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(57) Abstract: A method of manufacturing a fiber reinforced orthodontic appliance is provided. The method may include a) providing one or more monomer resin-coated fibers, b) shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient, and c) spot curing the shaped portion of the one or more monomer resin-coated fibers as the shaping is carried out to obtain the fiber reinforced orthodontic appliance. The method may further include marking the center portion and/or a side portion of the cured appliance. A fiber reinforced orthodontic appliance and an apparatus for manufacturing a fiber reinforced orthodontic appliance are also provided.



A FIBER REINFORCED ORTHODONTIC APPLIANCE

TECHNICAL FIELD

[0001] Various embodiments relate to a method of manufacturing a fiber reinforced
5 orthodontic appliance, and an apparatus for manufacturing a fiber reinforced orthodontic
appliance.

BACKGROUND

[0002] Orthodontic treatment is based on the principle that if prolonged pressure is
10 applied to a tooth, tooth movement will occur as the bone around the tooth remodels. In
orthodontic treatment, teeth may be rearranged by implementing fixed or removable
orthodontic appliances into a patient's mouth so as to improve appearance of the wearer, and
occlusal stability and function.

[0003] Traditional orthodontic appliances may include fixed orthodontic appliances
15 having metallic or ceramic brackets adhered to the teeth and an arch wire formed from metals
such as 18-8 stainless steel, chrome-cobalt-nickel, and/or titanium containing alloys. The
metallic arch wire may be bent so as to transfer a desired force to the teeth. Shortcomings of
such orthodontic appliances include structural complexity of the appliances, resulting in poor
oral hygiene which may translate into tooth decay, and poor appearance of a patient wearing
20 the appliances.

[0004] Fiber-reinforced composites (FRC) may be used to replace metal wires for use as
orthodontic arch wires. Advantageously, fiber reinforced composite wires may have strength
comparable to steel wires, but only a fraction of their weight. Furthermore, fiber reinforced
composite wires in the form of continuous unidirectional glass fiber wires as a translucent
25 arch wire may be used in combination with traditional brackets as an aesthetically pleasing
alternative to traditional orthodontic appliances formed of metal wires to improve appearance
of a patient wearing the orthodontic appliance. State of the art fiber reinforced composite
wires for orthodontic purposes may be fabricated by conforming monomer resin-coated wires
to a specific morphology on a die, such as that described in US patent No. US 7,758,785 B2
30 (FIBER REINFORCED COMPOSITE AND METHODS OF FORMING THE SAME).

[0005] **FIG. 1** is a schematic diagram illustrating the method described in US patent No.
US 7,758,785 B2. In the described method, **1** denotes placing a composite of fiber and resin

in an elongate tunnel of a shrinkable die; **2** denotes shrinking the die to reduce the transversal cross-section of the tunnel of the die along a longitudinal extent of the tunnel so as to compress the composite in the tunnel; **3** denotes curing the composite; **5** denotes an optional step of bending the die lengthwise so as to shape the composite in the die prior to curing; and

5 **4** denotes peeling the die from the composite to obtain the fiber reinforced composite.

[0006] The method depicted in US patent No. US7,758,785B2 may suffer from shortcomings, such as variability in the force applied to the arch wire shaping process thus resulting in arch wires that are not accurate representations of the patient's teeth profile, and labor intensive which is not adaptable for large scale mass production. Furthermore, use of

10 the method may result in defects in the fiber reinforced composite wires such as inconsistent combination ratio of glass fiber and resin as well as defects shown in **FIG. 2A** to **FIG. 2F**.

[0007] In view of the above, there exists a need for an improved method of manufacturing a fiber reinforced orthodontic appliance that overcomes or at least alleviates one or more of the above-mentioned problems.

15

SUMMARY

[0008] In a first aspect, a method of manufacturing a fiber reinforced orthodontic appliance is provided. The method comprises

- a) providing one or more monomer resin-coated fibers,
- 20 b) shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient, and
- c) spot curing the shaped portion of the one or more monomer resin-coated fibers as the shaping is carried out to obtain the fiber reinforced orthodontic appliance.

25 [0009] In a second aspect, a fiber reinforced orthodontic appliance prepared by a method according to the first aspect is provided.

[0010] In a third aspect, an apparatus for manufacturing a fiber reinforced orthodontic appliance is provided. The apparatus comprises

- a) a wire bending unit configured to shape one or more monomer resin-coated
- 30 fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient; and

- b) a spot curing unit configured to spot cure a shaped portion of the one or more monomer resin-coated fibers as the shaping is carried out.

[0011] In a fourth aspect, use of a method according to the first aspect or an apparatus according to the third aspect in the manufacture of a fiber reinforced orthodontic appliance is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The invention will be better understood with reference to the detailed description when considered in conjunction with the non-limiting examples and the accompanying drawings, in which:

[0013] **FIG. 1** is a schematic diagram depicting a state of the art method to manufacture a fiber reinforced orthodontic wire. In the method shown, **1** denotes placing a composite of fiber and resin in an elongate tunnel of a shrinkable die; **2** denotes shrinking the die to reduce the transversal cross-section of the tunnel of the die along a longitudinal extent of the tunnel so as to compress the composite in the tunnel; **3** denotes curing the composite; **5** denotes an optional step of bending the die lengthwise so as to shape the composite in the die prior to curing; and **4** denotes peeling the die from the composite.

[0014] **FIG. 2A** is an optical image taken using a 40x microscope of a fiber reinforced orthodontic wire prepared by the method depicted in **FIG. 1**. As shown in the figure, fiber reinforced orthodontic wire **201** has a defect in the form of a foreign material **221** lodged therein, which may have been due to presence of the foreign material **221** on a surface of the shrinkable die used to prepare the fiber reinforced orthodontic wire.

[0015] **FIG. 2B** is an optical image taken using a 40x microscope of a fiber reinforced orthodontic wire prepared by the method depicted in **FIG. 1**. As shown in the figure, fiber reinforced orthodontic wire **202** has a defect in the form of air bubbles **222** lodged therein, which may have been due to placement of the composite of fiber and resin in the shrinkable die.

[0016] **FIG. 2C** is an optical image taken using a 40x microscope of a fiber reinforced orthodontic wire prepared by the method depicted in **FIG. 1**. As shown in the figure, fiber reinforced orthodontic wire **203** has a defect in the form of splinters **223** branching out from the fiber reinforced orthodontic wire **203**. Splintering of the fiber may have resulted when the composite of fiber and resin is removed from the shrinkable die.

[0017] **FIG. 2D** is an optical image taken using a 40x microscope of a fiber reinforced orthodontic wire prepared by the method depicted in **FIG. 1**. As shown in the figure, fiber reinforced orthodontic wire **204** has a defect in the form of cutting lines **224** present on a surface of the fiber reinforced orthodontic wire **204**, which may have been due to movement of the composite of fiber and resin in the shrinkable die.

[0018] **FIG. 2E** is an optical image taken using a 40x microscope of a fiber reinforced orthodontic wire prepared by the method depicted in **FIG. 1**. As shown in the figure, fiber reinforced orthodontic wire **205** has a defect in the form of a dent mark **225** present on a surface of the fiber reinforced orthodontic wire **205**, which may have occurred as a result of improper handling of the shrinkable die by an operator.

[0019] **FIG. 2F** is an optical image taken using a 40x microscope of a fiber reinforced orthodontic wire prepared by the method depicted in **FIG. 1**. As shown in the figure, fiber reinforced orthodontic wire **206** has a defect in the form of a dirt mark **226** present on a surface of the fiber reinforced orthodontic wire **206**, which may have been due to presence of impurities or dirt particles on a surface of the shrinkable die used to prepare the fiber reinforced orthodontic wire.

[0020] **FIG. 3** is a process flowchart detailing a method according to an embodiment disclosed herein. **301** denotes loading fibers into a forming unit comprising a reservoir containing a monomer resin; **302** denotes wetting the fibers by coating an external surface of each fiber with the monomer resin to form monomer resin-coated fibers; **303** denotes bundling the monomer resin-coated fibers to form a bundled fiber; **304** denotes modifying a cross-sectional size and/or cross-sectional shape of the bundled fiber by conveying the bundled fiber through an aperture defined by an inner wall of a forming part, wherein the aperture is configured to define a cross-sectional size and/or cross-sectional shape of the bundled fiber; **305** denotes shaping the resultant fiber continually along the length of the fiber according to digital information correlated to the dental anatomy of an individual patient; **306** denotes spot curing the shaped portion of the fiber as the shaping is carried out; and **307** denotes trimming the cured fiber to a predetermined length.

[0021] **FIG. 4** is a schematic diagram of an apparatus **400** for manufacturing a fiber reinforced orthodontic appliance according to an embodiment disclosed herein. In the embodiment shown, the apparatus **400** for manufacturing a fiber reinforced orthodontic appliance comprises a wire bending unit **411** configured to shape one or more monomer

resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient, and a spot curing unit **412** configured to spot cure a shaped portion of the one or more monomer resin-coated fibers as the shaping is carried out. The one or more monomer resin-coated fibers may be placed into the wire bending unit **411** via an inlet **450** to the wire bending unit **411**. A single monomer resin-coated fiber or a bundled fiber comprising a plurality of monomer resin-coated fibers may be used. The inlet **450** may be connected to a loading unit (not shown) for loading the one or more monomer resin-coated fibers into the wire bending unit **411**. As the shaping of the one or more monomer resin-coated fibers is carried out by the wire bending unit **411**, the shaped portion of the resin-coated fiber(s) is spot cured by the spot curing unit **412**, which may take place at the same time as the shaping is carried out or within a predetermined period of time from the shaping. The cured fiber(s) may be removed from the spot curing unit **412** via an outlet **451** of the spot curing unit **412**. The outlet **451** may be connected to an unloading unit (not shown) for unloading the cured fiber(s), or to a trimming unit (not shown) configured to trim the cured fiber(s) to a predetermined length.

