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(54) **SLEEP APNEA AND ANTI-SNORING SYSTEM**

**Publication Classification**

(71) Applicant: **Real 3D Polymers Group LLC**, Troy, MI (US)

(51) **Int. Cl.**  
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*A61F 5/56* (2006.01)  
*A61B 5/00* (2006.01)  
*A61B 5/08* (2006.01)

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**Nidhi Shah**, Chicago, IL (US); **Dinesh Shah**, Troy, MI (US); **Shail Chokhavatia**, Paramus, NJ (US)

(52) **U.S. Cl.**  
CPC ..... *A61C 7/08* (2013.01); *A61F 5/566* (2013.01); *A61B 5/4818* (2013.01); *A61B 5/0816* (2013.01)

(21) Appl. No.: **17/564,908**

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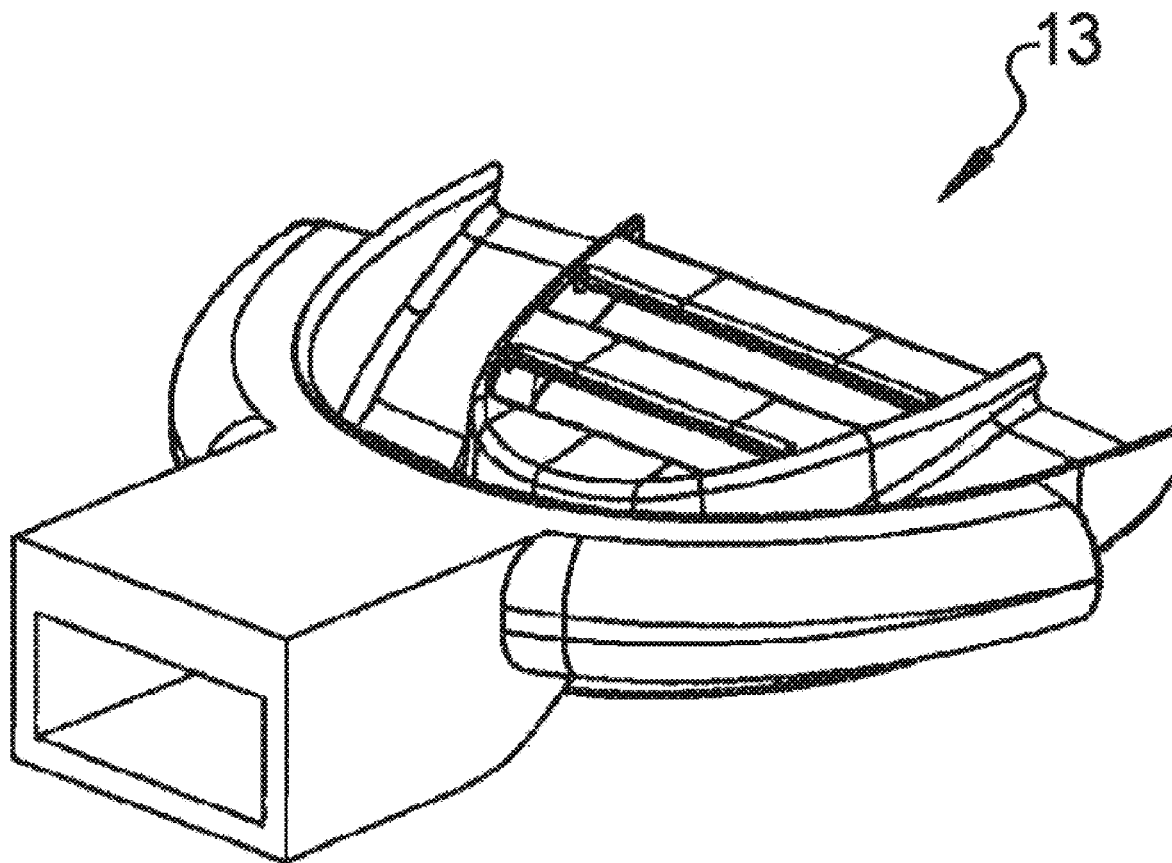
(57) **ABSTRACT**

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 15/383,514, filed on Dec. 19, 2016.

(60) Provisional application No. 62/269,331, filed on Dec. 18, 2015.

A micro, single piece, tubeless, cordless, directly inserted oral, nasal or hybrid sleep apnea treatment/anti-snoring device having controlled positive air-flow using a vibrationally isolated micro-blower to maintain an individual's upper airway unobstructed (pharynx area) with or without lower jaw, mandibular advancement is disclosed.



