048,

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6149620 A (Baker et al.) 21 November 2000, see entire document.	1-29

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

08 April 2002 (08.04.2002)

Date of mailing of the international search report

10 JUN 2002

Name and mailing address of the ISA/US

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