[0022] **FIG. 5** is a schematic diagram of an apparatus **500** for manufacturing a fiber reinforced orthodontic appliance according to an embodiment disclosed herein. In the embodiment shown, the apparatus **500** for manufacturing a fiber reinforced orthodontic appliance comprises a forming unit **501**, a pre-shaping unit **502**, a forming part **503**, a wire bending unit **511**, a spot curing unit **512**, a wire pulling unit **504**, a trimming unit **505**, and a marking unit **506**. The forming unit **501** comprises a reservoir **5011** configured to receive a monomer resin and a conveying mechanism **5012** configured to convey one or more fibers through the reservoir so that an external surface of each of the one or more fibers is coated with the monomer resin to form one or more monomer resin-coated fibers. The one or more fibers may be placed into the forming unit **501** via an inlet **550** to the forming unit **501**. The inlet **550** may be connected to a loading unit (not shown) for loading the one or more fibers into the forming unit **501**. Upon coating an external surface of each of the one or more fibers with a monomer resin, the one or more monomer resin-coated fibers is conveyed by conveying mechanism **5012** through an outlet **551** which is arranged on the same side of the forming unit as inlet **550**. The pre-shaping unit **502** is configured to bundle a plurality of monomer resin-coated fibers to form a bundled fiber. The bundled fiber may be conveyed

through forming part **503** having an inner wall defining an aperture, the aperture being configured to define a cross-sectional size and/or cross-sectional shape of the bundled fiber. The resultant fiber may be conveyed to the wire bending unit **511**. While shaping of the fiber is carried out or within a predetermined period of time from shaping of the fiber by the wire bending unit **511**, the shaped portion of the fiber is spot cured by the spot curing unit **512**. The spot curing unit **512** comprises a radiation source **5121** and a radiation focusing component **5122**. The cured fiber may be moved from the spot curing unit **512** by a wire pulling unit **504** configured to pull the cured fiber through the wire bending unit **511**, to a trimming unit **505** configured to trim the cured fiber to a predetermined length. The trimmed fiber may be conveyed to a marking unit **506** configured to make a marking at a center portion of the trimmed fiber, before removing from the marking unit **506** via an outlet **551** of the marking unit **506**. The outlet **551** may be connected to an unloading unit (not shown) for unloading the fiber, which may directly be used as a fiber reinforced orthodontic appliance.

[0023] **FIG. 6A** is a schematic diagram depicting a method of manufacturing a fiber reinforced orthodontic appliance according to an embodiment. In the embodiment shown, a monomer resin-coated fiber **671** is conveyed through a forming part **603** having an inner wall defining an aperture **6031**. The aperture **6031** is configured to define a cross-sectional size and/or cross-sectional shape of the monomer resin-coated fiber **671**. Optionally, the forming part **603** is programmable in that size and/or shape of the aperture **6031** may be varied according to specific requirements of the fiber reinforced orthodontic appliance. The monomer resin-coated fiber **671** is conveyed through a wire bending unit **611**. While the shaping of the fiber is carried out by the wire bending unit **611** or within a predetermined period of time from the shaping, the spot curing unit **612** comprising a radiation source **6121** and a radiation focusing component **6122** provides a spot focused radiation **6123** and spot cures the shaped portion of the monomer resin-coated fiber **671**. The cured fiber **672** may be moved from the spot curing unit **612** by a wire pulling unit **604** configured to pull the cured fiber through the wire bending unit **611**, to a trimming unit **605** configured to trim the cured fiber to a predetermined length to obtain the fiber reinforced orthodontic appliance.

[0024] **FIG. 6B** is a schematic diagram showing a wire bending unit **611** according to an embodiment. In the embodiment shown, the wire bending unit **611** is in the form of a six freedoms wire bending part. The wire bending unit **611** comprises a grabber **6115** having an inner wall defining a slot **6116** and configured to releasably hold a cured fiber. A movable

component may extend from an inner wall of the slot **6116**, and may be configured to move towards or away from an opposing wall of the slot **6116** so as to releasably hold a cured fiber positioned between the movable component and the wall. In some instances, the movable component may comprise two parts, each extending from opposing walls of the slot **6116**, and configured to move towards or away from each other so as to releasably hold the cured fiber therebetween. The grabber **6115** is connected to a base frame **6111** of the wire bending unit **611** via three legs **6112**, **6113**, and **6114**. Besides acting as a base frame of the wire bending unit **611**, the base frame **6111** also provides rotation of the grabber **6115** by turning along the Y-axis. Length of each of the three legs **6112**, **6113**, and **6114** may be varied, and may independently be controlled by a servo system attached to the legs. By controlling length of each of the legs, they may work together to provide movements along X-Y-Z axis and rotation along X and Z axis. For example, when length of **6112** increases, grabber **6115** may be rotated towards (-Z) direction. When the length of all three legs increases, grabber **6115** may be pushed towards Y direction. Movement of the movable component in the grabber **6115**, base frame **6111** and the legs **6112**, **6113**, and **6114** may be driven by servo motors, and controlled via a control system that allows precise movement of the above parts and which may be connected to a computer which contains digital information correlated to the dental anatomy of an individual patient. In so doing, the monomer resin-coated fiber(s) may be shaped continually by the wire bending unit **611** along the length of the fiber according to digital information correlated to the dental anatomy of an individual patient.

[0025] **FIG. 7** is a schematic diagram depicting a forming unit **701** according to an embodiment. In the embodiment shown, the forming unit **701** comprises a reservoir **7011** configured to receive a monomer resin and a conveying mechanism **7012** configured to convey one or more fibers through the reservoir so that an external surface of each of the one or more fibers is coated with the monomer resin to form one or more monomer resin-coated fibers. The conveying mechanism **7012** shown comprises rollers and driving rollers to move the fibers **771**. A monomer resin **7013** is contained in the reservoir **7011**. By passing the fibers **771** through the monomer resin **7013**, an external surface of each fiber is coated with a monomer resin. The monomer resin-coated fibers **772** are conveyed by the conveying mechanism **7012**, and exit the forming unit **701** on the side at which the dry fibers **771** enter the forming unit **701**.

[0026] **FIG. 8** is a schematic diagram depicting a pre-shaping unit **802** according to an embodiment. The pre-shaping unit **802**, which is configured to bundle a plurality of monomer resin-coated fibers to form a bundled fiber, may be arranged downstream of a forming unit as described herein. As shown, monomer resin-coated fibers **871** may be conveyed via a conveying mechanism **8022** to a pre-shaping roller **8021**, which bundles the monomer resin-coated fibers **871** to form a bundled fiber **872**.

[0027] **FIG. 9** is a schematic diagram showing a perspective view of an apparatus **900** for manufacturing a fiber reinforced orthodontic appliance disclosed herein. Fibers for feeding into the apparatus **900** may be wound on one or more spool rollers **9001** disposed on a top surface of the apparatus **900**. A container **9002** for containing monomer resin may be disposed next to the one or more fiber rollers **9001** on the top surface of the apparatus **900**. A user interface comprising a control panel **9003** and a display **9004** may be arranged on a surface of the apparatus **900**. Outlet **9005** for the fiber reinforced orthodontic appliance product may be arranged on a second surface of the apparatus **900**.

DETAILED DESCRIPTION

[0028] Advantageously, by spot curing the shaped portion of the one or more monomer resin-coated fibers at the same time as, or at a predetermined period of time after, the shaping is carried out, any undesirable movement and/or shifting of the monomer resin-coated fiber which may take place as a result of alleviation of built-up stress within the monomer resin-coated fibers may be prevented. The movement and/or shifting of the monomer resin-coated fiber, which may take place when the entire shaped monomer resin-coated fiber is cured by placing into a curing chamber, is undesirable as they may result in inaccuracies in the fiber reinforced orthodontic appliance fabricated, leading to a bad fit for the end user. Furthermore, since shaping of the one or more monomer resin-coated fibers is carried out continually along the length of the one or more monomer resin-coated fibers, movement and/or shifting of the monomer resin-coated fiber due to the spot curing, if any, may be remedied by adjusting shaping of subsequent portions of the monomer resin-coated fiber prior to curing. Advantageously, methods disclosed herein allow a fiber reinforced orthodontic appliance manufactured with improved accuracy, resulting in a better fit and treatment for the end user.

[0029] With the above in mind, various embodiments refer in a first aspect to a method of manufacturing a fiber reinforced orthodontic appliance.

[0030] As used herein, the term “fiber reinforced orthodontic appliance” refers to an orthodontic appliance formed from or containing fiber-reinforced composites. An orthodontic appliance refers to a device for mounting on teeth, and which applies a corrective force to the teeth and/or their supporting structure so as to control growth and development of the teeth. The orthodontic appliance may be affixed to or removably attached to the teeth. Examples of orthodontic appliance include, but are not limited to, archwires, circular orthodontic bands, and ligature wires. In various embodiments, the orthodontic appliance is an archwire.

[0031] The term “fiber-reinforced composites” refers generally to a mixture of material comprising one or more fibers contained in a matrix formed by a polymeric component. The term “fibers” refers to elongated structures, such as filaments or ribbons, which may be produced by conventional techniques such as electrospinning, interfacial polymerization, and the like. The fibers may be incorporated in fiber-reinforced composites to reinforce mechanical properties of the composites.

[0032] Examples of fibers include, but are not limited to, glass fibers, polymer fibers, ceramic fibers, cellulose and natural fibers, quartz fibers, graphite fibers, nano-fiber or mixtures thereof. Examples of polymer fibers include, but are not limited to, fibers formed of polyethylene, polypropylene, Ultra High Molecular Weight Polyethylene (UHMWPE), Nylon. In various embodiments, the fibers in the fiber-reinforced composites comprise or consist of glass.

[0033] The method of manufacturing a fiber reinforced orthodontic appliance comprises providing one or more monomer resin-coated fibers.

[0034] As used herein, the term “monomer resin” refers to a prepolymer compound which may be polymerized or cured to form a polymer. In various embodiments, the monomer resin is a compound which may be polymerized or cured when subjected to a radiation source. Examples of suitable monomer resin include, but are not limited to, acrylic monomer resin, acrylate monomer resins such as methacrylate monomer resin, cyanoacrylate monomer resin, methylmethacrylate monomer resin, hydroxy ethyl methylmethacrylate monomer resin or combinations thereof, epoxy monomer resin, carbonate monomer resin, or combinations thereof.

[0035] In specific embodiments, the monomer resin comprises a mixture of ethoxylated bisphenol A dimethacrylate, glass frit, and triethyleneglycol dimethacrylate, which may respectively be present in a concentration range of about 15 to 40 wt%, about 40 to 70 wt%, and about 8 to 30 wt%, based on total weight of the monomer resin. Such a monomer resin may, for example, be AELITEFLO/ AELITEFLO LV which is available from Bisco.

[0036] The one or more monomer resin-coated fibers comprise a layer of monomer resin disposed on an external surface of the one or more fibers. For example, the one or more fibers may be present as a single fiber, or as a bundled or woven fiber formed from several fibers, such as 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, or 15 fibers. The layer of monomer resin may accordingly be disposed on an external surface of the single fiber, or the bundled or woven fiber formed from several fibers.