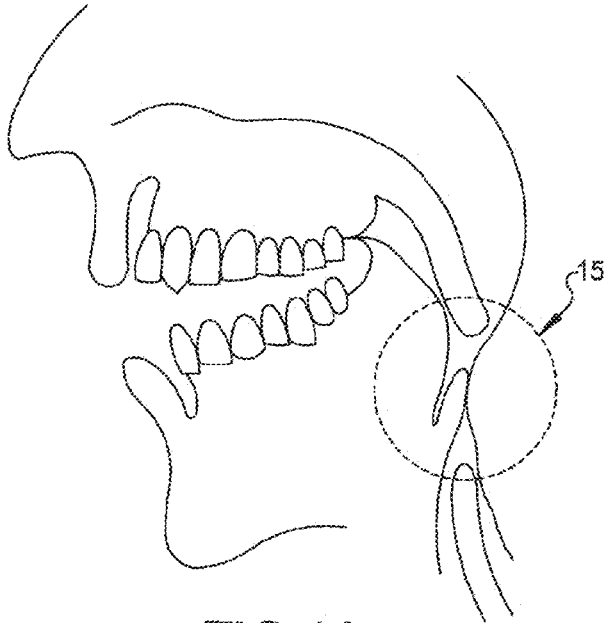


FIG 1A

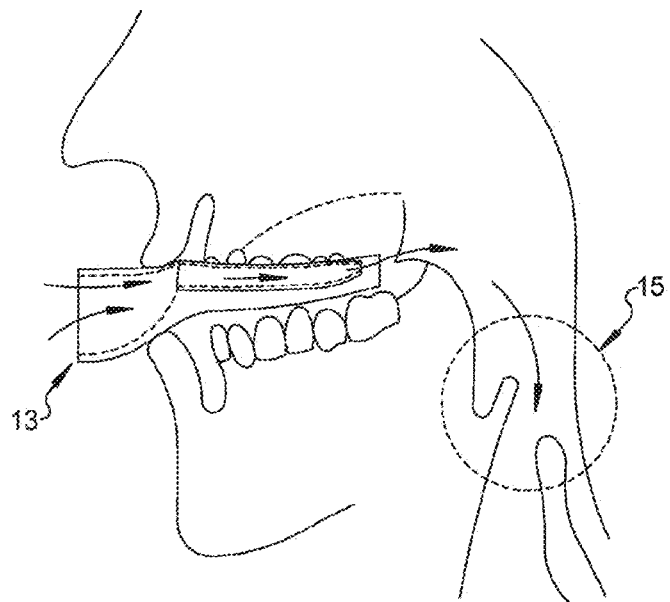


FIG 1B

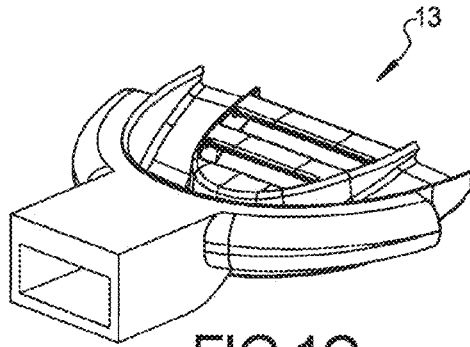


FIG 1C

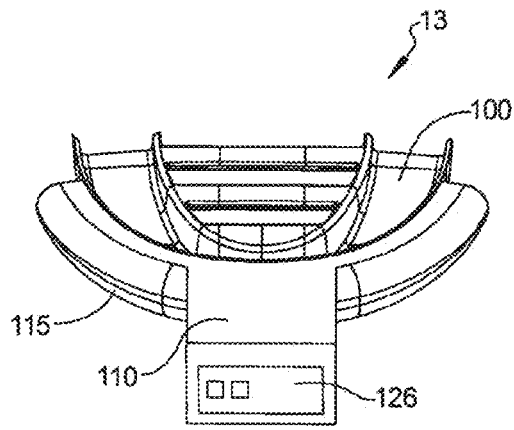


FIG 1D

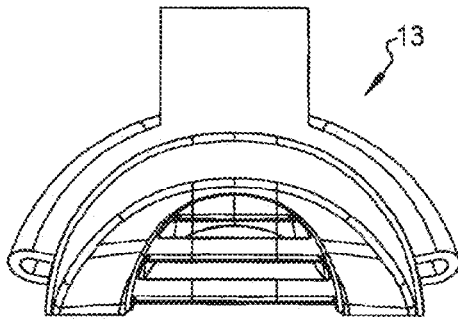


FIG 1E

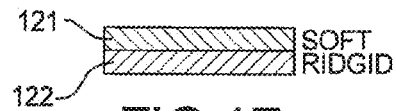


FIG 1F

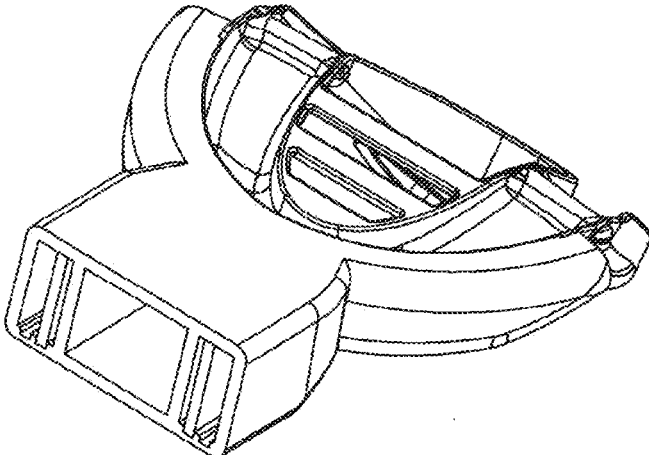


FIG 1G

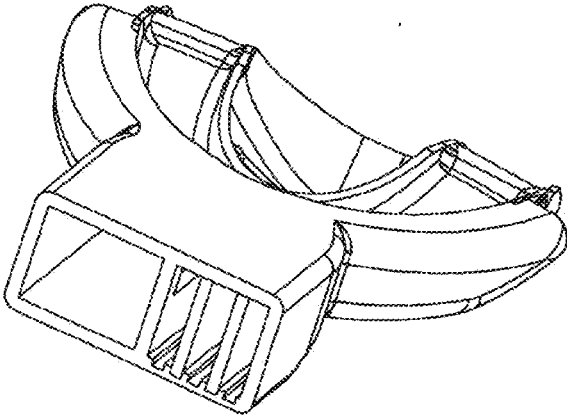


FIG 1H

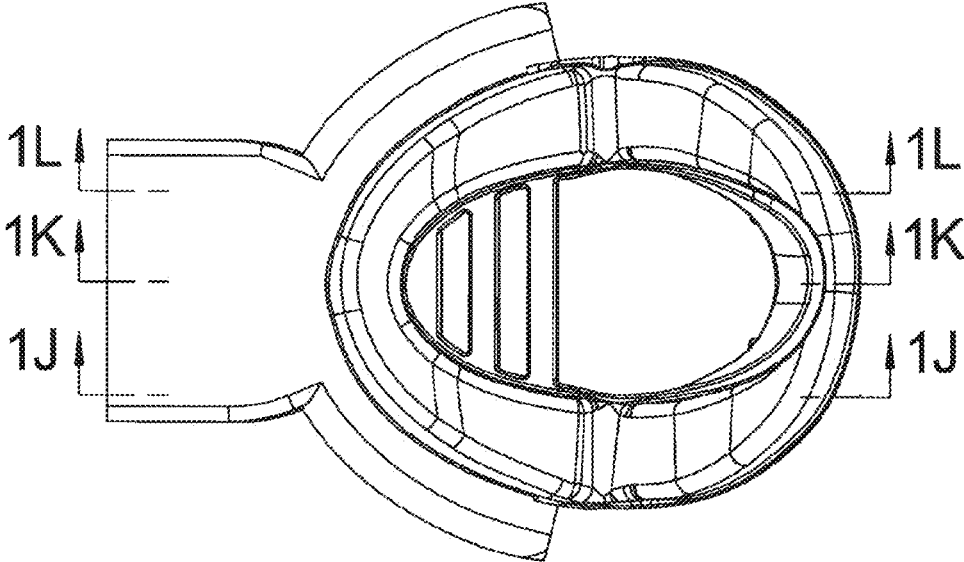


FIG 1I

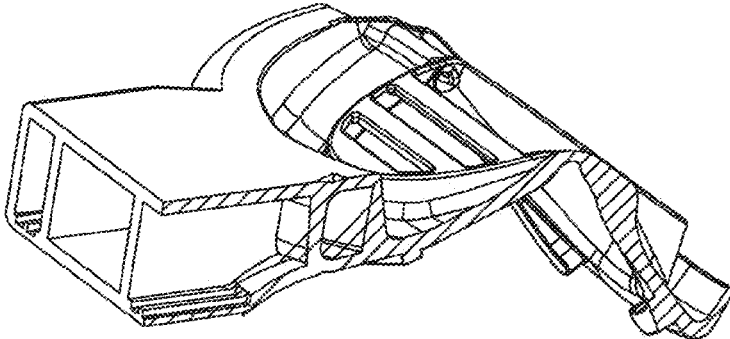


FIG 1J

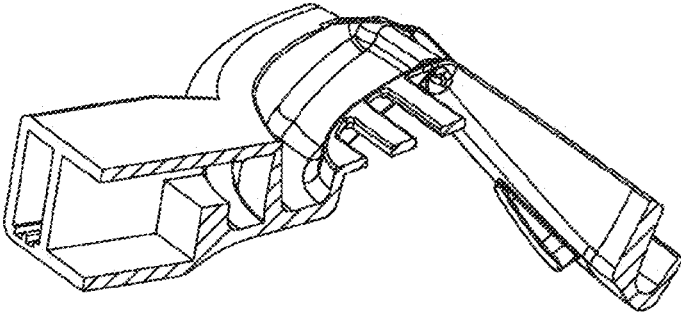


FIG 1K

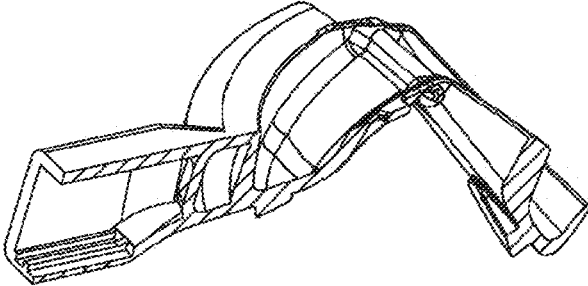


FIG 1L

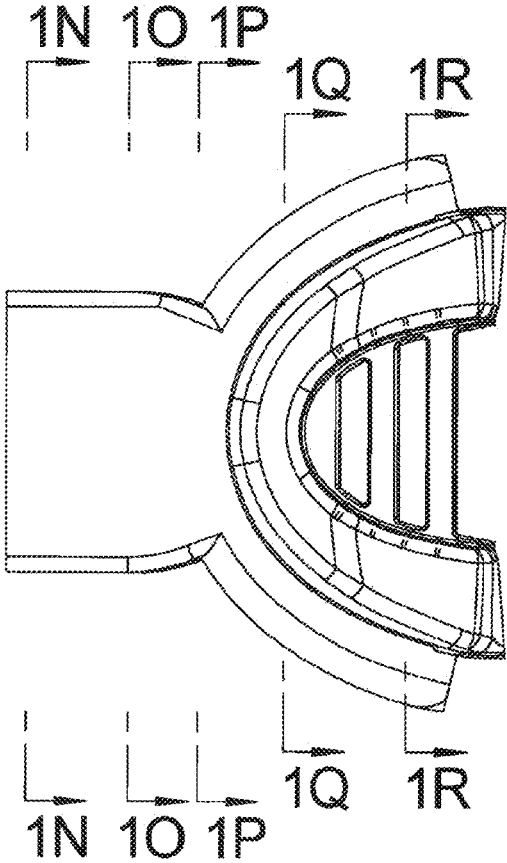


FIG 1M

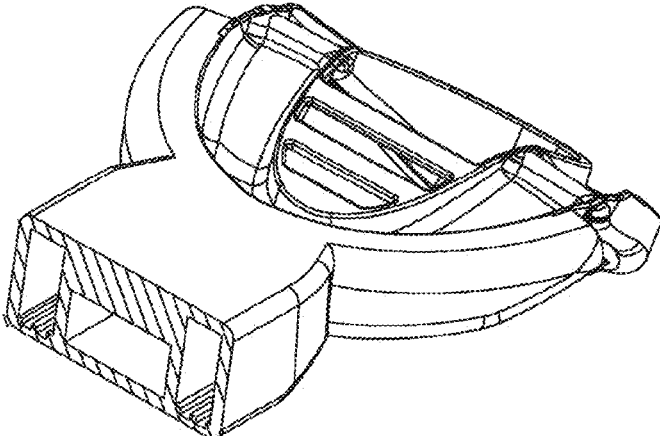


FIG 1N

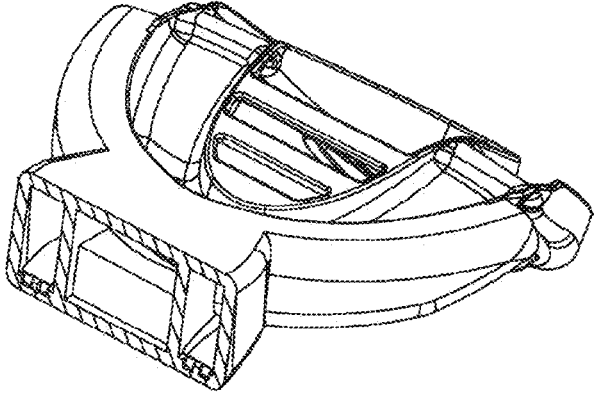


FIG 10



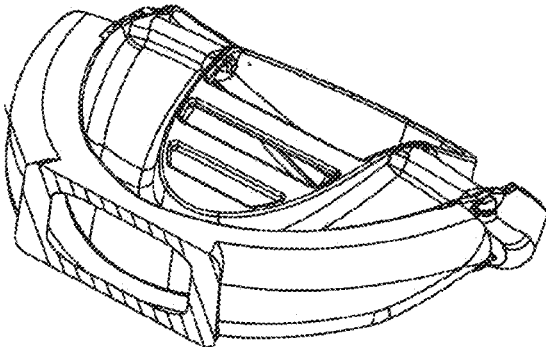


FIG 1P

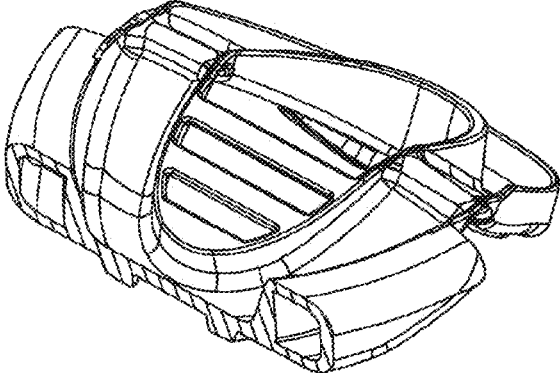


FIG 1Q

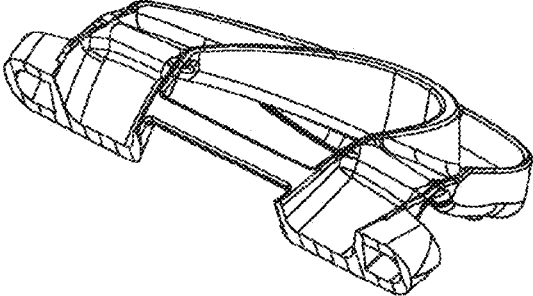


FIG 1R

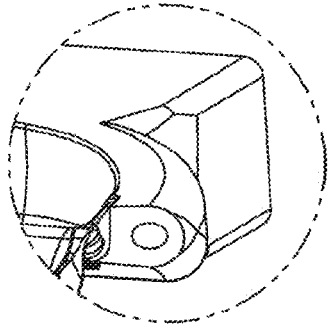


FIG 1S

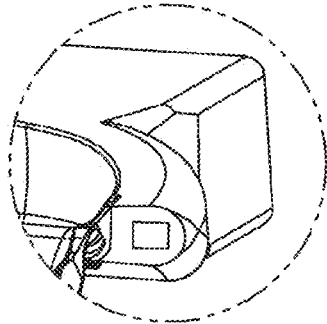


FIG 1T

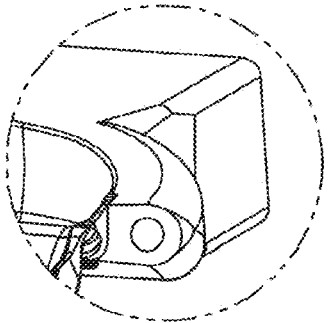


FIG 1U

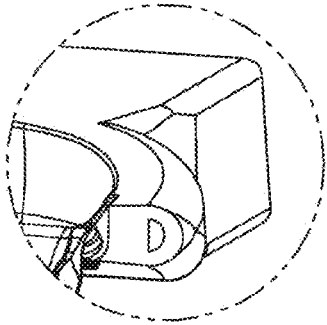


FIG 1V

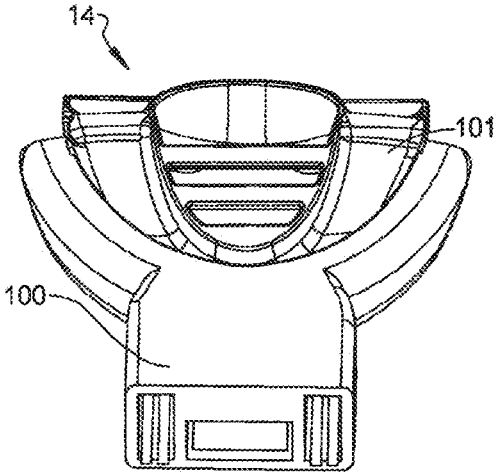


FIG 1W

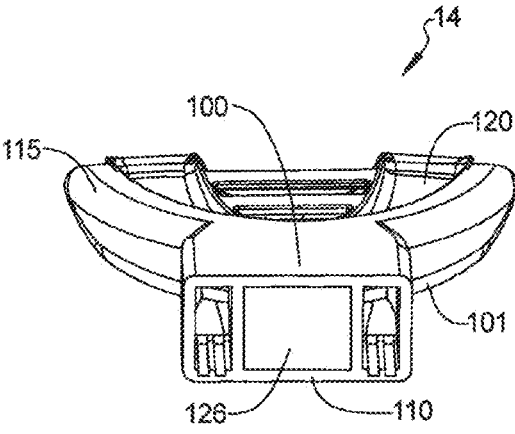


FIG 1X

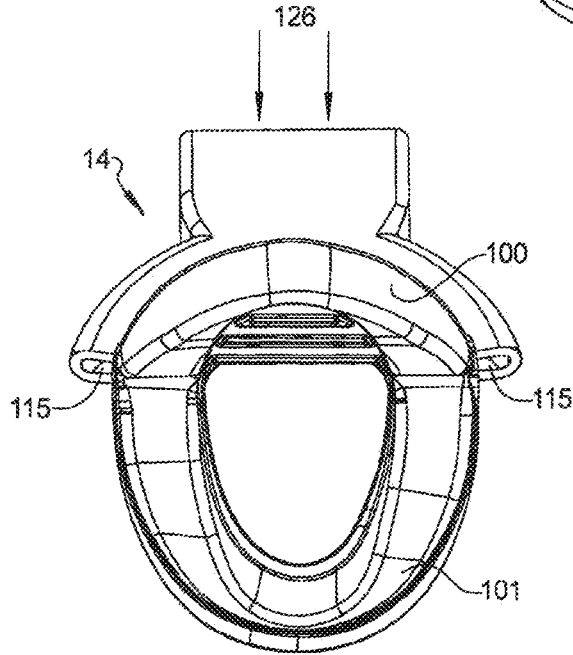


FIG 1Y

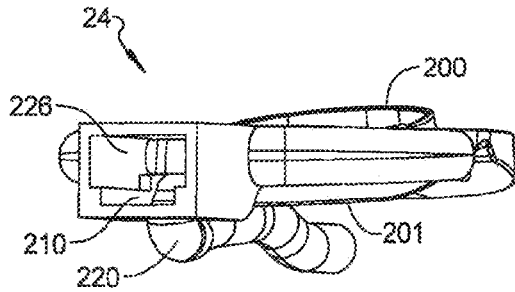


FIG 2A

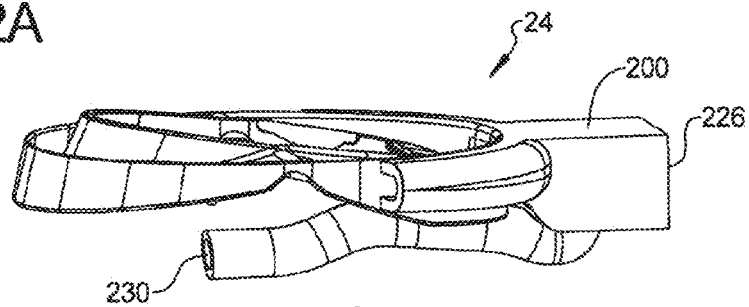


FIG 2B

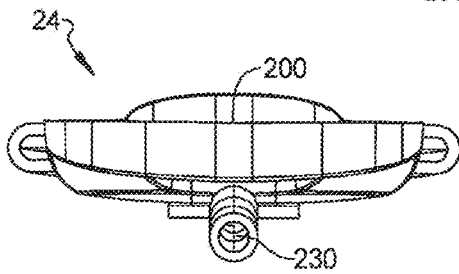


FIG 2C

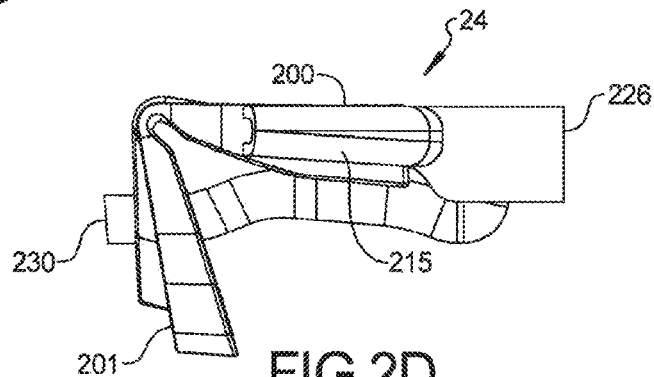


FIG 2D

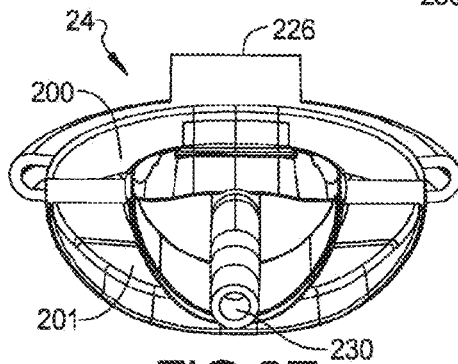


FIG 2E

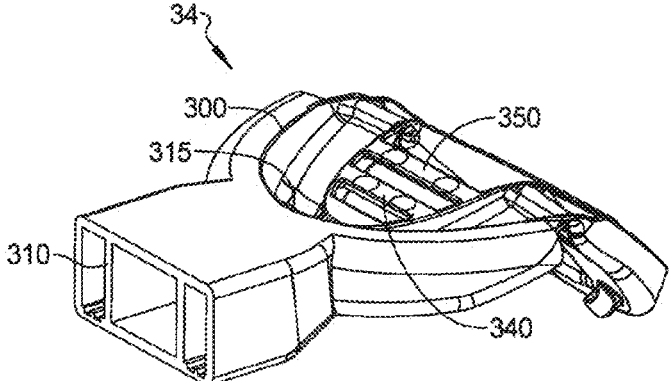


FIG 3A

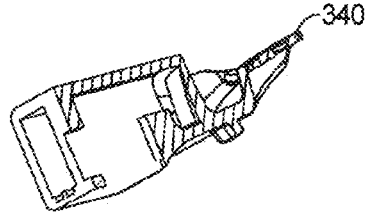
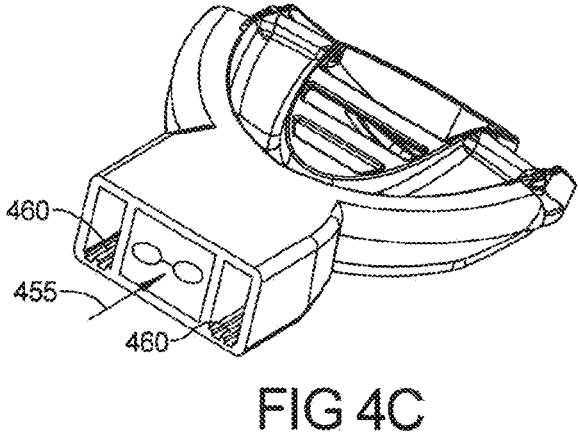
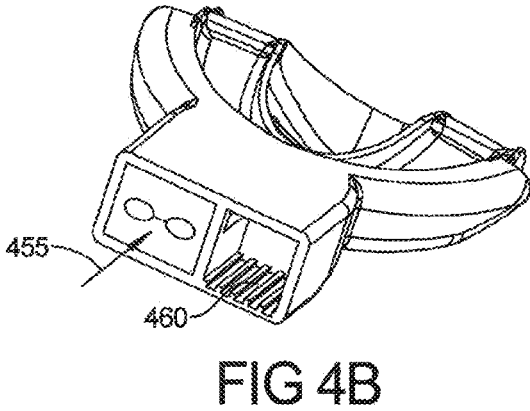
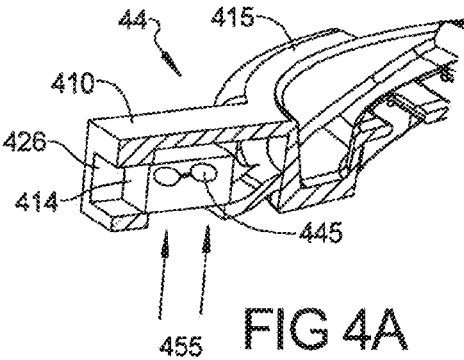