[0037] In embodiments wherein the one or more monomer resin-coated fibers is a bundled or woven fiber formed from several fibers, the monomer resin may or may not form a layer around each of the fibers that make up the bundled or woven fiber. In various embodiments, the one or more monomer resin-coated fibers comprise a layer of monomer resin disposed on an external surface of each of the one or more fibers.

[0038] The coating of monomer resin on the fiber may have a weight ratio in the range of about 1:1 to about 1:1.5 to the amount of fiber present. For example, weight ratio of the monomer resin to the fiber may be in the range of about 1:1.1 to about 1:1.5, about 1:1.2 to about 1:1.5, about 1:1.3 to about 1:1.5, about 1:1 to about 1:1.4, about 1:1 to about 1:1.3, about 1:1 to about 1:1.2, or about 1:1.1 to about 1:1.4. In various embodiments, the coating of monomer resin on the fiber has a thickness which is at least substantially uniform along the length of the fiber.

[0039] In various embodiments, providing one or more monomer resin-coated fibers comprises coating an external surface of each of one or more fibers with a monomer resin. Examples of suitable monomer resin have already been described above.

[0040] Coating an external surface of each of one or more fibers with a monomer resin may be carried out in a forming unit comprising a reservoir configured to receive a monomer resin and a conveying mechanism configured to convey one or more fibers through the reservoir.

[0041] In various embodiments, coating an external surface of each of the one or more fibers with a monomer resin comprises conveying the one or more fibers through a reservoir

containing the monomer resin so that the one or more monomer resin-coated fibers exit the reservoir on the same side at which the one or more fibers enter the reservoir. In this configuration whereby the one or more monomer resin-coated fibers exit the reservoir on the same side at which the one or more fibers enter the reservoir, any excess resin that may be present on the fiber may be retrieved by the reservoir, thereby allowing recycling of the resin. Furthermore, it may provide a more consistent thickness of the monomer resin-coated layer.

[0042] Conveying the one or more fibers through the reservoir containing the monomer resin may be carried out using a conveying mechanism such as rollers. Advantageously, use of rollers is gentler on the fibers, which may translate into lower incidence of defects as compared to state of the art methods to prepare fiber reinforced orthodontic appliances.

[0043] For illustration purposes only, the coating of an external surface of each of the one or more fibers with a monomer resin disclosed herein may take place in a forming unit, such as that shown in **FIG. 7**.

[0044] Referring to **FIG. 7**, the forming unit **701** comprises a reservoir **7011** configured to receive a monomer resin and a conveying mechanism **7012** configured to convey one or more fibers through the reservoir so that an external surface of each of the one or more fibers is coated with the monomer resin to form one or more monomer resin-coated fibers. The conveying mechanism **7012** shown comprises rollers and driving rollers to move the fibers **771**. A monomer resin **7013** is contained in the reservoir **7011**. By passing the fibers **771** through the monomer resin **7013**, an external surface of each fiber is coated with a monomer resin. The rollers and driving rollers may function to spread out the fibers so as to allow formation of a substantially uniform coating of the monomer resin on an external surface of each of the fibers. The monomer resin-coated fibers **772** may be conveyed by the conveying mechanism **7012**, and exit the forming unit **701** on the side at which the dry fibers **771** enter the forming unit **701**.

[0045] As mentioned above, one or more monomer resin-coated fibers may be provided. In various embodiments, a plurality of the monomer resin-coated fibers is provided. 4, 6, 8, or 10 monomer resin-coated fibers may be provided to produce each fiber reinforced orthodontic appliance. The plurality of the monomer resin-coated fibers may be provided as separate fibers (non-bundled form) or in a bundled form as a bundled fiber. In embodiments wherein the plurality of the monomer resin-coated fibers are provided as separate fibers in a

non-bundled form, the method disclosed herein may further comprise bundling the plurality of monomer resin-coated fibers to form a bundled fiber.

[0046] This may, for example, be carried out by conveying the plurality of monomer resin-coated fibers through a pre-shaping unit configured to bundle the plurality of monomer resin-coated fibers to form the bundled fiber. By varying the number of monomer resin-coated fibers in the bundled fiber, for example, this may allow customization of properties such as thickness and/or strength of the resultant fiber reinforced orthodontic appliance.

[0047] An example of a pre-shaping unit is shown in **FIG. 8**. The pre-shaping unit **802**, which is configured to bundle a plurality of monomer resin-coated fibers to form a bundled fiber, may be arranged downstream of a forming unit described herein. As shown in the figure, monomer resin-coated fibers **871** may be conveyed via a conveying mechanism **8022** to a pre-shaping roller **8021**, which bundles the monomer resin-coated fibers **871** to form a bundled fiber **872**. In various embodiments, the pre-shaping roller **8021** has a smaller cross-sectional width or diameter in the center portion, so as to guide the monomer resin-coated fibers **871** to the center portion of the roller so that the monomer resin-coated fibers may **871** be bonded together to form the bundled fiber **872**. The conveyor mechanism **8022** may include a secondary resin dispenser (not shown) to control the resin coating thickness on the monomer resin-coated fibers **871**.

[0048] In embodiments wherein the plurality of monomer resin-coated fibers is already provided in a bundled form as a bundled fiber, it may not be necessary to pass the plurality of monomer resin-coated fibers through the pre-shaping unit.

[0049] The one or more monomer resin-coated fibers may be conveyed through an aperture defined by an inner wall of a forming part, wherein the aperture is configured to define a cross-sectional size and/or cross-sectional shape of the one or more monomer resin-coated fibers. By passing the one or more monomer resin-coated fibers through the aperture, this allows modification of the cross-sectional size and/or cross-sectional shape of the one or more monomer resin-coated fibers, since the one or more monomer resin-coated fibers may conform to or assume the cross-sectional size and/or cross-sectional shape of the aperture.

[0050] An example of a forming part is shown in **FIG. 6A**. **FIG. 6A** shows a forming part **603** having an inner wall defining an aperture **6031**. A monomer resin-coated fiber **671** is conveyed through the aperture **6031** defined by an inner wall of the forming part **603**.

[0051] In various embodiments, the aperture has a cross-sectional shape such as, but not limited to, circle, square, triangle, rectangle, oval, diamond, or be irregularly shaped.

[0052] In some embodiments, the aperture has a cross section that is circular in shape. The round aperture may have an inner diameter in the range of about 0.019 inches to about 0.021 inches, such as about 0.02 inches to about 0.021 inches, about 0.019 inches to about 0.02 inches, about 0.019 inches, about 0.02 inches, or about 0.021 inches.

[0053] In some embodiments, the aperture has a cross section that has a rectangular shape. One side of the rectangular aperture may have a dimension in the range of about 0.019 inches to about 0.021 inches, such as about 0.02 inches to about 0.021 inches, about 0.019 inches to about 0.02 inches, about 0.019 inches, about 0.02 inches, or about 0.021 inches, while the other side of the rectangular aperture may have a dimension of about 0.025 inches.

[0054] In specific embodiments, the aperture has a circular cross section with a diameter of about 0.019 inches, or about 0.021 inches, or a rectangular cross section with dimensions of about 0.019 inches by 0.025 inches, or about 0.021 inches by 0.025 inches.

[0055] The forming part may be programmable in that size and/or shape of the aperture may be varied according to specific requirements of the fiber reinforced orthodontic appliance. For example, the forming part may be formed of a material that is able to contract in size (or shrink) so as to constrict the aperture defined by an inner wall of the forming part. Such materials may include temperature sensitive materials that are able to change in size in response to heat, such as, but not limited to, polymers such as polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE), perfluoroalkoxy (PFA), fluorinated ethylene polymer (FEP), polyethylene terephthalate (PET), mixtures thereof, or copolymers thereof.

[0056] The method of manufacturing a fiber reinforced orthodontic appliance disclosed herein comprises shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient.

[0057] In various embodiments, shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient is carried out using a wire bending unit.

[0058] For example, the wire bending unit may comprise a robotic device and a control system. The wire bending unit may be termed a “six degrees of freedom” or a “six freedoms”

wire bending part because the robotic device has six freedoms to allow it to move to any point within a working area. The wire bending unit may be arranged downstream of the aperture, which may function as a fixed die. The one or more monomer resin-coated fibers may be conveyed out of the aperture to the wire bending unit, where they may be shaped continually by the wire bending unit along the length of the fibers according to digital information correlated to the dental anatomy of an individual patient.

[0059] An example of a wire bending unit is shown in **FIG. 6B**. In the embodiment shown, the wire bending unit **611** is in the form of a six freedoms wire bending part. The wire bending unit **611** comprises a grabber **6115** having an inner wall defining a slot **6116** and configured to releasably hold a cured fiber. A movable component may extend from an inner wall of the slot **6116**, and may be configured to move towards or away from an opposing wall of the slot **6116** so as to respectively, hold or release a cured fiber positioned between the movable component and the wall. In some instances, the movable component may comprise two parts, each extending from opposing walls of the slot **6116**, and configured to move towards or away from each other so as to releasably hold the cured fiber therebetween.

[0060] The grabber **6115** is connected to a base frame **6111** of the wire bending unit **611** via three legs **6112**, **6113**, and **6114**. Besides acting as a base frame of the wire bending unit **611**, the base frame **6111** also provides rotation of the grabber **6115** by turning along the Y-axis.

[0061] Length of each of the three legs **6112**, **6113**, and **6114** may be varied, and may independently be controlled by a servo system attached to the legs. By controlling length of each of the legs, they may work together to provide movements along X-Y-Z axis and rotation along X and Z axis. For example, when length of **6112** increases, grabber **6115** may be rotated towards (-Z) direction. When the length of all three legs increases, grabber **6115** may be pushed towards Y direction.

[0062] Movement of the movable component in the grabber **6115**, base frame **6111** and the legs **6112**, **6113**, and **6114** may be driven by servo motors, and controlled via a control system that allows precise movement of the above parts and which may be connected to a computer which contains digital information correlated to the dental anatomy of an individual patient. In so doing, the monomer resin-coated fiber(s) may be shaped continually by the wire bending unit **611** along the length of the fiber according to digital information correlated to the dental anatomy of an individual patient.

[0063] The wire bending unit is configured to shape one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient. The digital information correlated to the dental anatomy of an individual patient may be in the form of Computer Aided Design (CAD) model or drawings or digital output from sensors used in mapping the dental anatomy of an individual patient, for example. Using the digital information, the wire bending unit is able to shape the one or more monomer resin-coated fibers more accurately as compared to state of the art methods.