FIG 3B



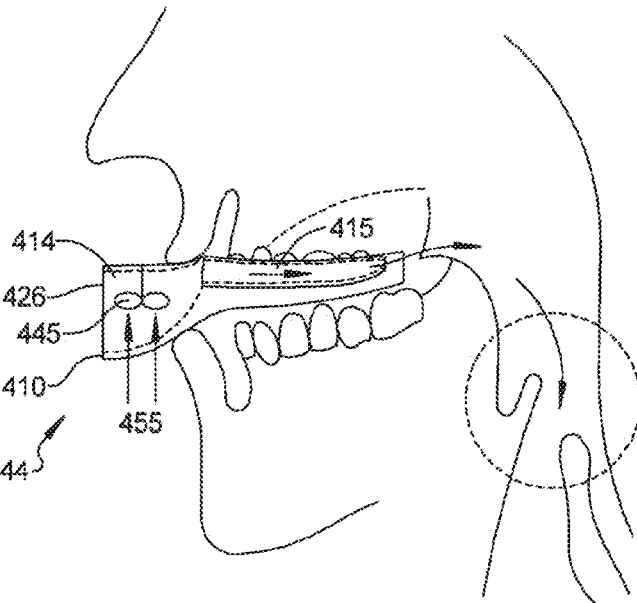


FIG 4D

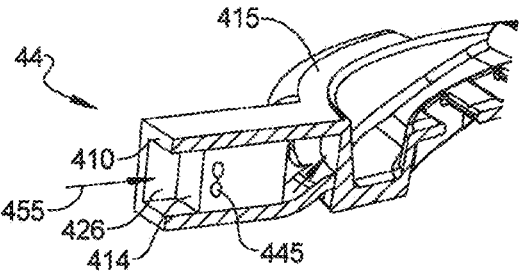


FIG 4E

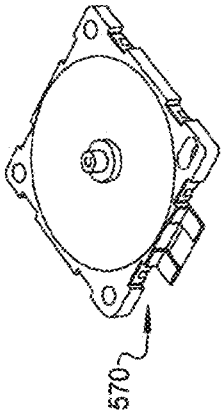


FIG 5A

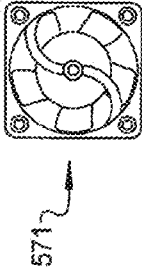


FIG 5B



FIG 5C

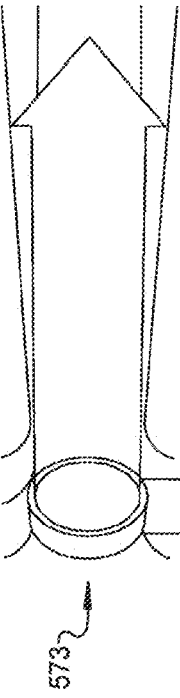
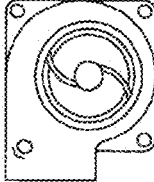
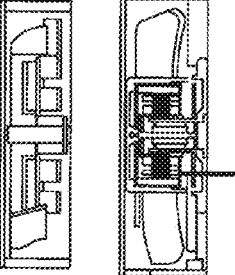
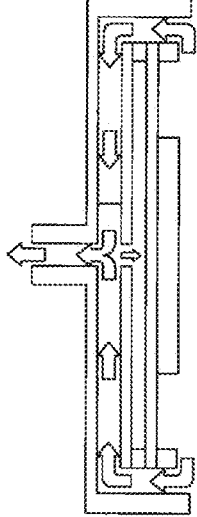
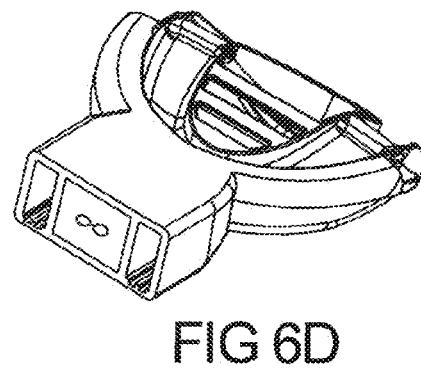
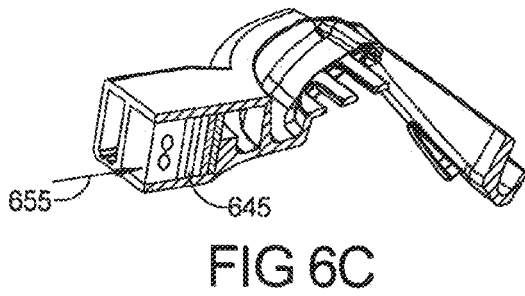
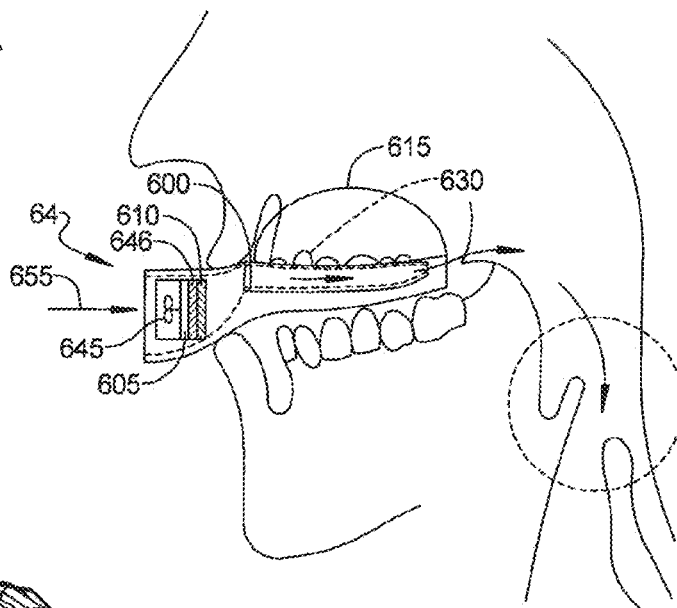
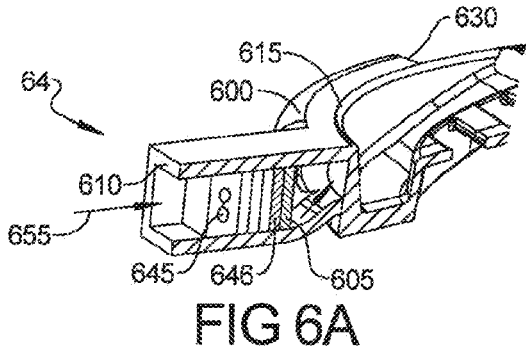
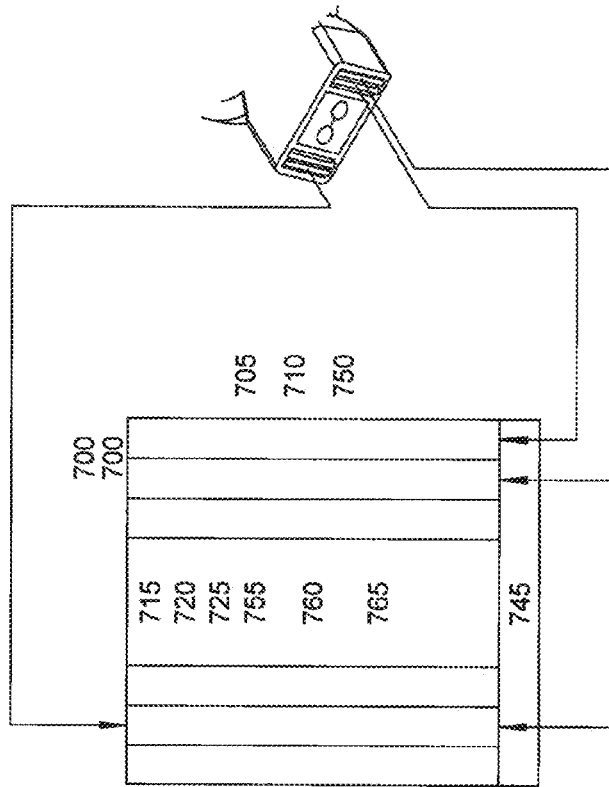


FIG 5D







MOBILE DEVICE SUCH AS  
SMART PHONE SYNC WITH  
DEVICE VIA BLUETOOTH  
770

730  
735  
740

RIP BELT  
785

PULSE OXIMETER  
780

FIG 7A

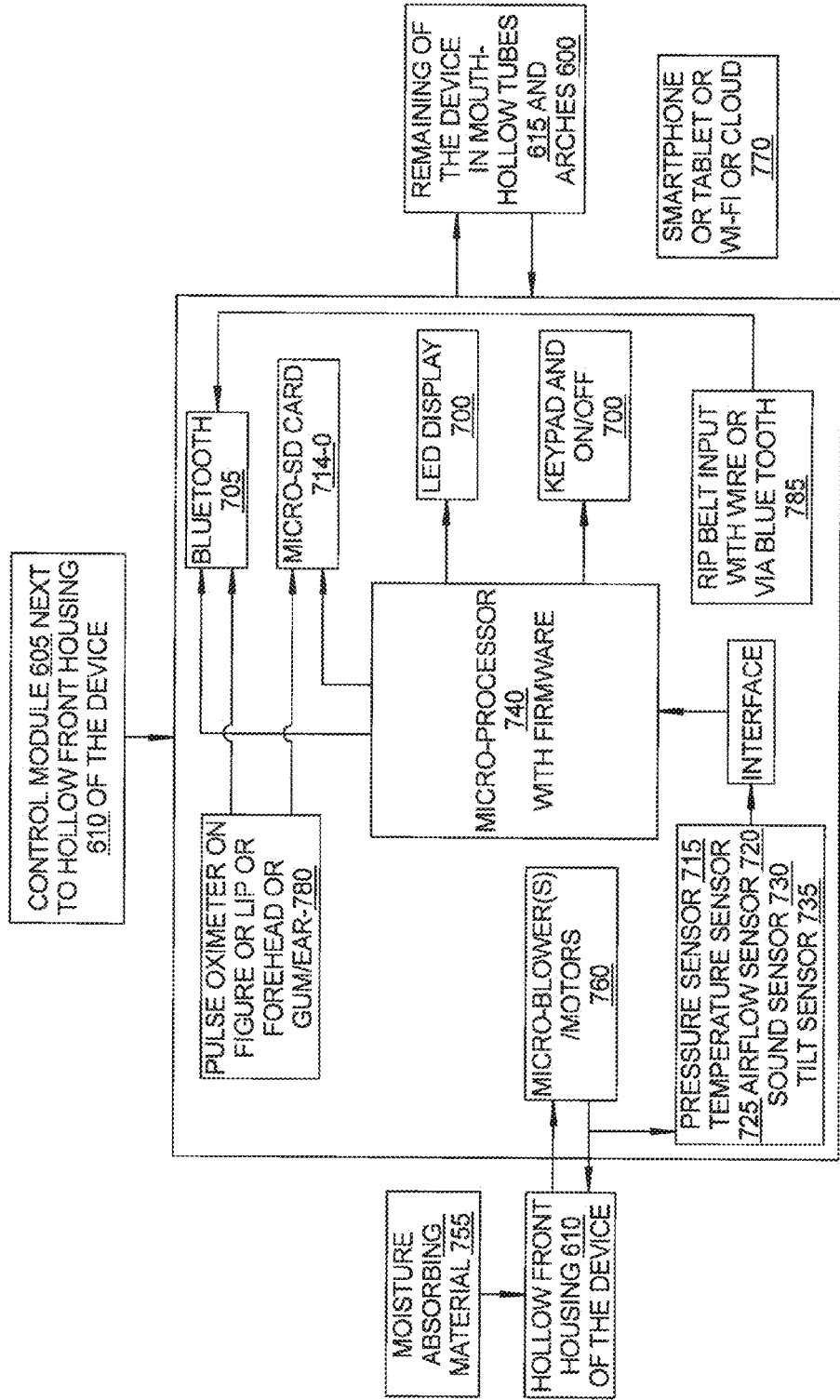


FIG 7B

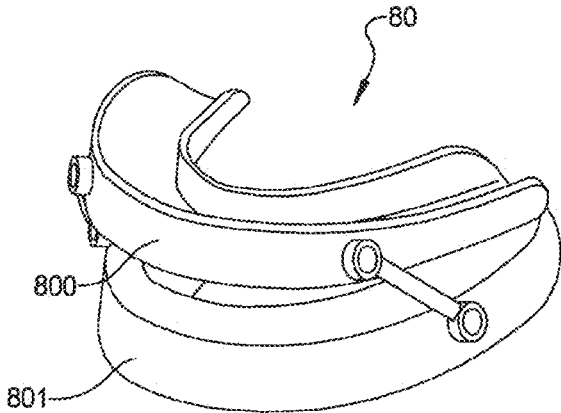


FIG 8A

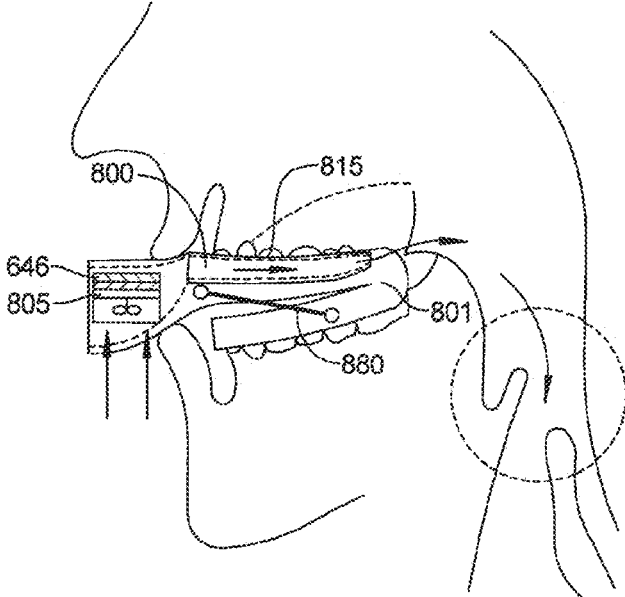


FIG 8B

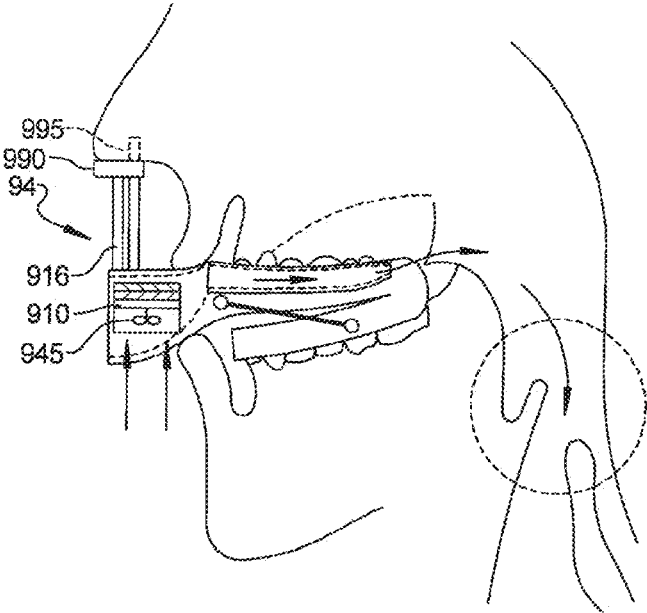


FIG 9

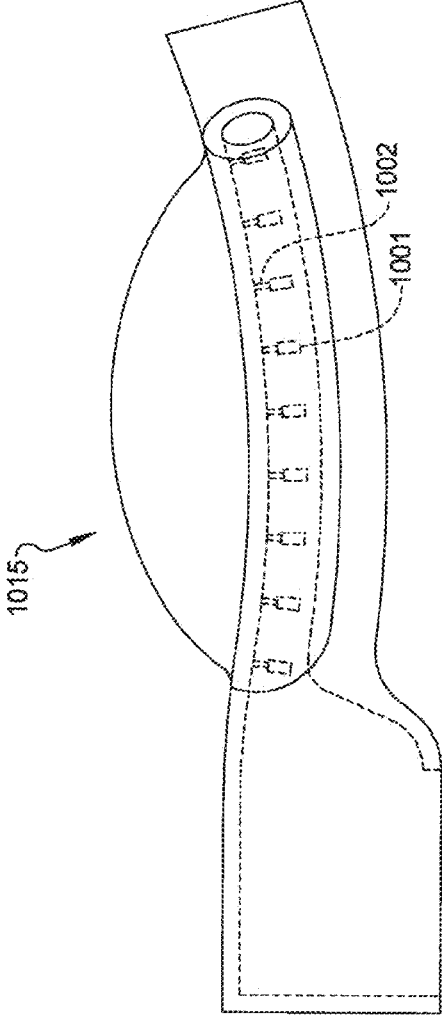


FIG 10

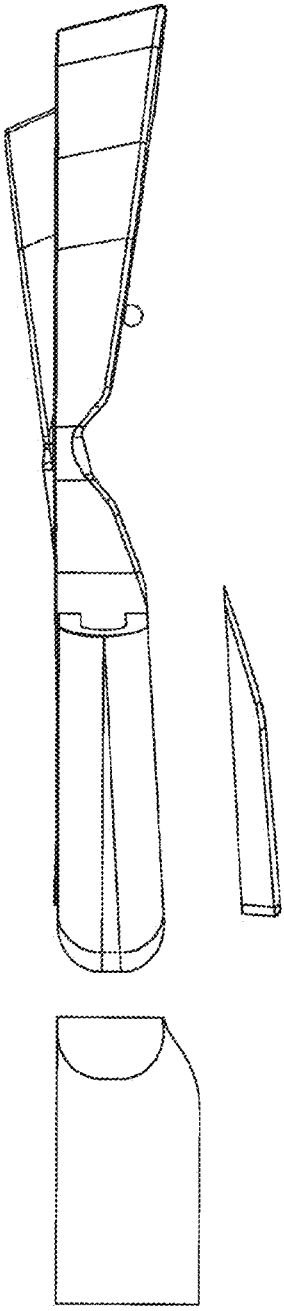


FIG 11

Both non-customized and customized devices consist of two pieces A and B, which are snap-fitted together to produce device

Front hollow housing A is made by injection molding with elastomeric ring either inserted or by two shot molding

Hollow Inner mouthpiece B is manufactured by one of the following process

1. Multi-step process: Separately injection mold partial hollow tube followed by bonding these two pieces to create hollow passage way in inner mouth piece.
2. One step injection molding process where partial walls of tube and mouthguard are molded in two cavities of a single mold, followed by rotating cavities where two halves are aligned and second material is injected at intersection, bonding these two pieces and creating hollow structure. Here, the second material is soft material or "Boil and Bite" material, creating customized oral device in a single step process.
3. Water or gas injection molding to achieve hollow air passage way
4. Lost core foam injection molding

Customizations of mouthguard on Inner Piece B (to fit the teeth perfectly) is achieved by processes such as

1. "boil and bite" concept – Mechanical bonding or two shot molding and
2. Micro-cellular foaming injection molding processes.

OR customized device is made by 3D Printing process (plastics or metal) as one piece or A and B separately OR Boil and Bite overmolding on 3D printed hollow device

Final Device Assembly – Snap fit Hollow Housing A and Hollow inner piece B, followed by inserting micro blowers, other items and control module

Fig. 12



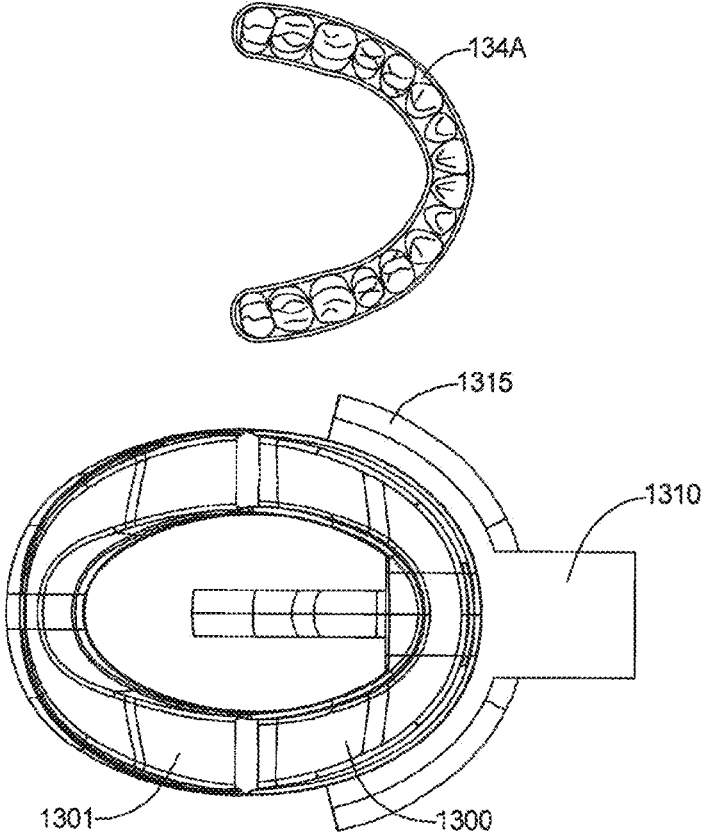


FIG 13A

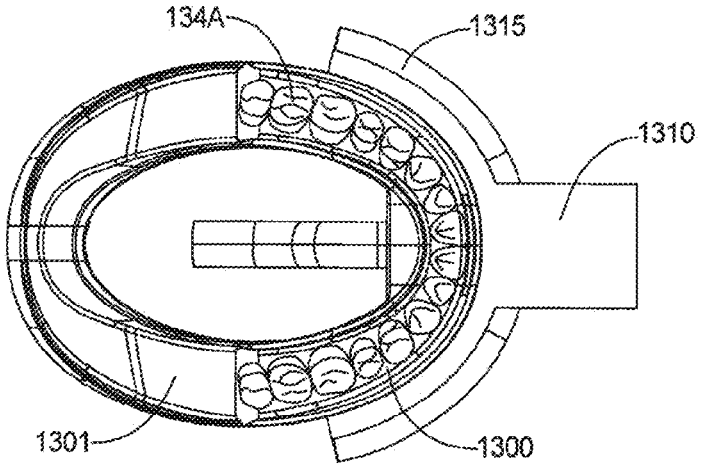


FIG 13B

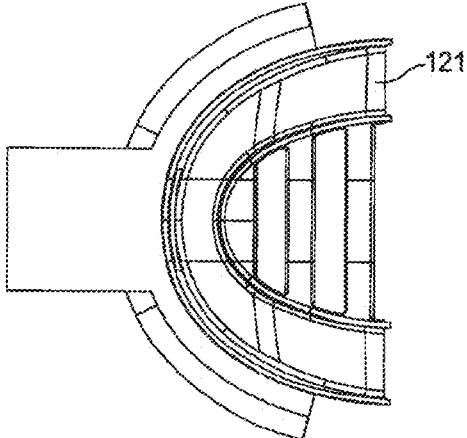
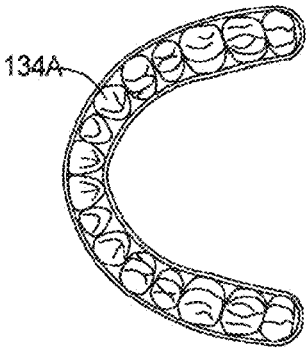