[0064] In various embodiments, the digital data correlated to the dental anatomy of an individual patient is stored off-site, for example, in an external laboratory or office. Accordingly, shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient may comprise retrieving the digital information from an external data server.

[0065] The process of shaping the one or more monomer resin-coated fibers is carried out continually along the length of the one or more monomer resin-coated fibers, wherein the one or more monomer resin-coated fibers may be pulled through the wire bending unit by a wire pulling unit configured to pull the one or more monomer resin-coated fibers through the wire bending unit. For example, the wire pulling unit may work in tandem with the wire bending unit to provide movements of the one or more monomer resin-coated fibers along their length. By the phrase “continually along the length”, this means that the wire bending unit shapes a first portion of the one or more monomer resin-coated fibers, and moves along the length of the one or more monomer resin-coated fibers to shape a second and further portions of the one or more monomer resin-coated fibers without backtracking. In so doing, a fiber reinforced orthodontic appliance with an accurate profile may be manufactured.

[0066] As the shaping is being carried out or at a predetermined period of time after the shaping is carried out, the method of manufacturing a fiber reinforced orthodontic appliance disclosed herein comprises spot curing the shaped portion of the one or more monomer resin-coated fibers to obtain the fiber reinforced orthodontic appliance. In other words, while the wire bending unit is shaping a first portion of the one or more monomer resin-coated fibers, or within seconds after the first portion of the one or more monomer resin-coated fibers is shaped, the same first portion may be spot cured.

[0067] As used herein, the term “curing” refers to polymerization or crosslinking of a prepolymer such as a monomer by a method that induces polymerization or crosslinking of the prepolymer. For example, curing may be carried out by irradiating the prepolymer using a radiation source, which may be selected from the group consisting of an infra-red radiation source, a visible light radiation source, an ultraviolet ray source, an x-ray source, a gamma ray source, a beta particle source, a high energy electron source, and combinations thereof.

[0068] The term “spot curing” as used herein refers to curing which is carried out or confined to a small and/or localized area. This may be carried out using a spot curing unit, which may comprise a radiation source and a radiation focusing component, such as an optical lens, for example. By directing radiation from the radiation source through the radiation focusing component, this allows spot curing to be carried out on the shaped portion of the one or more monomer resin-coated fibers.

[0069] In various embodiments, spot curing the shaped portion of the one or more monomer resin-coated fibers is carried out by irradiating a focused blue light on the shaped portion of the one or more monomer resin-coated fibers.

[0070] Because the shaped portion of the one or more monomer resin-coated fibers is being spot cured at the same time as the shaping, or at a predetermined period of time after the shaping, is carried out, any undesirable movement and/or shifting of the monomer resin-coated fiber due to alleviation of built-up stress within the monomer resin-coated fibers, and which may take place in instances where the entire monomer resin-coated fiber is cured by placing into a curing chamber, may be prevented. Furthermore, movement and/or shifting of the monomer resin-coated fiber due to the spot curing, if any, may be remedied by adjusting shaping of subsequent portions of the monomer resin-coated fiber. Advantageously, methods disclosed herein allow a fiber reinforced orthodontic appliance with an accurate profile to be manufactured.

[0071] The process of shaping and spot curing the one or more monomer resin-coated fibers may be carried out for a portion of or for an entire length of the one or more monomer resin-coated fibers until the fiber reinforced orthodontic appliance is obtained. In some embodiments, length of the cured fiber(s) corresponds to the intended length of the fiber reinforced orthodontic appliance, and further processing to trim the cured fiber(s), for example, is not required.

[0072] In some embodiments, the cured fiber(s) is trimmed to a specific or a predetermined length, which may in turn be tailored according to specifications. This may, for example, be carried out by a trimming unit configured to trim the cured fiber(s) to a predetermined length in the range of about 10 mm to about 200 mm, such as about 50 mm to about 200 mm, about 100 mm to about 200 mm, about 120 mm to about 200 mm, about 150 mm to about 200 mm, about 10 mm to about 150 mm, about 10 mm to about 100 mm, about 10 mm to about 50 mm, about 50 mm to about 150 mm, or about 60 mm to about 120 mm. Trimming of the cured fiber(s) may also be carried out in the event that two or more fiber reinforced orthodontic appliances are manufactured in a single production run, for example, sequentially along the one or more monomer resin-coated fibers, so as to separate the individual fiber reinforced orthodontic appliance.

[0073] An illustration of the above processes is shown in **FIG. 6A**. **FIG. 6A** shows the monomer resin-coated fiber **671** being conveyed through a wire bending unit **611**. While the shaping of the fiber is carried out by the wire bending unit **611** or within a predetermined period of time from the shaping, the spot curing unit **612** comprising a radiation source **6121** and a radiation focusing component **6122** provides a spot focused radiation **6123** and spot cures the shaped portion of the monomer resin-coated fiber **671**. The cured fiber **672** may be moved from the spot curing unit **612** by a wire pulling unit **604** configured to pull the cured fiber through the wire bending unit **611**, to a trimming unit **605** configured to trim the cured fiber to a predetermined length to obtain the fiber reinforced orthodontic appliance.

[0074] In various embodiments, the method disclosed herein further comprises making a single mark at a center portion of the shaped fiber. In some embodiments, the method disclosed herein further comprises making two marks on the shaped fiber, one at a center portion and the other at a side portion of the shaped fiber. The marking may be carried out in a marking unit configured to make a single mark at a center portion, or two marks at a center portion and a side portion of the shaped fiber. The side portion of the shaped fiber may be located on the right hand side of the shaped fiber, and corresponding to the left hand side of a patient. These marks may be used to guide an orthodontist in installing the fiber reinforced orthodontic appliance in the proper position in a patient's mouth.

[0075] To mark the center portion and/or the side portion of the shaped fiber, a computer vision system may be used. In addition, or alternatively, the wire pulling unit may be used to

measure the length of the wire and a center portion of the shaped fiber may be located according to its CAD model.

[0076] Various embodiments refer in a second aspect to a fiber reinforced orthodontic appliance manufactured by a method according to the first aspect. As mentioned above, methods disclosed herein allow a fiber reinforced orthodontic appliance with an accurate profile to be manufactured.

[0077] In a further aspect, an apparatus for manufacturing a fiber reinforced orthodontic appliance is provided. Advantageously, the apparatus disclosed herein allows the method of manufacturing a fiber reinforced orthodontic device to be automated, thereby improving accuracy of the resultant appliance as well as increasing efficiency of the manufacturing process.

[0078] The apparatus comprises a wire bending unit configured to shape one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient; and a spot curing unit configured to spot cure a shaped portion of the one or more monomer resin-coated fibers as the shaping is carried out. Details of the wire bending unit and the spot curing unit have already been discussed above.

[0079] In various embodiments, the wire bending unit comprises a six freedoms wire bending part.

[0080] The spot curing unit may comprise a radiation source and a radiation focusing component. The radiation source may, for example, be selected from the group consisting of an infra-red radiation source, a visible light radiation source, an ultraviolet ray source, an x-ray source, a gamma ray source, a beta particle source, a high energy electron source, and combinations thereof. The radiation focusing component may comprise an optical lens. In various embodiments, the spot curing unit is configured to generate a spot focused radiation having a maximal width in the range of about 2 mm to about 10 mm, such as about 4 mm to about 10 mm, about 5 mm to about 10 mm, about 8 mm to about 10 mm, about 2 mm to about 8 mm, about 2 mm to about 5 mm, about 3 mm to about 8 mm, or about 4 mm to about 6 mm. In specific embodiments, the spot curing unit is configured to generate a spot focused radiation having a maximal width in the range of about 3 mm to about 5 mm.

[0081] As mentioned above, the shaped portion of the one or more monomer resin-coated fibers may be spot cured at the same time as or at a predetermined period of time after the

shaping is carried out. In various embodiments, the spot curing unit is configured to spot cure the shaped portion of the one or more monomer resin-coated fibers within 15 seconds from forming of the shaped portion, such as within 12 seconds, 10 seconds, 8 seconds, 6 seconds, 5 seconds, 3 seconds, or 1 second, from forming of the shaped portion. In specific
5 embodiments, the spot curing unit is configured to spot cure the shaped portion of the one or more resin-coated fibers immediately as the shaped portion is being formed.

[0082] To convey the one or more monomer resin-coated fibers for shaping by the wire bending unit, the apparatus may further comprise a wire pulling unit configured to pull the one or more monomer resin-coated fibers through the wire bending unit. As discussed above,
10 the wire pulling unit may work in tandem with the wire bending unit to provide movements of the one or more monomer resin-coated fibers through the wire bending unit, in order that the one or more monomer resin-coated fibers may be shaped continually by the wire bending unit along their length according to digital information correlated to the dental anatomy of an individual patient.

[0083] As mentioned above, the digital data correlated to the dental anatomy of an individual patient may be stored in an off-site location or not stored on the apparatus. Accordingly, shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient may comprise retrieving the digital
20 information from an external data server.

[0084] The apparatus disclosed herein may therefore further comprise a communication unit that is adapted to remotely transfer data with an external device. The communication unit may be adapted to transfer data via a network, such as a local area network (LAN), a wireless local area network (WLAN), a wide area network (WAN), a wireless wide area network
25 (WWAN), a virtual private network (VPN), cellular network, a wireless network, a wired network, the internet, an intranet, a satellite communication network, bluetooth, infrared and a combination thereof. Accordingly, the communication unit may be a modem for connecting to the internet, or a mobile communication unit such as a cellular phone. A data storage unit may also be comprised in the apparatus for storing the digital information.

[0085] In various embodiments, the apparatus for manufacturing a fiber reinforced orthodontic appliance further comprises a forming unit. The forming unit may comprise a reservoir configured to receive a monomer resin, and a conveying mechanism configured to
30

convey one or more fibers through the reservoir so that an external surface of each of the one or more fibers is coated with the monomer resin to form one or more monomer resin-coated fibers. The conveying mechanism may comprise one or more rollers. Details of the forming unit comprising the reservoir and the conveying mechanism have already been described
5 above.

[0086] In some embodiments, the conveying mechanism is configured to convey the one or more fibers through the reservoir so that the one or more monomer resin-coated fibers exit the reservoir on the same side at which the one or more fibers enter the reservoir. As the one or more monomer resin-coated fibers exit the reservoir on the same side at which the one or
10 more fibers enter the reservoir, the forming unit may be horizontally disposed such as that shown in **FIG. 7**.

[0087] The apparatus disclosed herein may further comprise a pre-shaping unit configured to bundle a plurality of monomer resin-coated fibers to form a bundled fiber. The pre-shaping unit may be arranged downstream of the forming unit to allow coating of the one or more
15 fibers with the monomer resin prior to bundling. In various embodiments, the pre-shaping unit comprises a pre-shaping roller. Details of the pre-shaping unit have already been discussed above.

[0088] In various embodiments, the apparatus disclosed herein further comprises a forming part having an inner wall defining an aperture, the aperture being configured to
20 define a cross-sectional size and/or cross-sectional shape of the one or more monomer resin-coated fibers. As mentioned above, the forming part may be programmable in that size and/or shape of the aperture may be varied according to specific requirements of the fiber reinforced orthodontic appliance.

[0089] The apparatus disclosed herein may further comprise a trimming unit configured to
25 trim the cured fiber(s) to a desired length, and/or a marking unit configured to make a single marking at a center portion, or two markings at a center portion and a side portion of the shaped fiber.

[0090] Advantageously, some or all of the above-mentioned units and components may be contained within a housing. The housing may protect the units contained within, and may
30 confer portability to the apparatus, i.e. it may be carried or transported easily. It is envisioned that for different embodiments, for example different models of the apparatus, combinations of the above-mentioned units such as the forming unit, the pre-shaping unit, the forming part,

the wire pulling unit, the trimming unit and/or the marking unit, may be comprised within the housing.

[0091] Depending on the combination of units in the housing, a transport unit may be present in the apparatus to transfer the fibers to the various units in the apparatus. Any transporting unit that is operative to transfer the fibers from the various units in the apparatus may be used. For example, the transporting unit may be rollers, a conveyor belt, or robotic arms. A loading unit and an unloading unit adapted to load and unload the fibers and/or fiber reinforced orthodontic appliance from the apparatus may also be present.

[0092] Various embodiments also refer in a further aspect to a use of a method according to the first aspect or an apparatus according to the third aspect in the manufacture of a fiber reinforced orthodontic device. As mentioned above, the method and apparatus disclosed herein may improve accuracy of the resultant appliance as well as increase efficiency of the manufacturing process.

[0093] The invention has been described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the invention. This includes the generic description of the invention with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

[0094] Other embodiments are within the following claims and non-limiting examples. In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognize that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0095] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

CLAIMS

1. A method of manufacturing a fiber reinforced orthodontic appliance, the method comprising
 - 5 a) providing one or more monomer resin-coated fibers,
 - b) shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient, and
 - 10 c) spot curing the shaped portion of the one or more monomer resin-coated fibers as the shaping is carried out to obtain the fiber reinforced orthodontic appliance.
2. The method according to claim 1, wherein providing one or more monomer resin-coated fibers comprises coating an external surface of each of one or more fibers with a monomer resin.
- 15 3. The method according to claim 2, wherein coating an external surface of each of the one or more fibers with a monomer resin comprises conveying the one or more fibers through a reservoir containing the monomer resin so that the one or more monomer resin-coated fibers exit the reservoir on the same side at which the one or more fibers enter the reservoir.
- 20 4. The method according to claim 3, wherein conveying the one or more fibers through the reservoir containing the monomer resin is carried out using rollers.
- 25 5. The method according to any one of claims 1 to 4, wherein a plurality of the monomer resin-coated fibers is provided.
6. The method according to claim 5, further comprising bundling the plurality of monomer resin-coated fibers to form a bundled fiber.
- 30 7. The method according to claim 6, wherein bundling the plurality of monomer resin-coated fibers comprises conveying the plurality of monomer resin-coated fibers through a pre-shaping unit configured to bundle the plurality of monomer resin-coated fibers to form the bundled fiber.

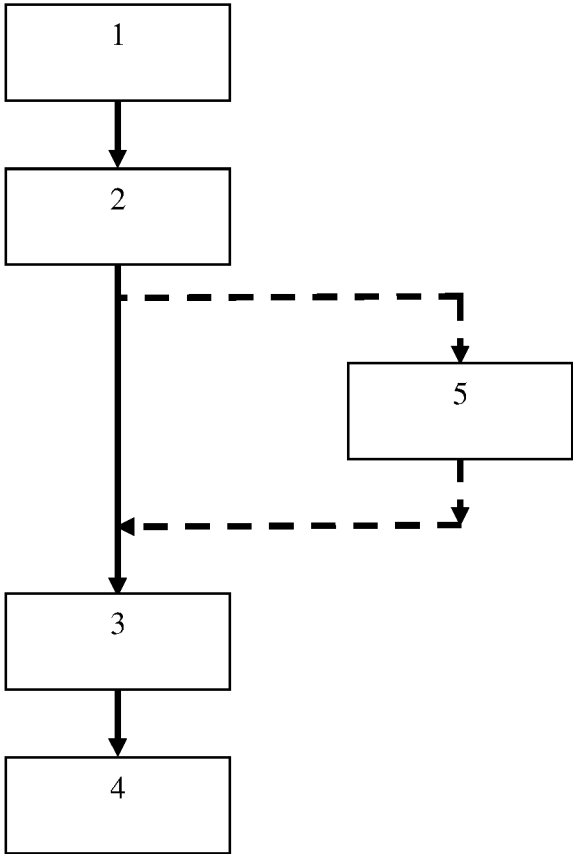
8. The method according to any one of claims 1 to 7, further comprising conveying the one or more monomer resin-coated fibers through an aperture defined by an inner wall of a forming part, wherein the aperture is configured to define a cross-sectional size and/or cross-sectional shape of the one or more monomer resin-coated fibers.
9. The method according to any one of claims 1 to 8, wherein shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient is carried out using a wire bending unit.
10. The method according to claim 9, wherein the wire bending unit comprises a six freedoms wire bending part.
11. The method according to any one of claims 1 to 10, wherein shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient comprises retrieving the digital information from an external data server.
12. The method according to any one of claims 1 to 11, wherein shaping the one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient comprises pulling the one or more monomer resin-coated fibers through the wire bending unit by a wire pulling unit.
13. The method according to any one of claims 1 to 12, wherein spot curing the shaped portion of the one or more monomer resin-coated fibers comprises irradiating a focused blue light on the shaped portion.
14. The method according to any one of claims 1 to 13, further comprising trimming the cured fiber(s) to a predetermined length.

15. The method according to any one of claims 1 to 14, further comprising making a mark at a center portion and/or at a side portion of the shaped fiber.
- 5 16. A fiber reinforced orthodontic appliance manufactured by a method according to any one of claims 1 to 15.
17. An apparatus for manufacturing a fiber reinforced orthodontic appliance, the apparatus comprising
 - 10 a) a wire bending unit configured to shape one or more monomer resin-coated fibers continually along the length of the one or more monomer resin-coated fibers according to digital information correlated to the dental anatomy of an individual patient; and
 - b) a spot curing unit configured to spot cure a shaped portion of the one or more
15 monomer resin-coated fibers as the shaping is carried out.
18. The apparatus according to claim 17, further comprising a reservoir configured to receive a monomer resin.
- 20 19. The apparatus according to claim 18, further comprising a conveying mechanism configured to convey one or more fibers through the reservoir so that an external surface of each of the one or more fibers is coated with the monomer resin to form one or more monomer resin-coated fibers.
- 25 20. The apparatus according to claim 19, wherein the conveying mechanism is configured to convey the one or more fibers through the reservoir so that the one or more monomer resin-coated fibers exit the reservoir on the same side at which the one or more fibers enter the reservoir.
- 30 21. The apparatus according to claim 19 or 20, wherein the conveying mechanism comprises one or more rollers.

22. The apparatus according to any one of claims 17 to 21, further comprising a pre-shaping unit configured to bundle a plurality of monomer resin-coated fibers to form a bundled fiber.
- 5 23. The apparatus according to claim 22, wherein the pre-shaping unit comprises a pre-shaping roller.
24. The apparatus according to any one of claims 17 to 23, further comprising a forming part having an inner wall defining an aperture, the aperture being configured to define
10 a cross-sectional size and/or cross-sectional shape of the one or more monomer resin-coated fibers.
25. The apparatus according to any one of claims 17 to 24, wherein the wire bending unit comprises a six freedoms wire bending part.
15
26. The apparatus according to any one of claims 17 to 25, further comprising a wire pulling unit configured to pull the one or more monomer resin-coated fibers through the wire bending unit.
- 20 27. The apparatus according to any one of claims 17 to 26, wherein the spot curing unit comprises a radiation source and a radiation focusing component.
28. The apparatus according to claim 27, wherein the radiation source is selected from the group consisting of an infra-red radiation source, a visible light radiation source, an
25 ultraviolet ray source, an x-ray source, a gamma ray source, a beta particle source, a high energy electron source, and combinations thereof.
29. The apparatus according to claim 27 or 28, wherein the radiation focusing component comprises an optical lens.
30

30. The apparatus according to any one of claims 17 to 29, wherein the spot curing unit is configured to generate a spot focused radiation having a maximal width in the range of about 3 mm to about 5 mm.
- 5 31. The apparatus according to any one of claims 17 to 30, wherein the spot curing unit is configured to spot cure the shaped portion of the one or more monomer resin-coated fibers immediately as the shaped portion is being formed.
- 10 32. The apparatus according to any one of claims 17 to 31, further comprising a trimming unit configured to trim the cured fiber(s) to a predetermined length.
- 15 33. The apparatus according to any one of claims 17 to 32, further comprising a marking unit configured to make a marking at a center portion and/or at a side portion of the fiber.
34. Use of a method according to any one of claims 1 to 15 or an apparatus according to any one of claims 17 to 33 in the manufacture of a fiber reinforced orthodontic appliance.