FIG 13C

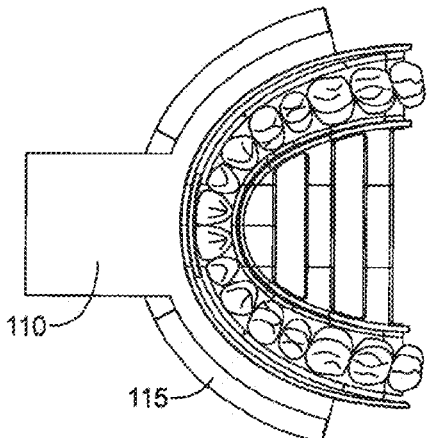


FIG 13D

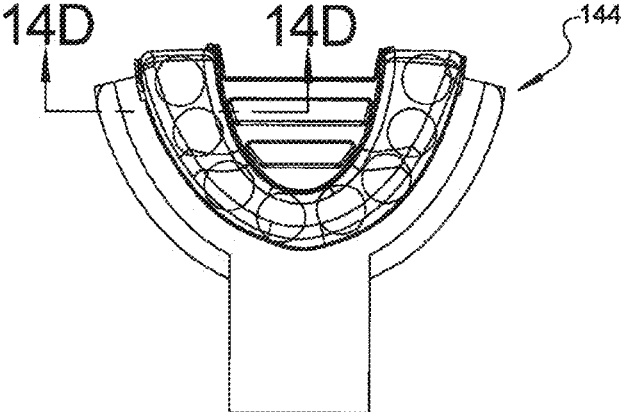


FIG 14C

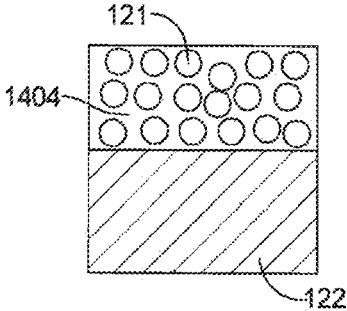


FIG 14A

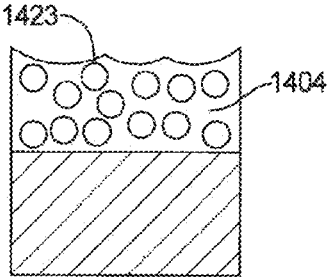


FIG 14B

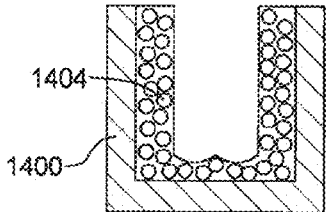


FIG 14D

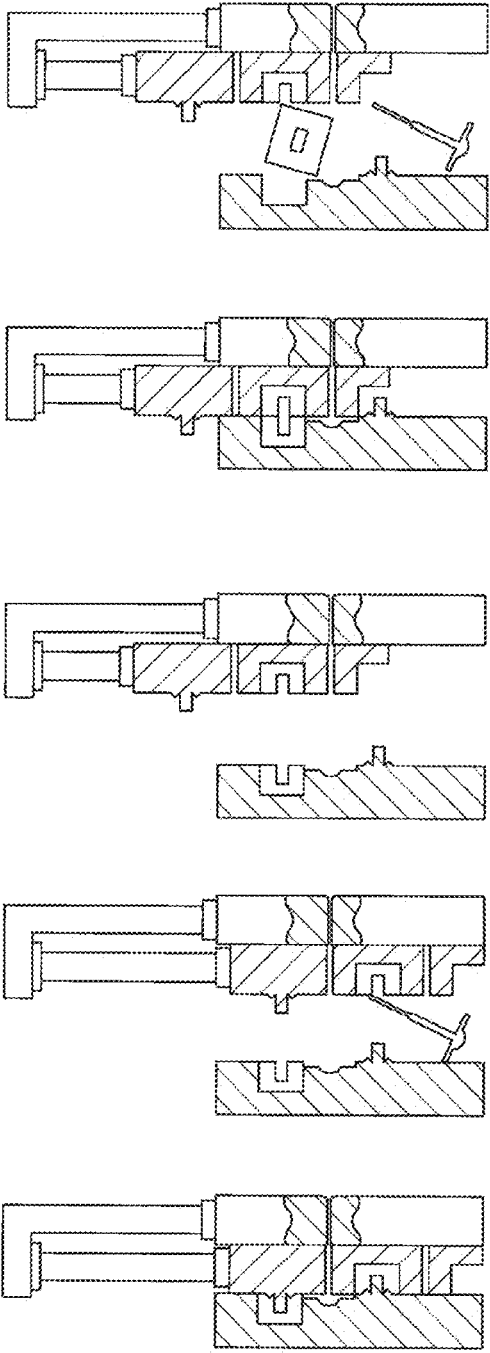


FIG 15

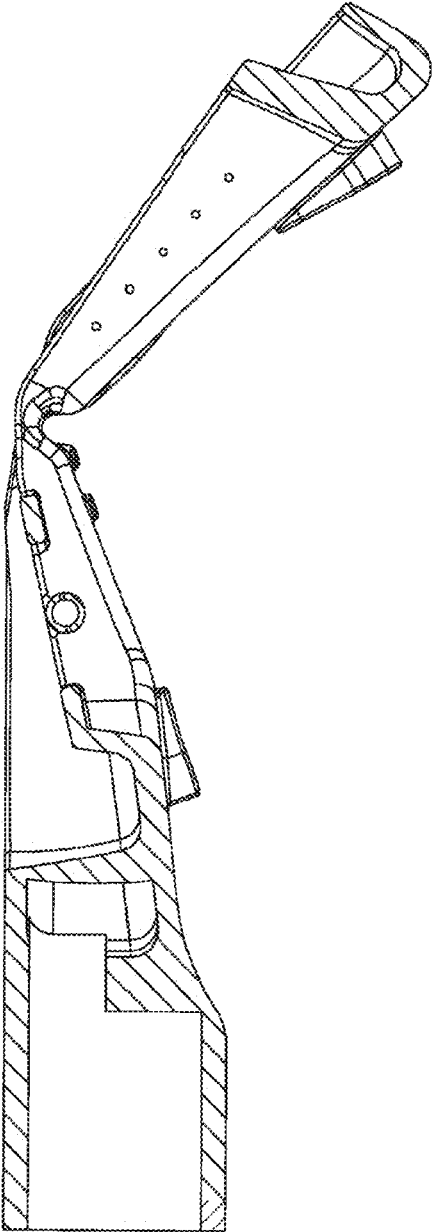


FIG 16

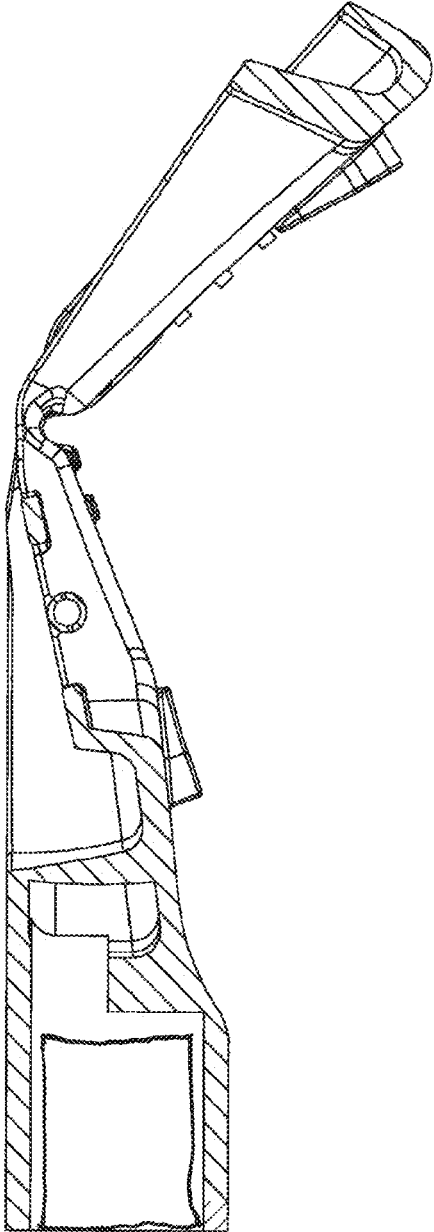


FIG 17

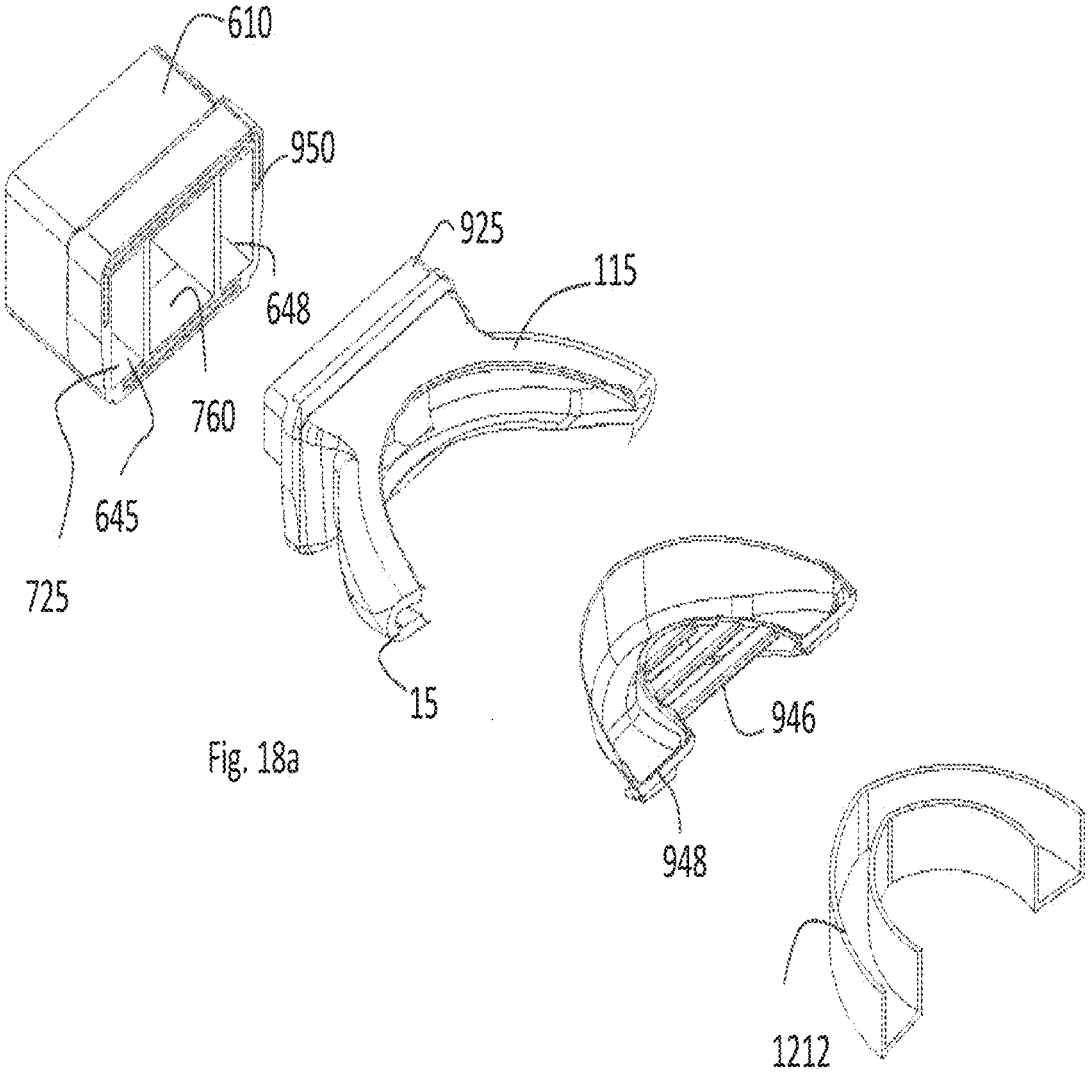


Fig. 18a

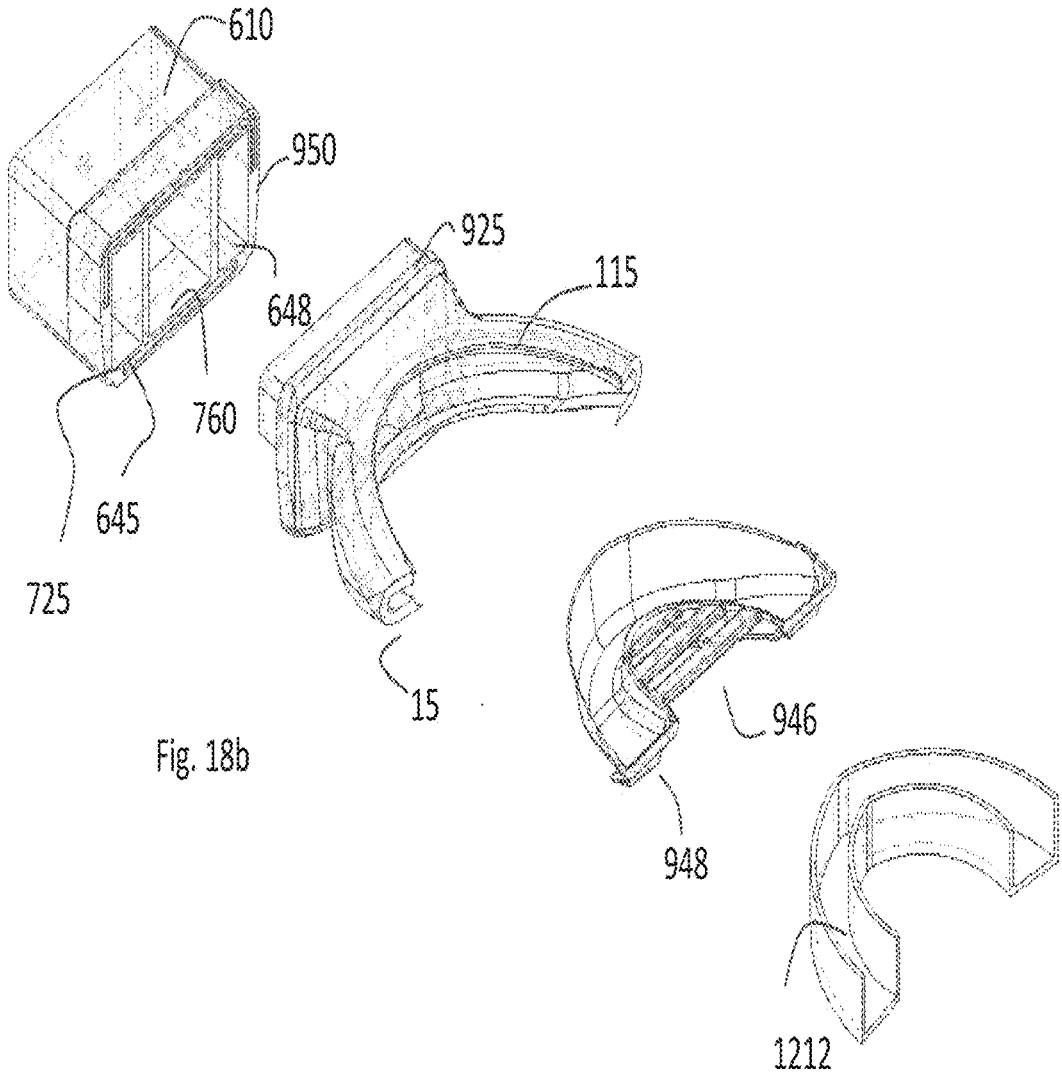


Fig. 18b



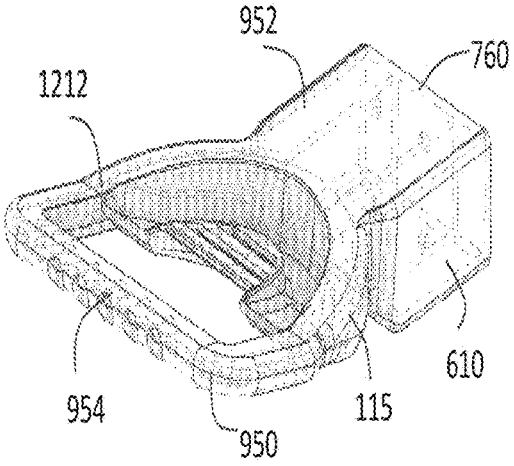


Fig. 19a

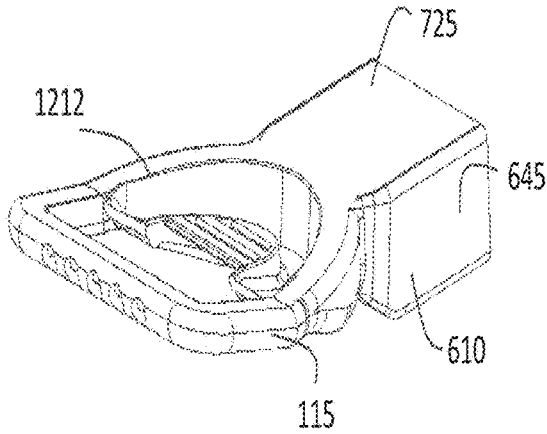
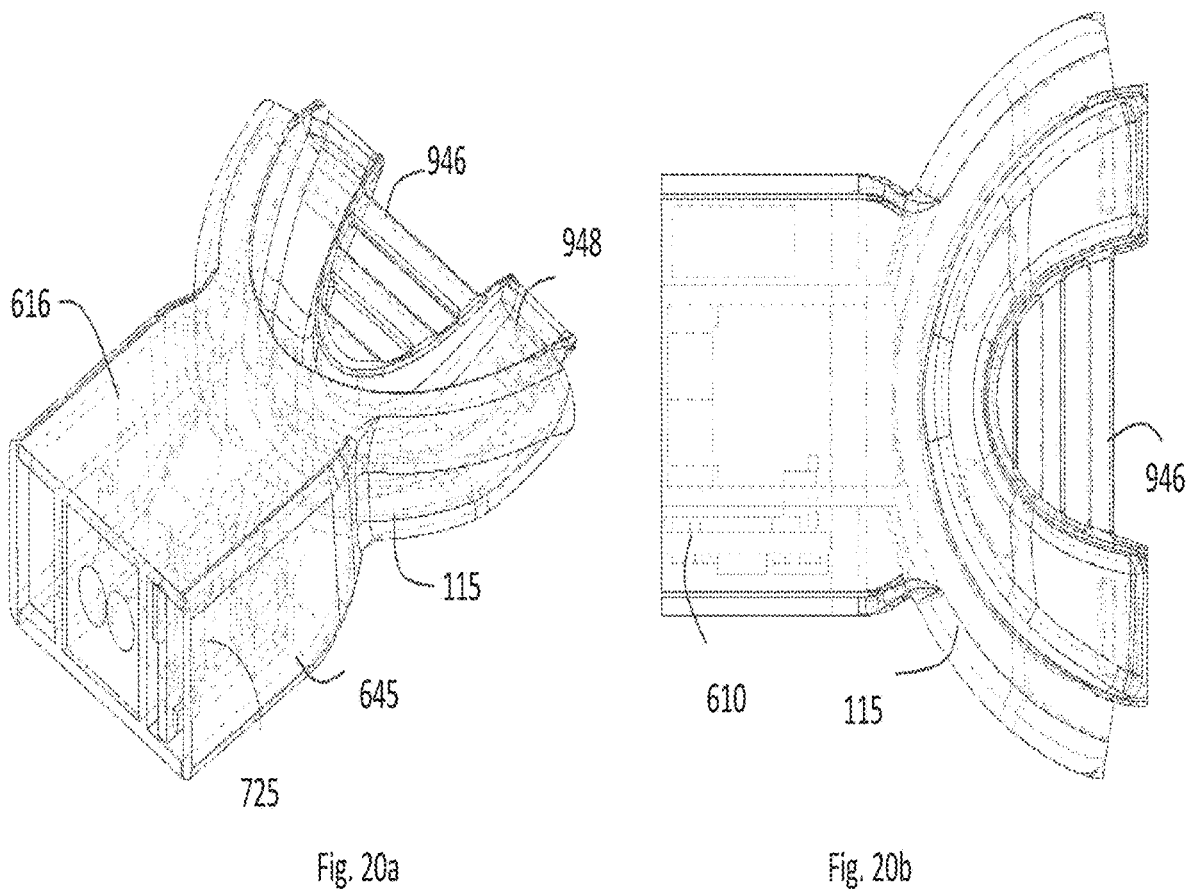