FIG. 1 (PRIOR ART)



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FIG. 2A

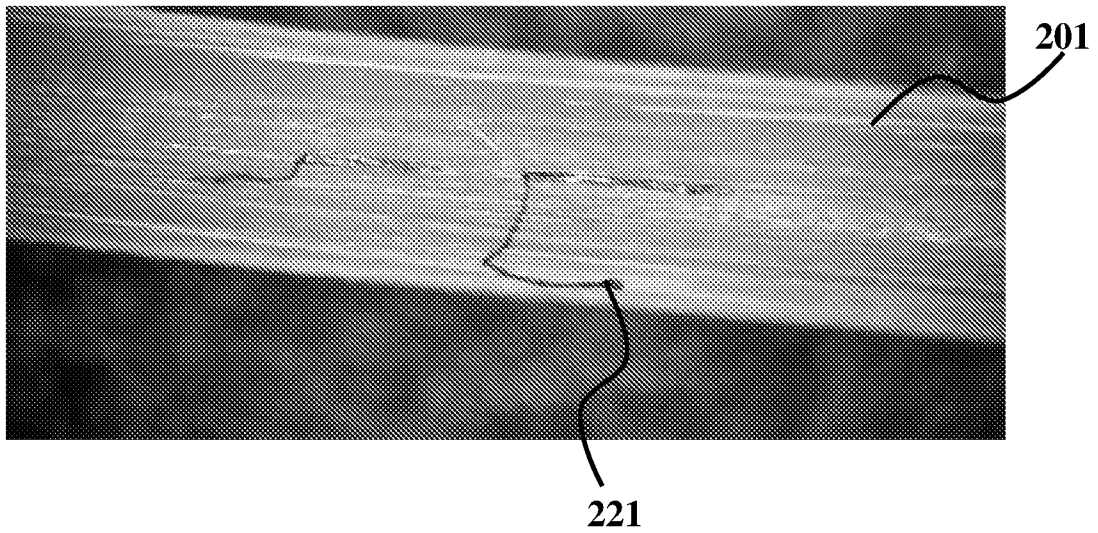
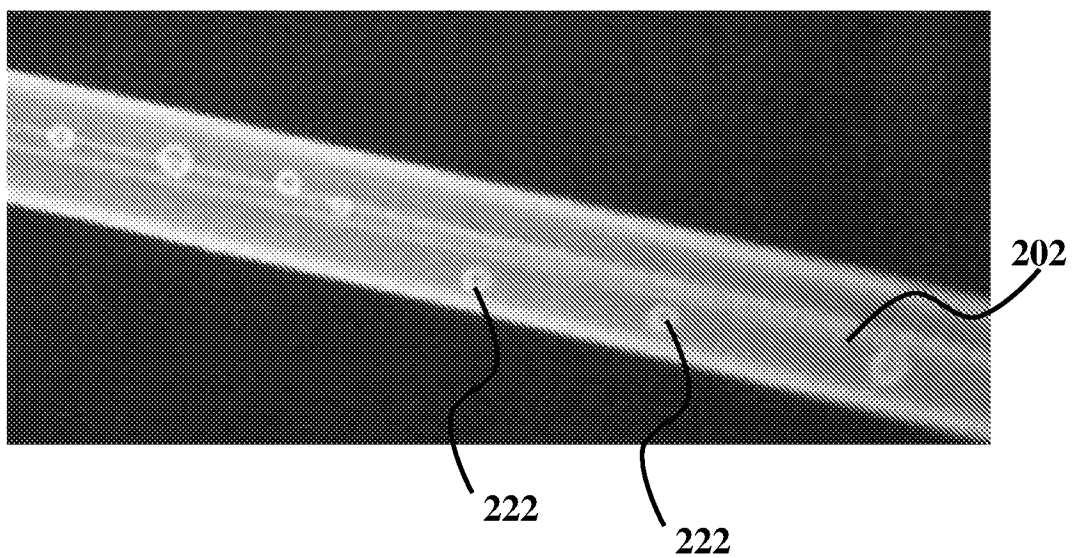


FIG. 2B



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FIG. 2C

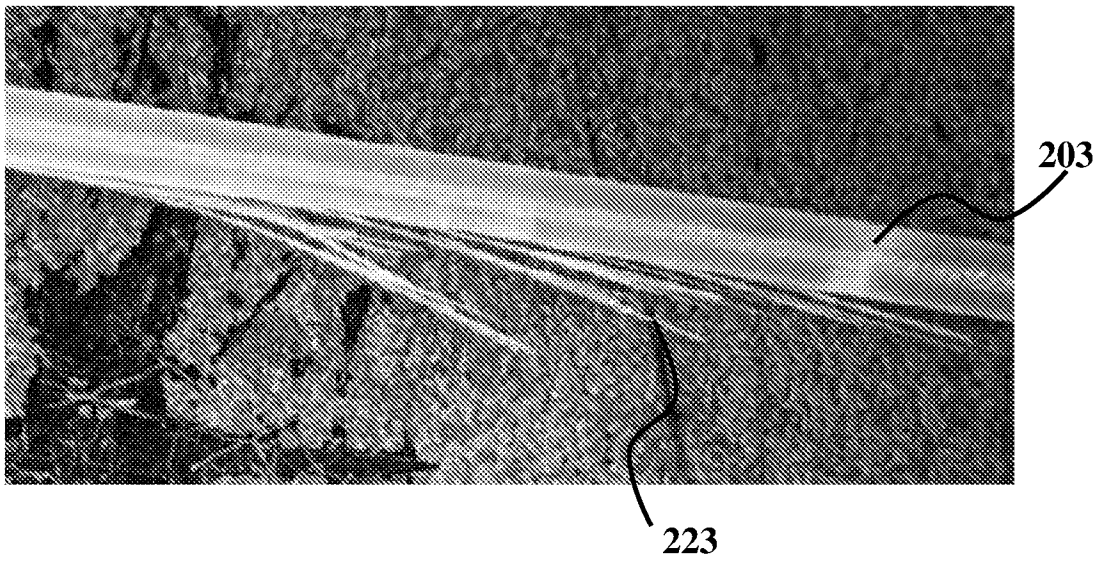
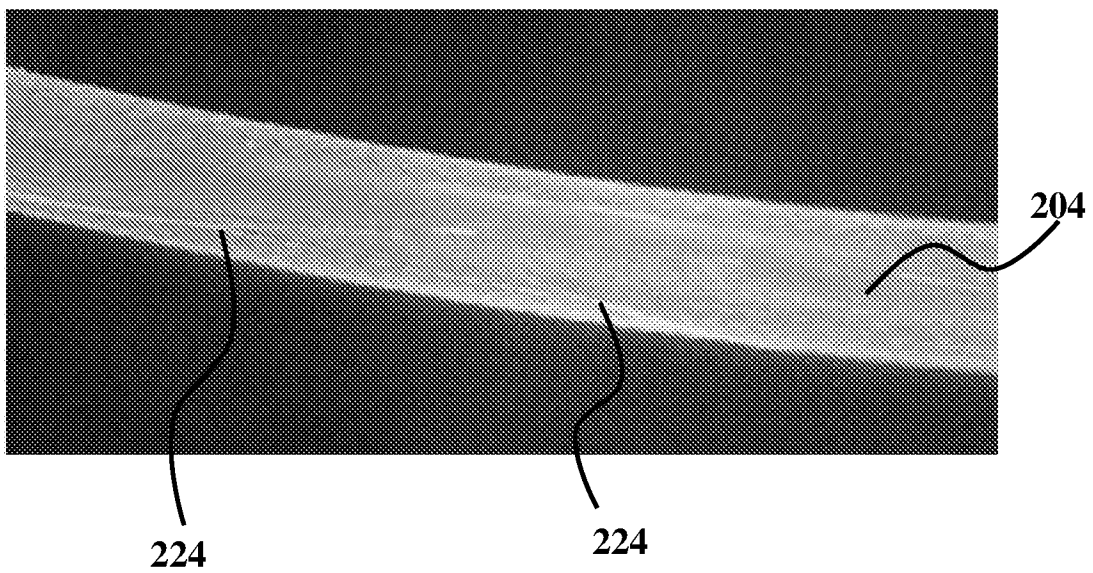


FIG. 2D



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FIG. 2E

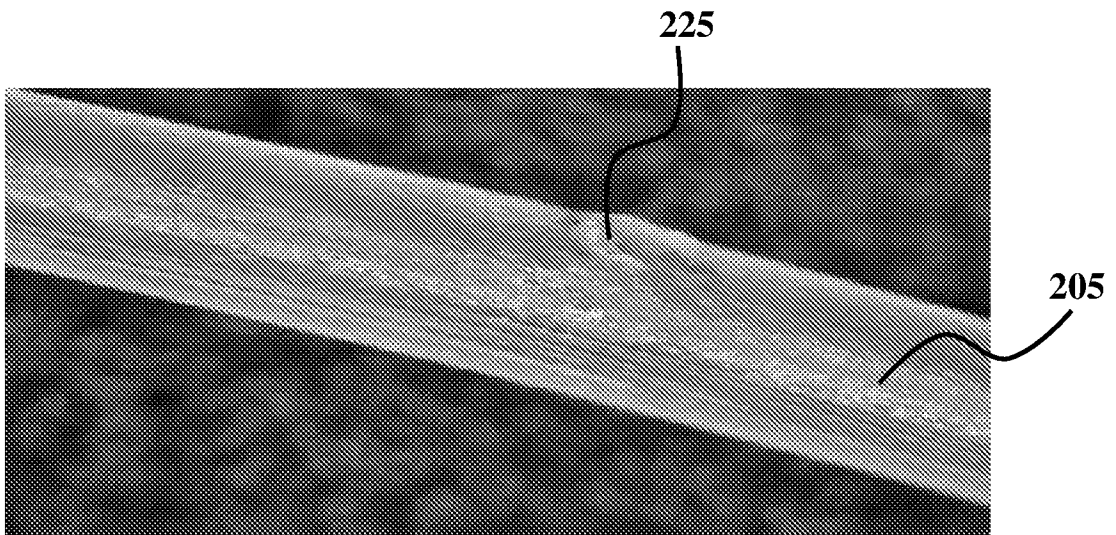


FIG. 2F

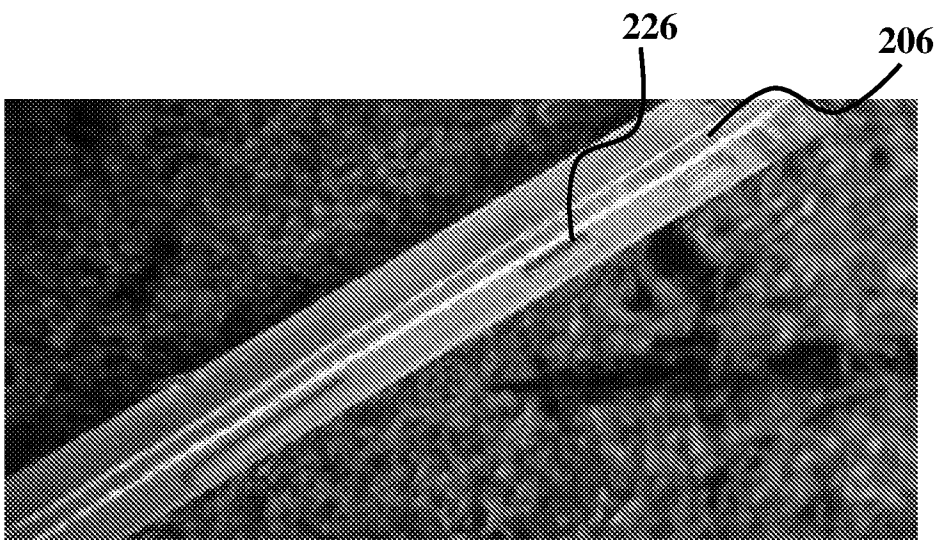


FIG. 3

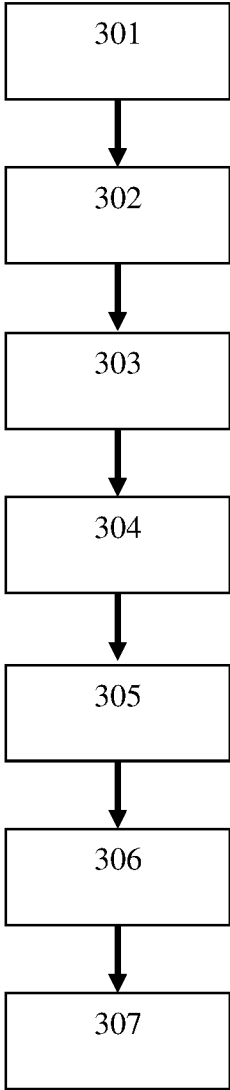


FIG. 4

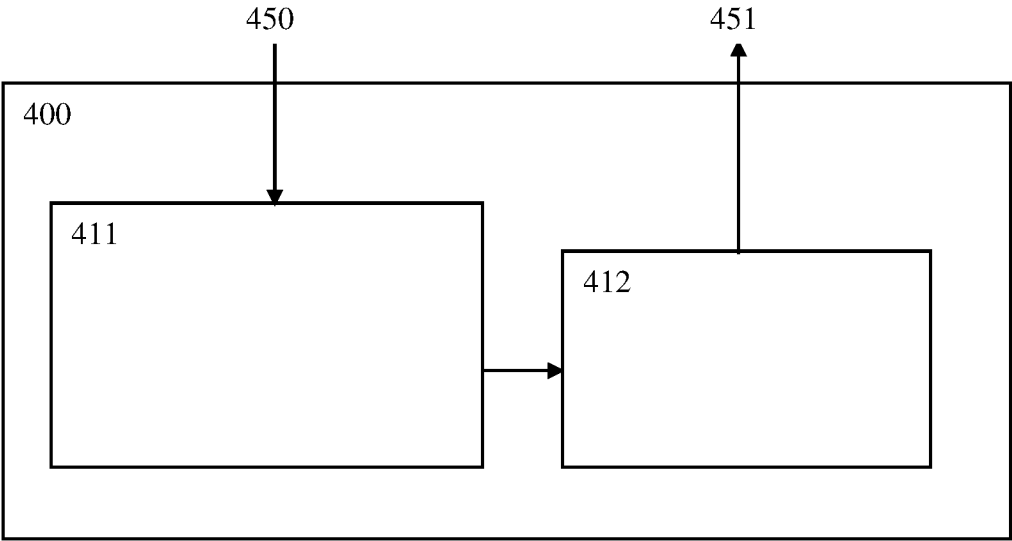


FIG. 5

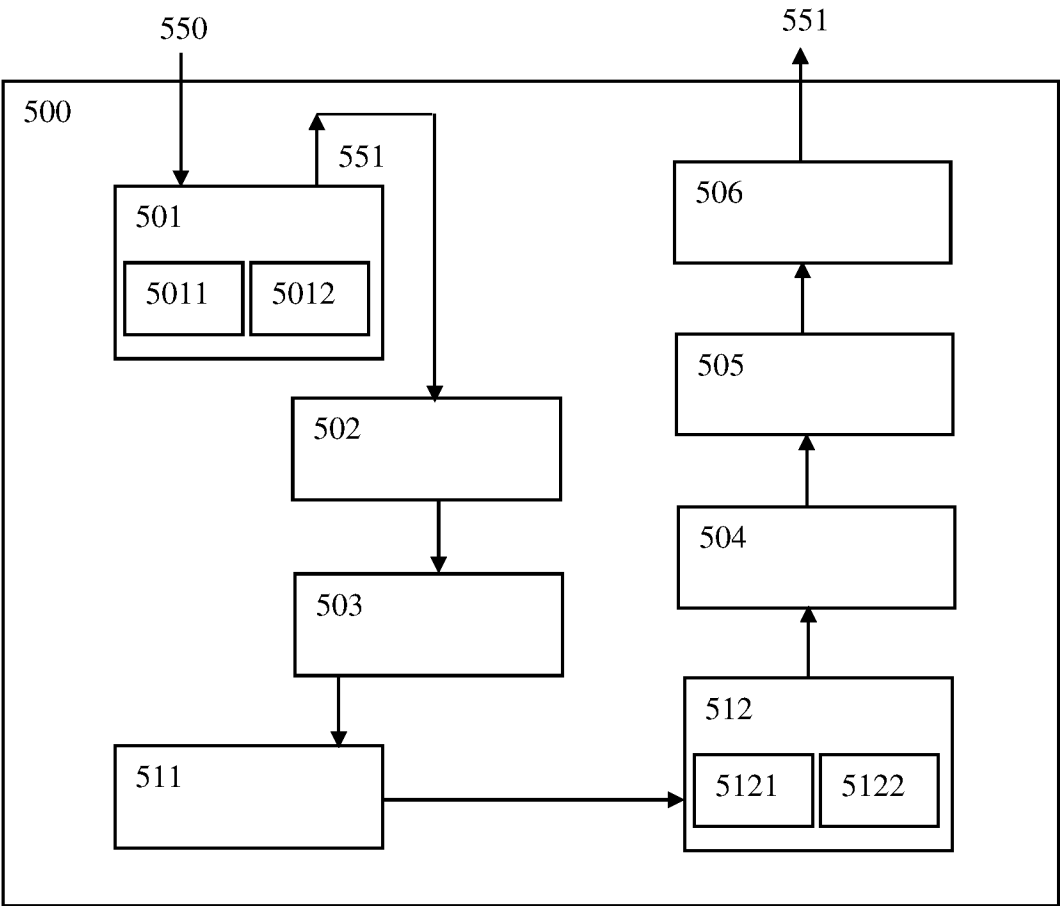
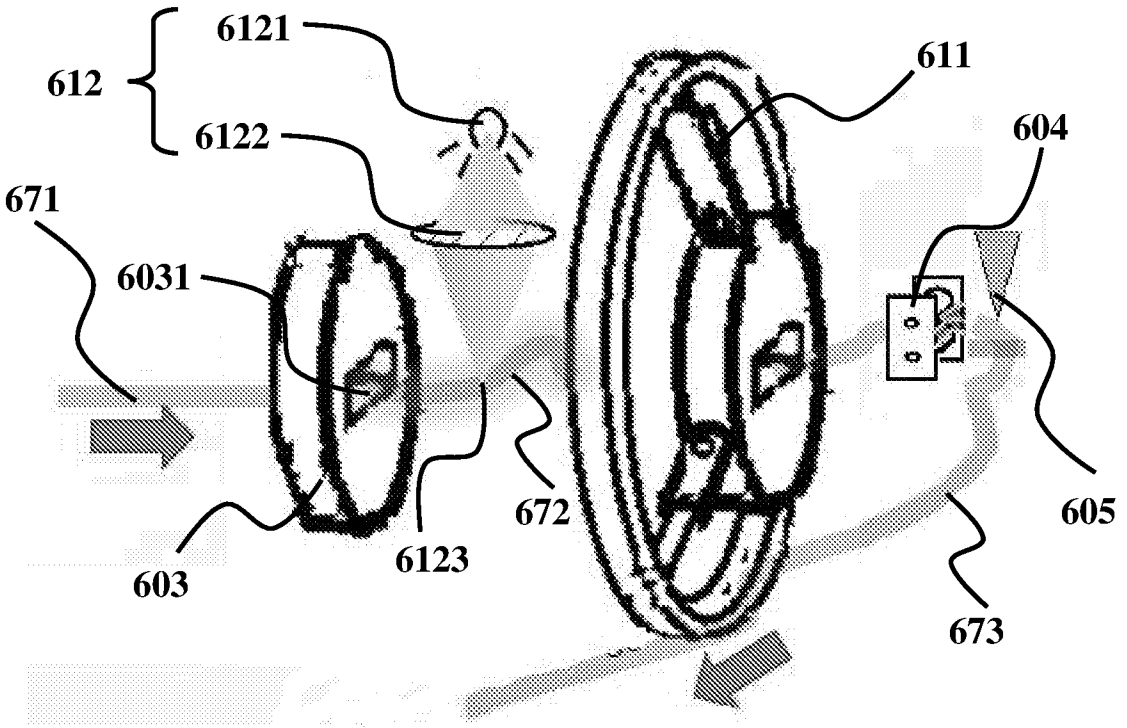
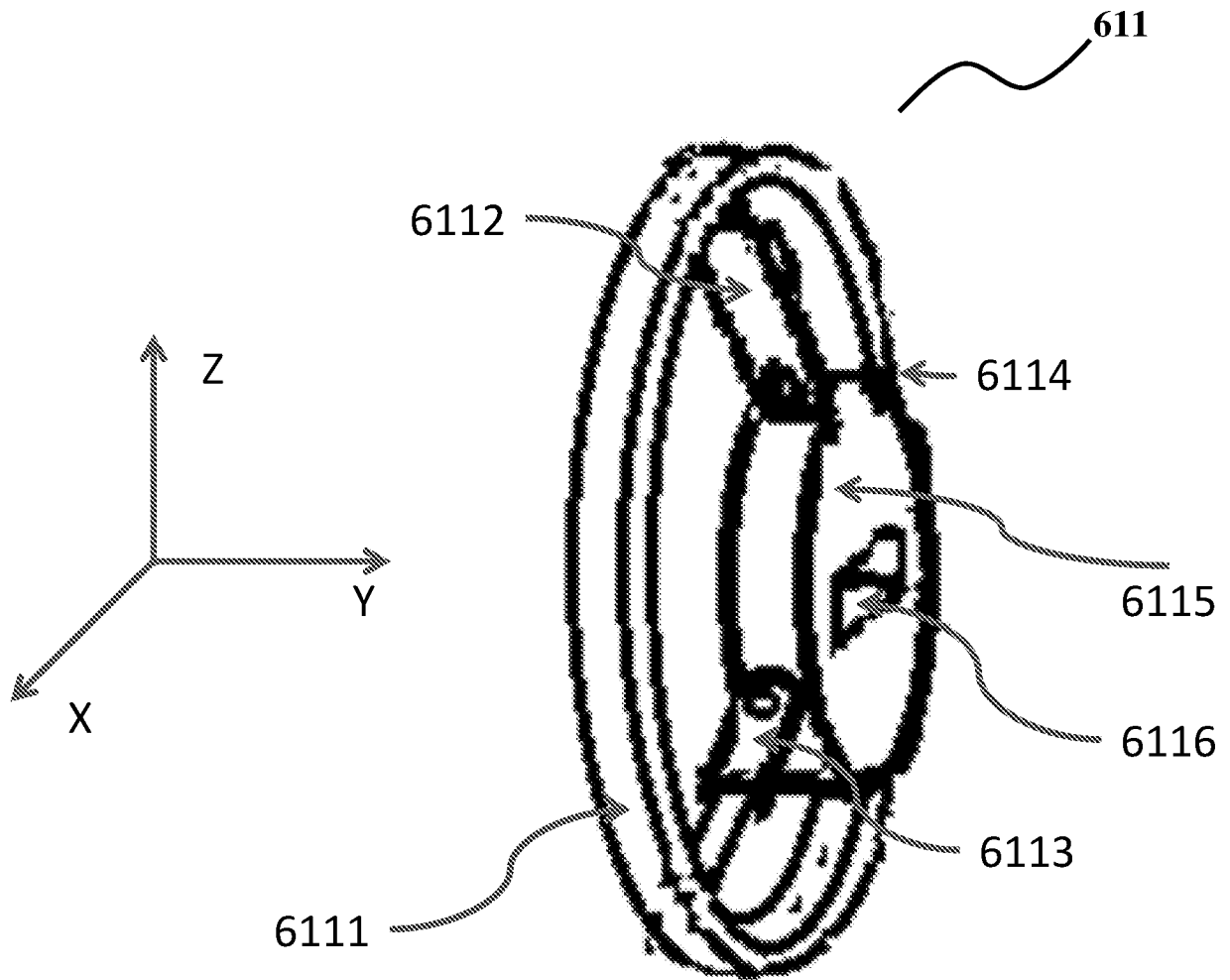