Fig. 19b



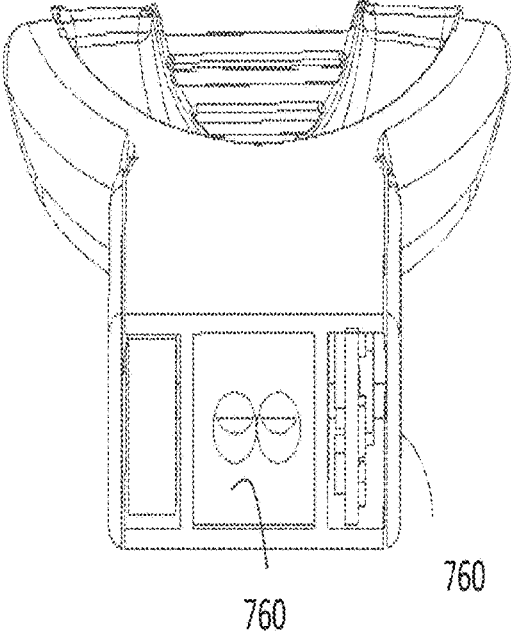


Fig 21a

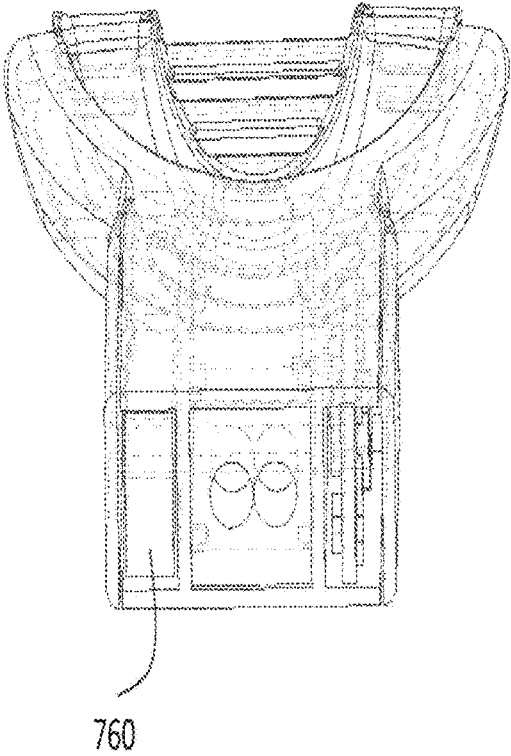


Fig 21b

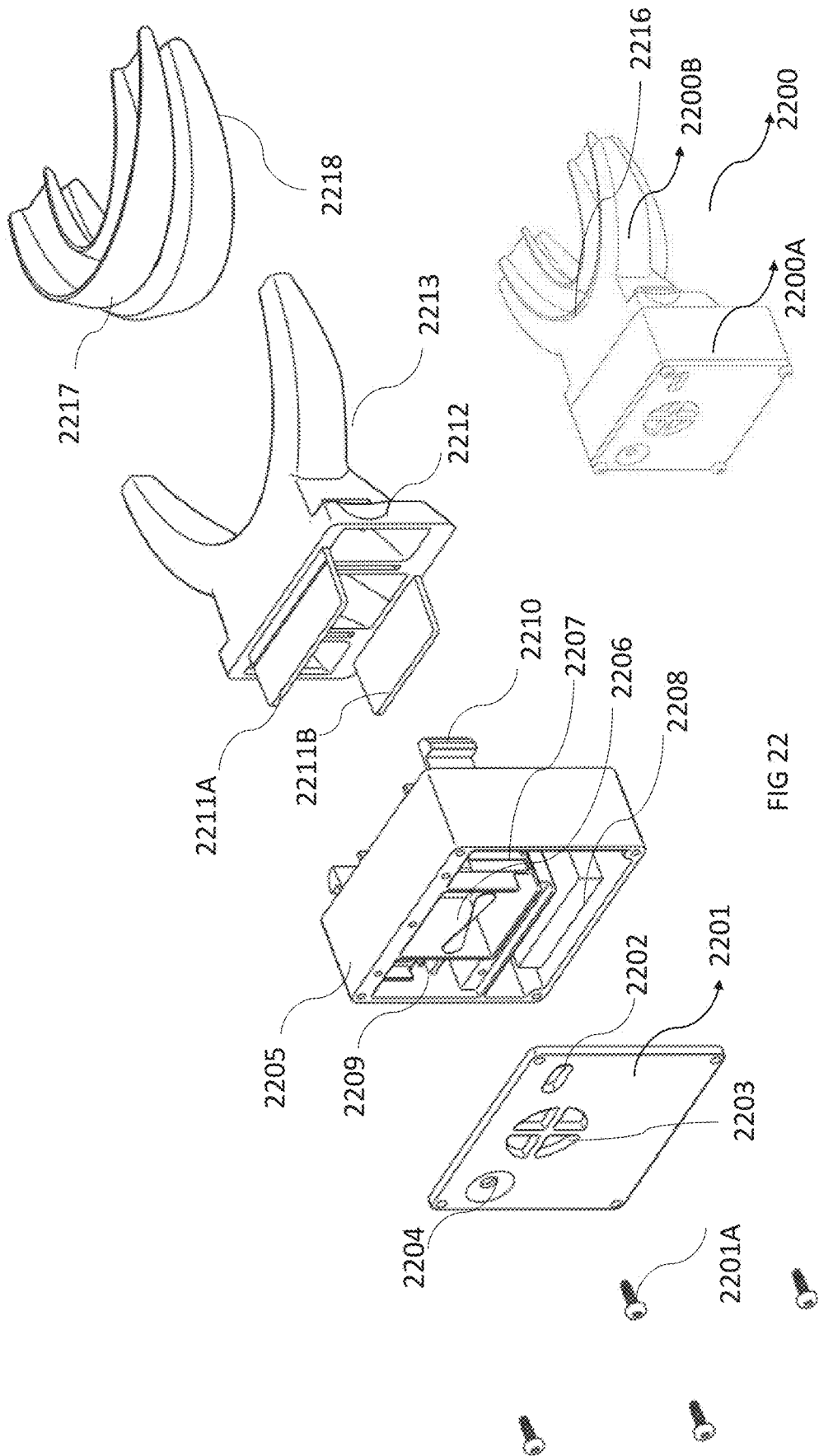


FIG 22



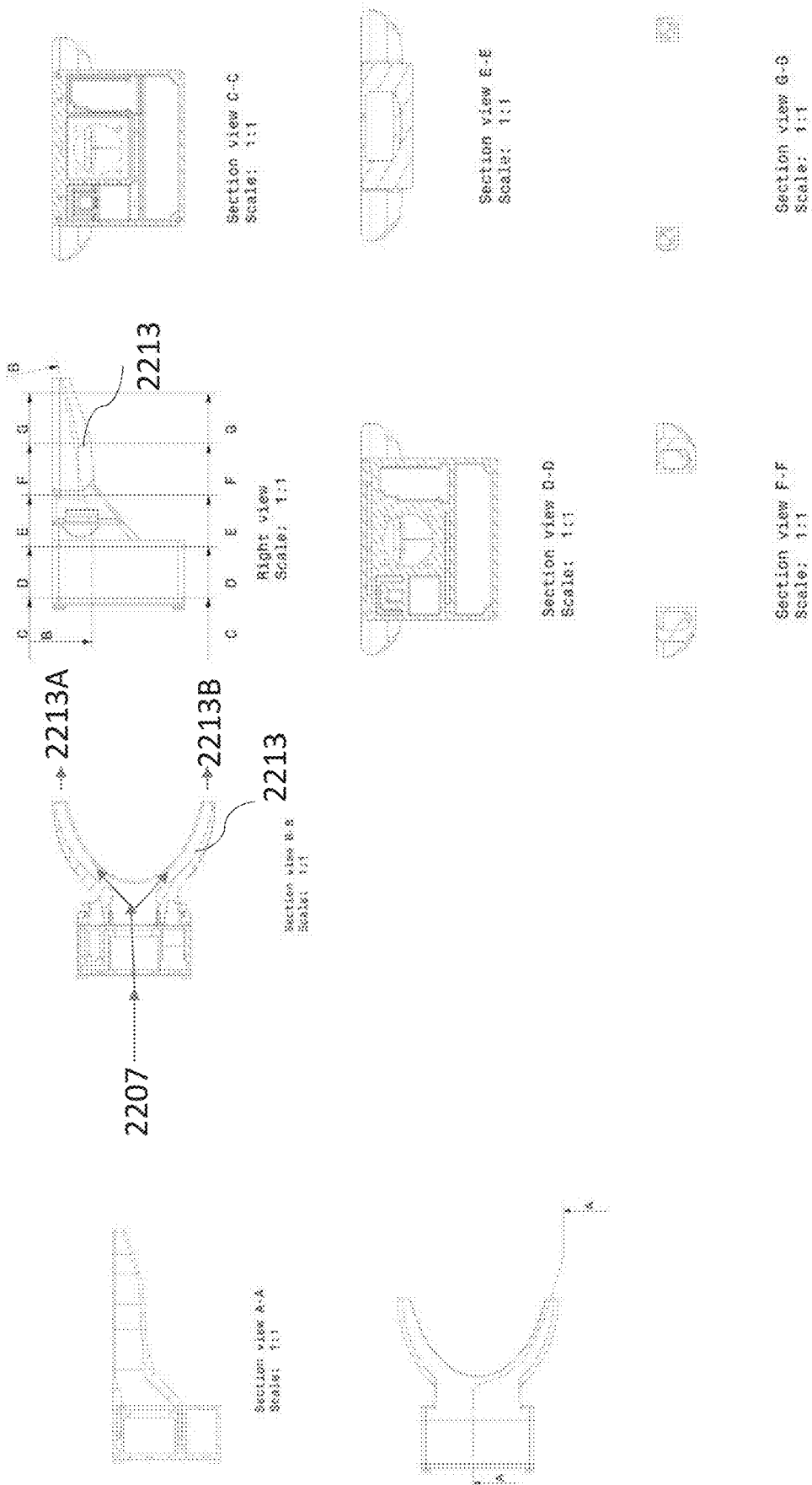


FIG 24