FIG. 6A



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FIG. 6B



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FIG. 7

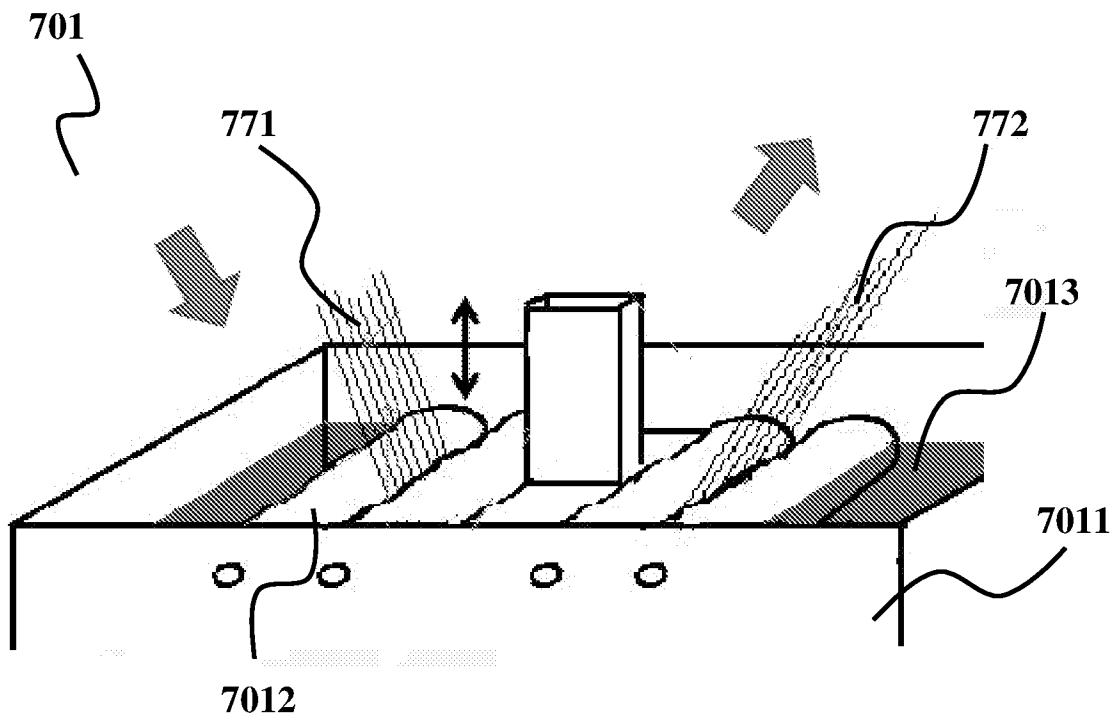


FIG. 8

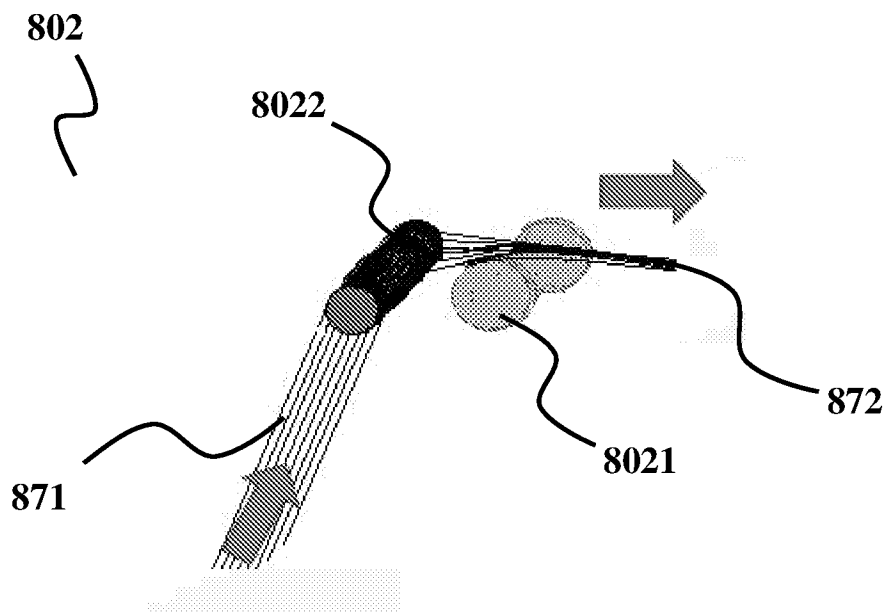
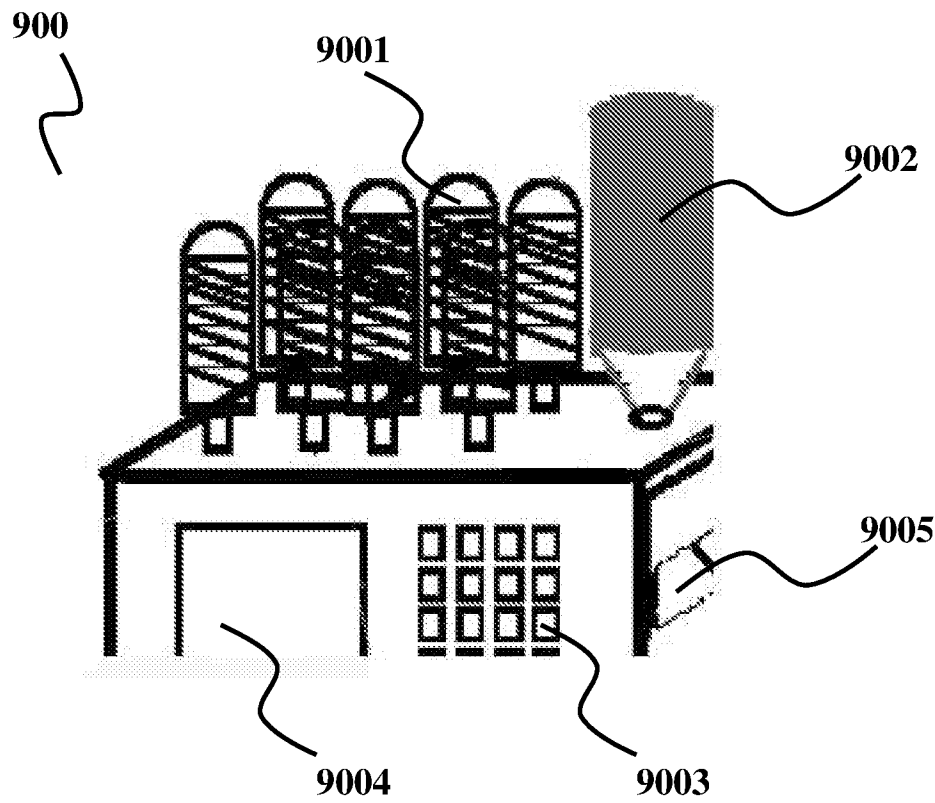


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050595

A. CLASSIFICATION OF SUBJECT MATTER

A61C 7/20 (2006.01) A61C 7/02 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61C, B29C, G06F

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)

EPODOC/WPI/TXTE/SCOPUS: orthodontic, appliance, archwire, resin, shape, bend, cure, polymerize and like terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2002/0180112 A1 (KUSY R. P. ET AL.) 5 December 2002 para.[0031]-[0036]; figures 1-2	1-34
Y	WO 01/80761 A2 (ORAMETRIX, INC.) 1 November 2001 figures 1, 95; page 8, lines 1-12	1-34
Y	US 2003/0056561 A1 (BUTSCHER W. ET AL.) 27 March 2003 para.[0013],[0067]-[0068], [0080]	1-34
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Y	US 2004/0072120 A1 (LAUREN, M. D.) 15 April 2004 figures 1-3; para.[0012]	1-34

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050595**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

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X	US 4869666 A (TALASS M. F.) 26 September 1989 figures 1-3; column 2, lines 7-43	16
X	ZHANG M. ET AL., E-Glass Fiber Reinforced Composites in Dental Applications. <i>Silicon</i> , 1 March 2011, Vol. 4, No. 1, pages 73-78 [Retrieved on 2017-02-07] <DOI: 10.1007/S12633-011-9075-X> sections 2-6 & 10	16

INTERNATIONAL SEARCH REPORT

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