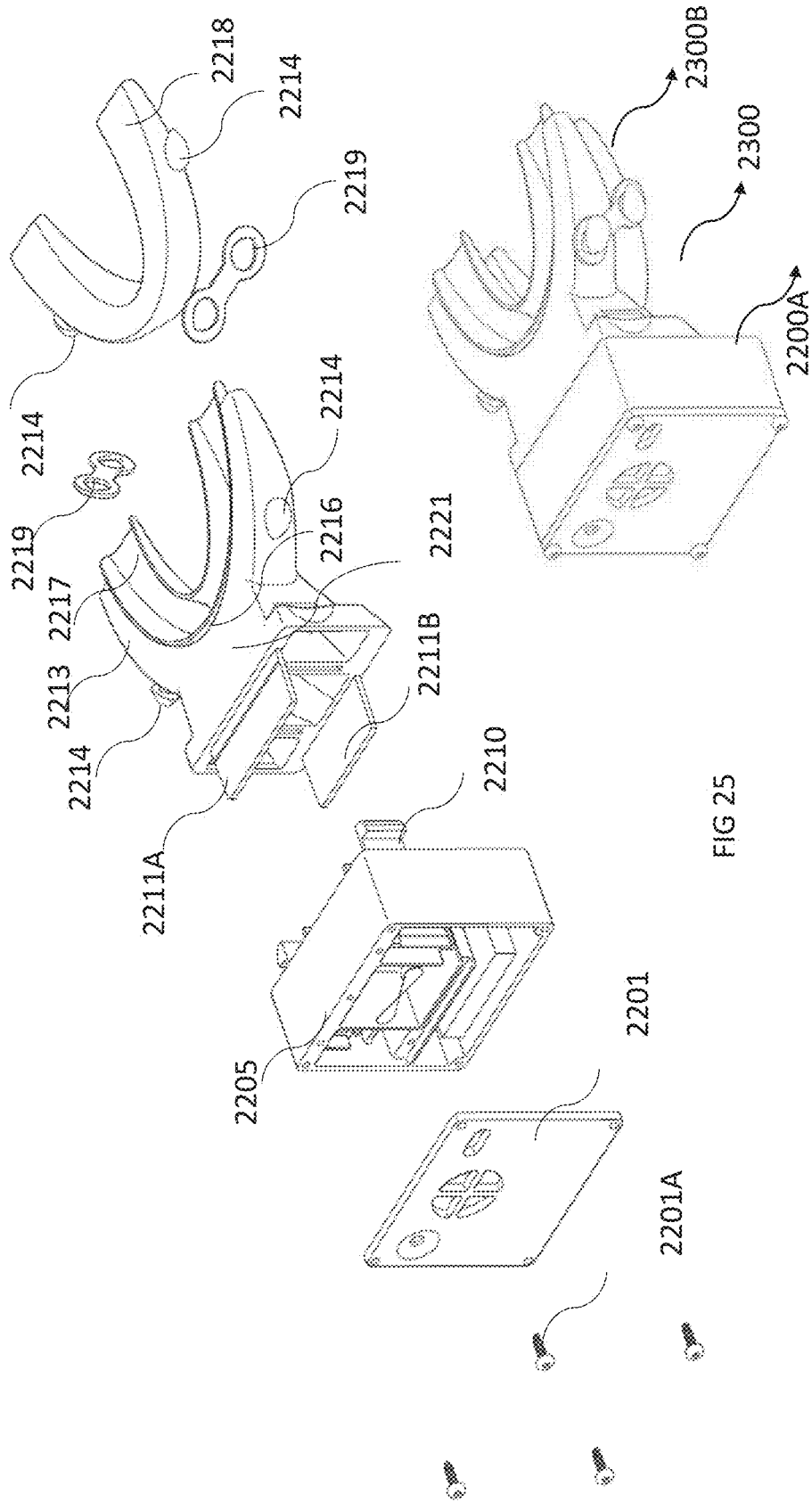


FIG 25

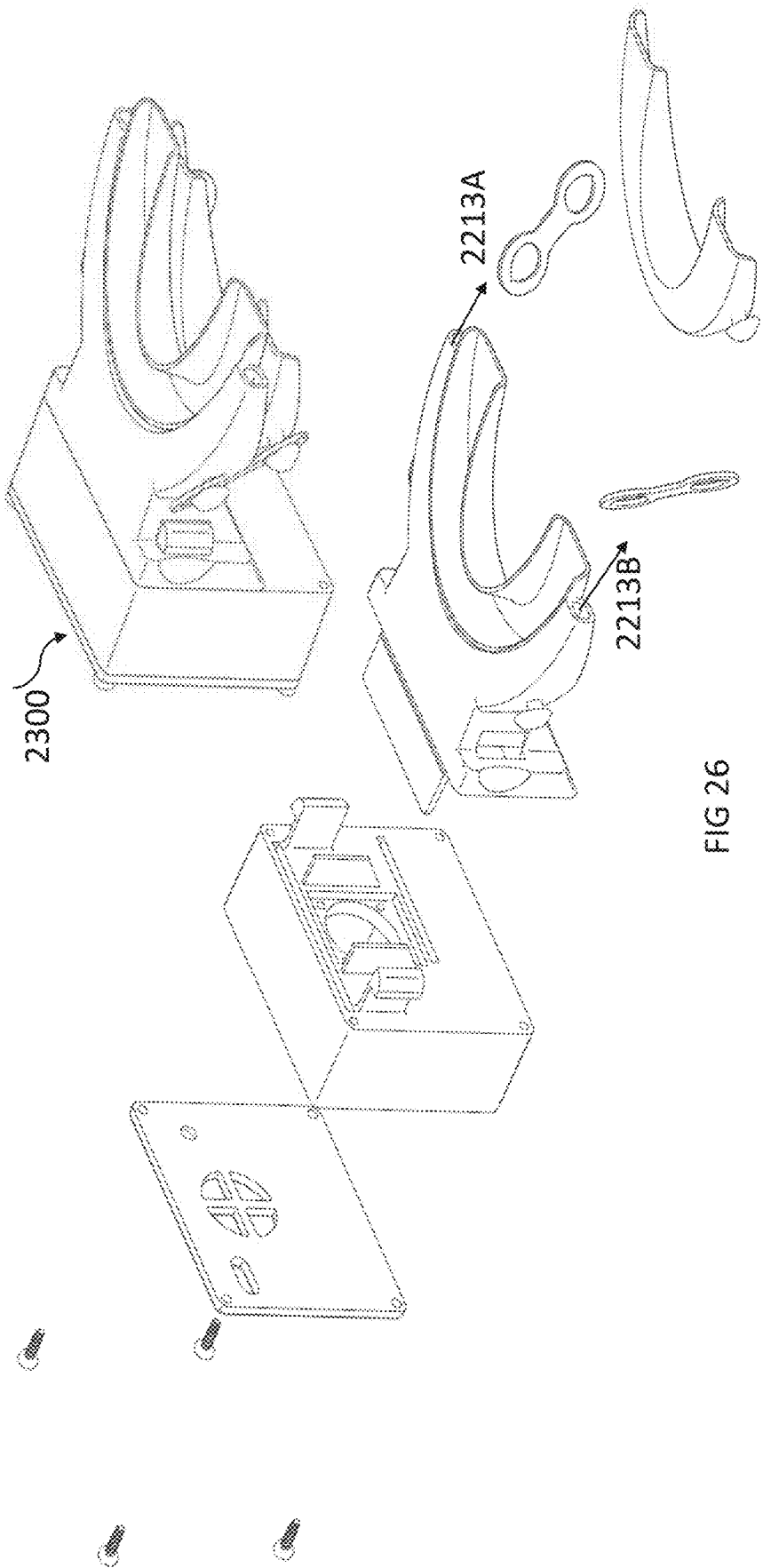


FIG 26



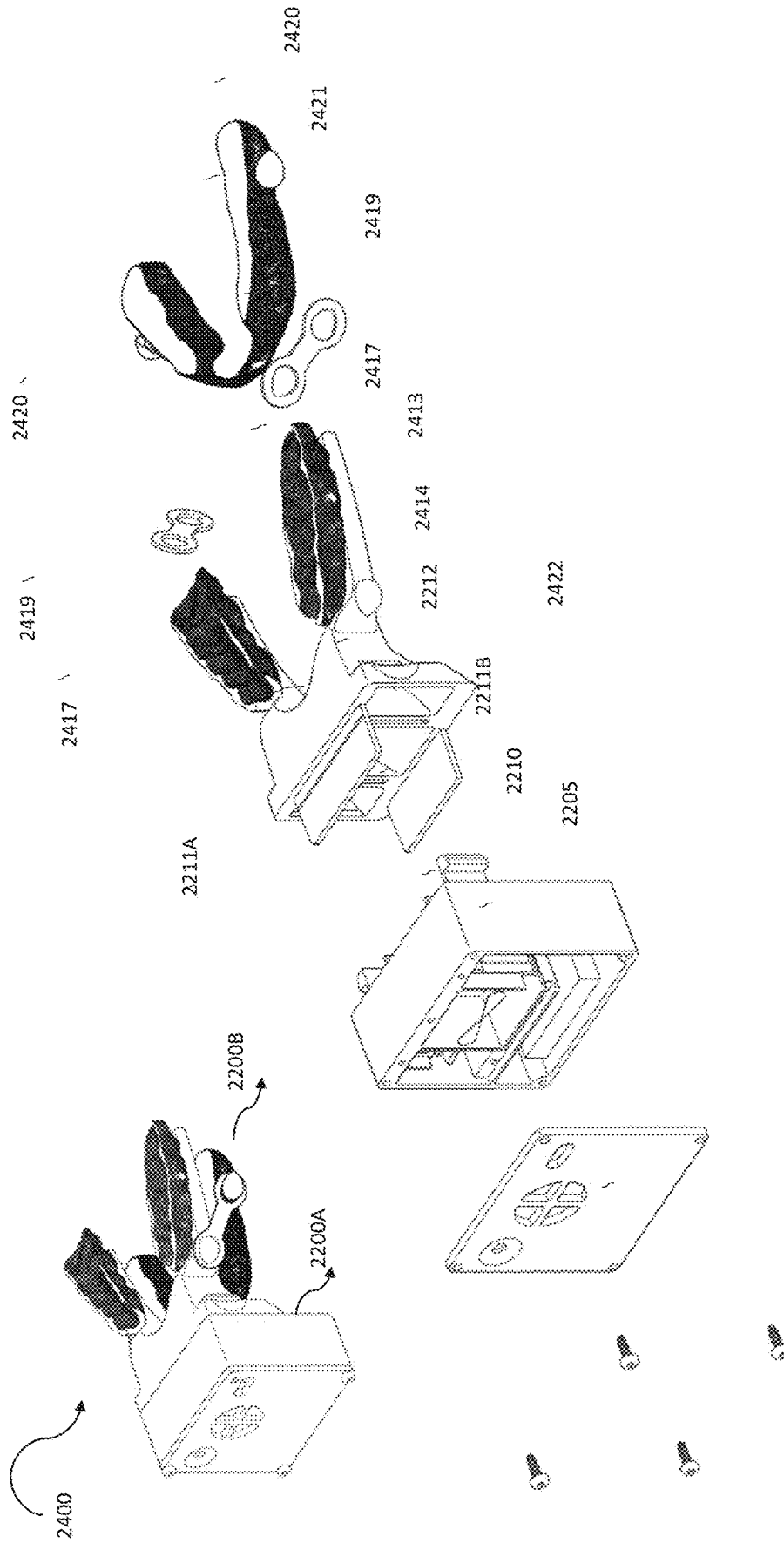


FIG 27

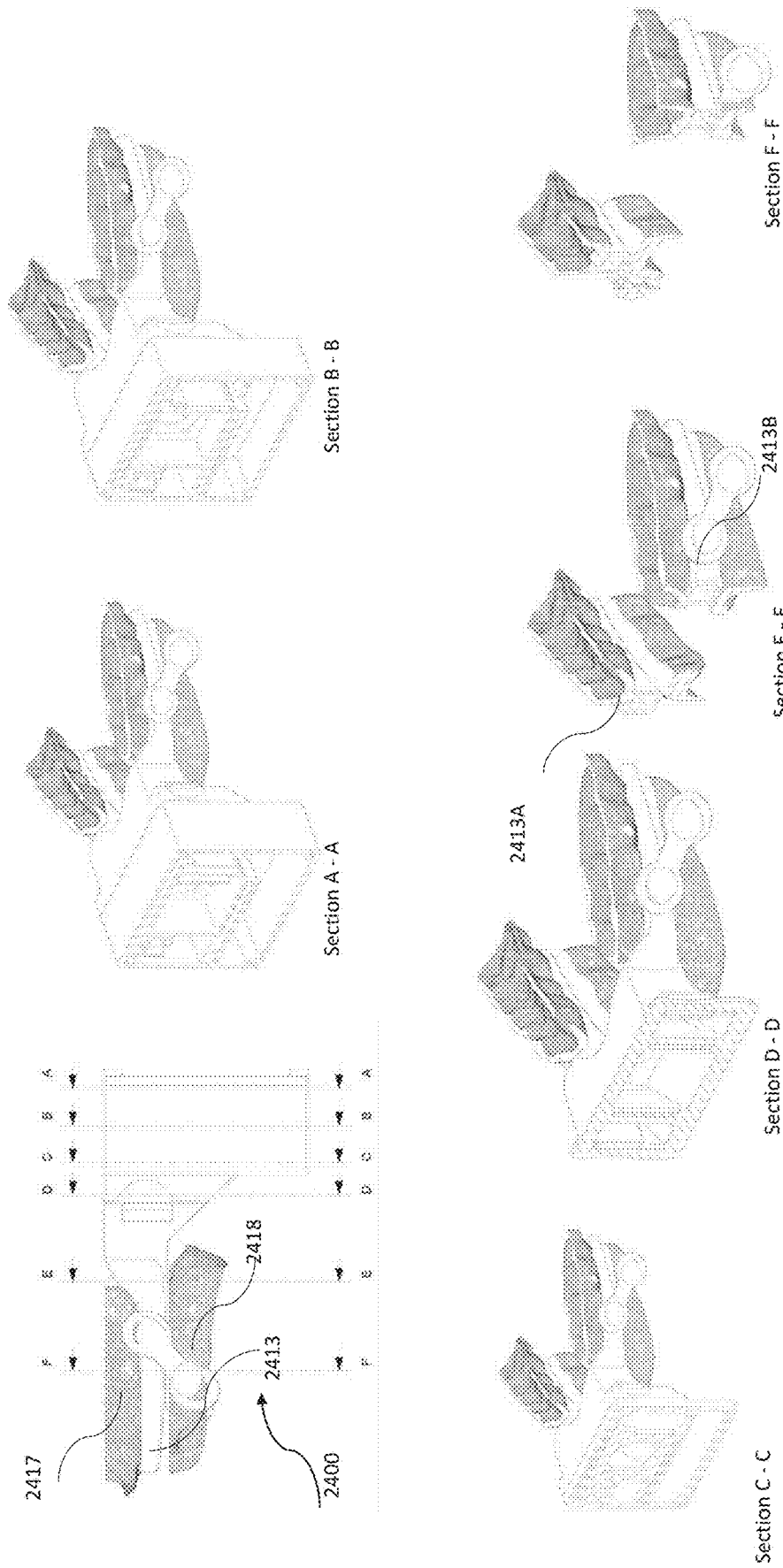


FIG 28



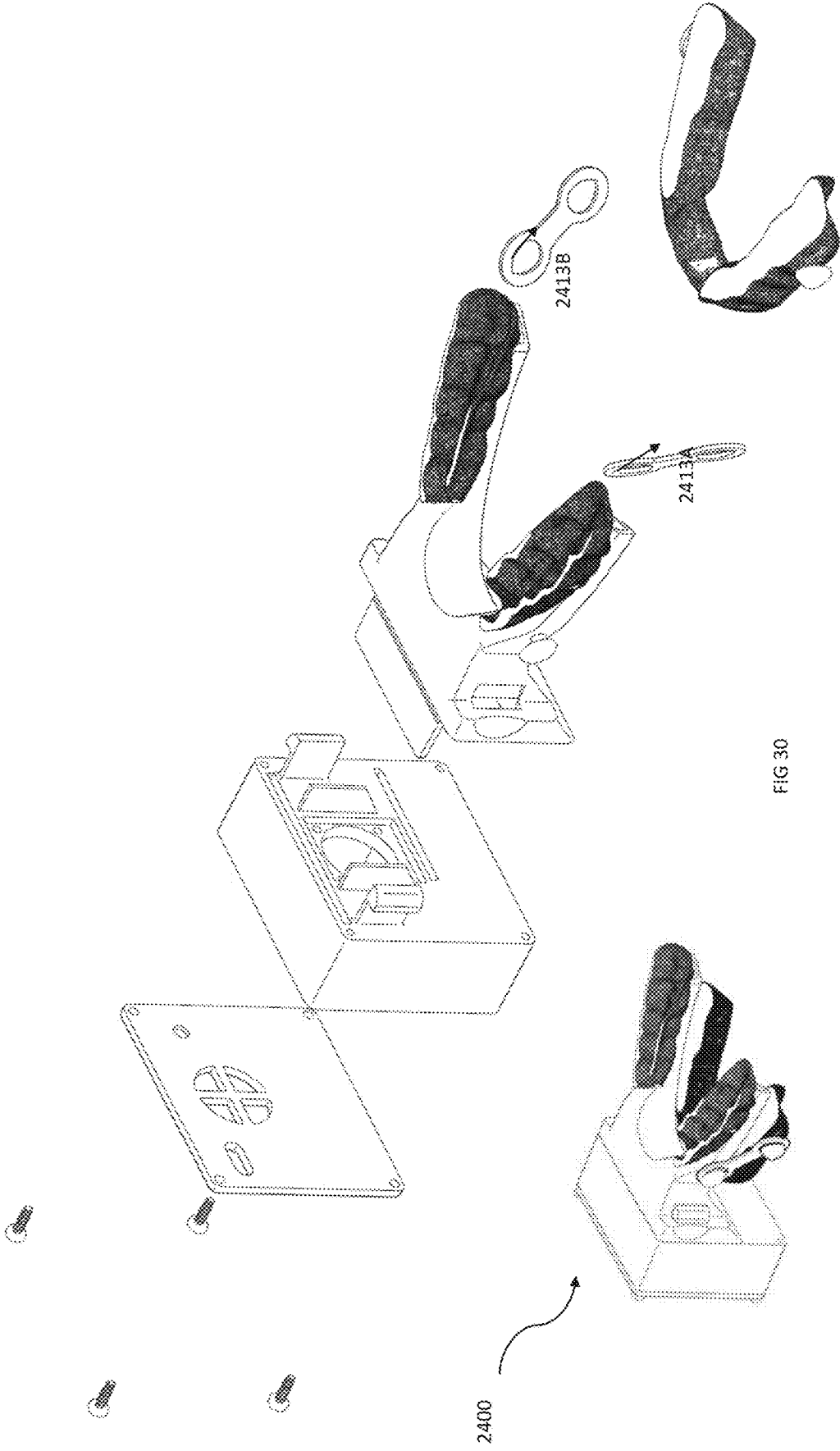


FIG 30

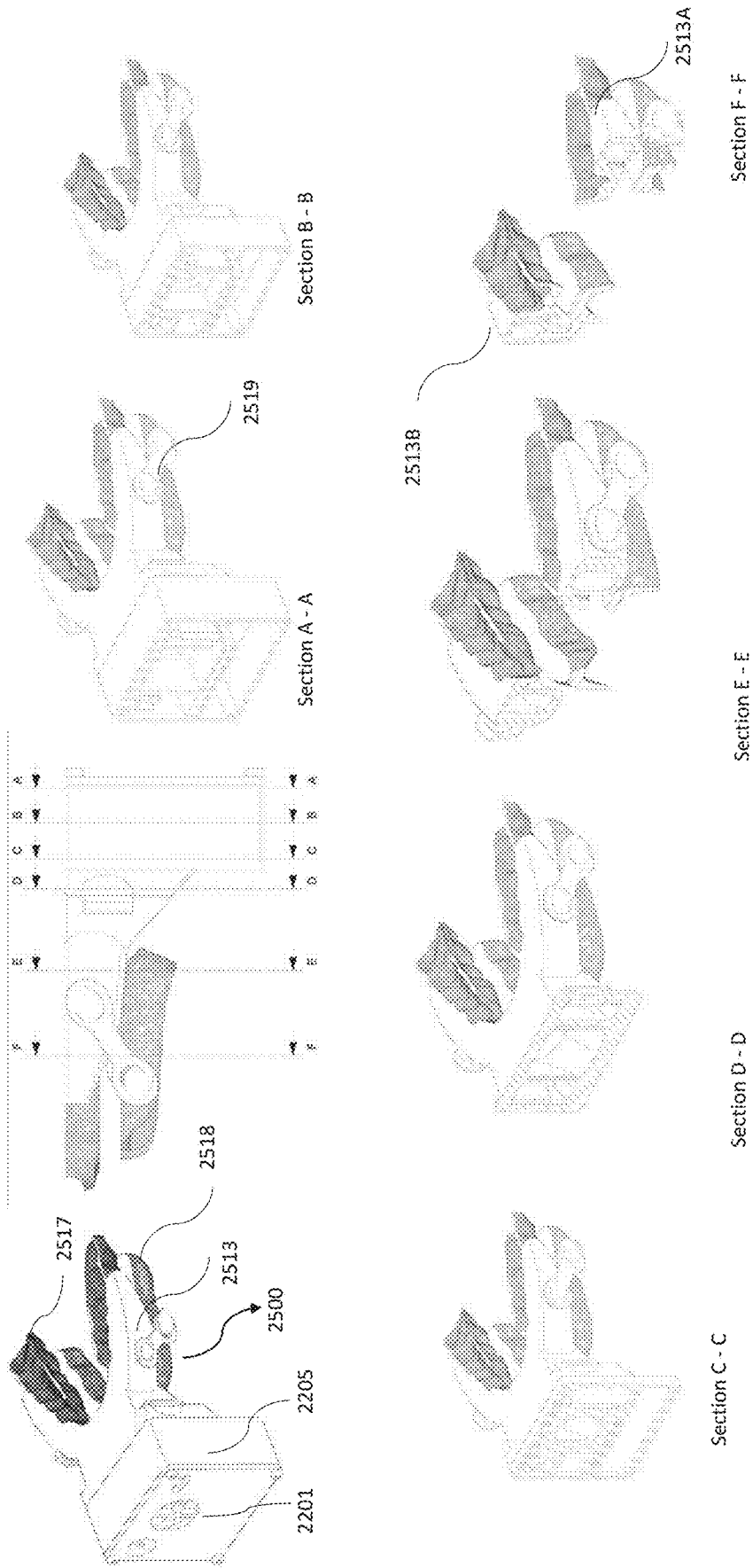


FIG 31

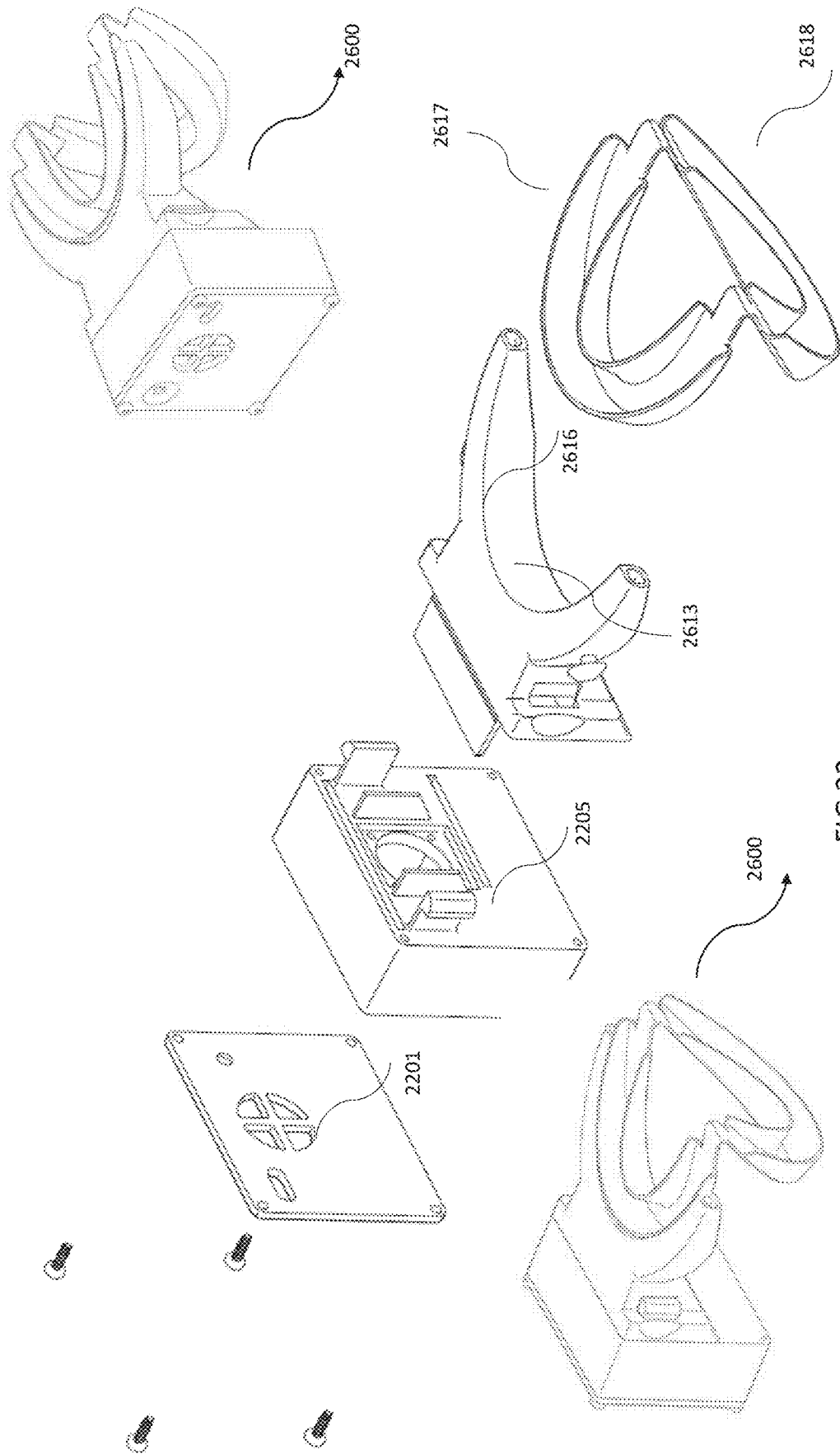


FIG 32

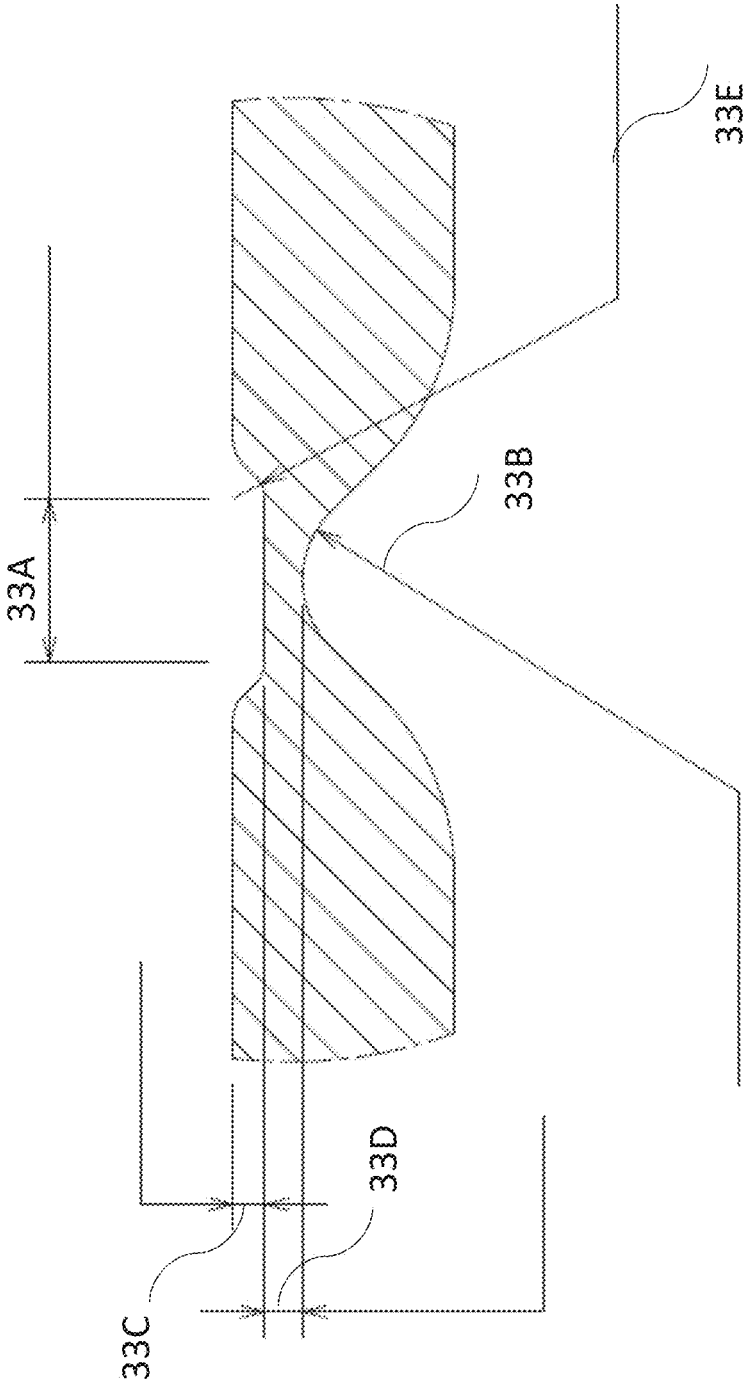


FIG 33

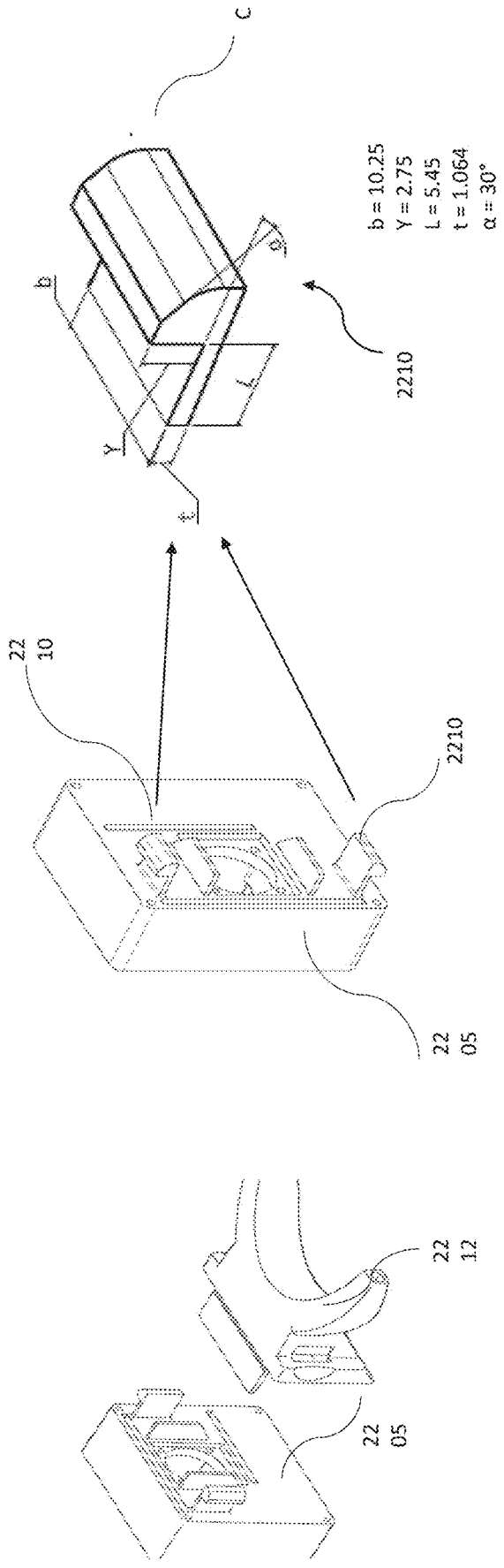


FIG 34



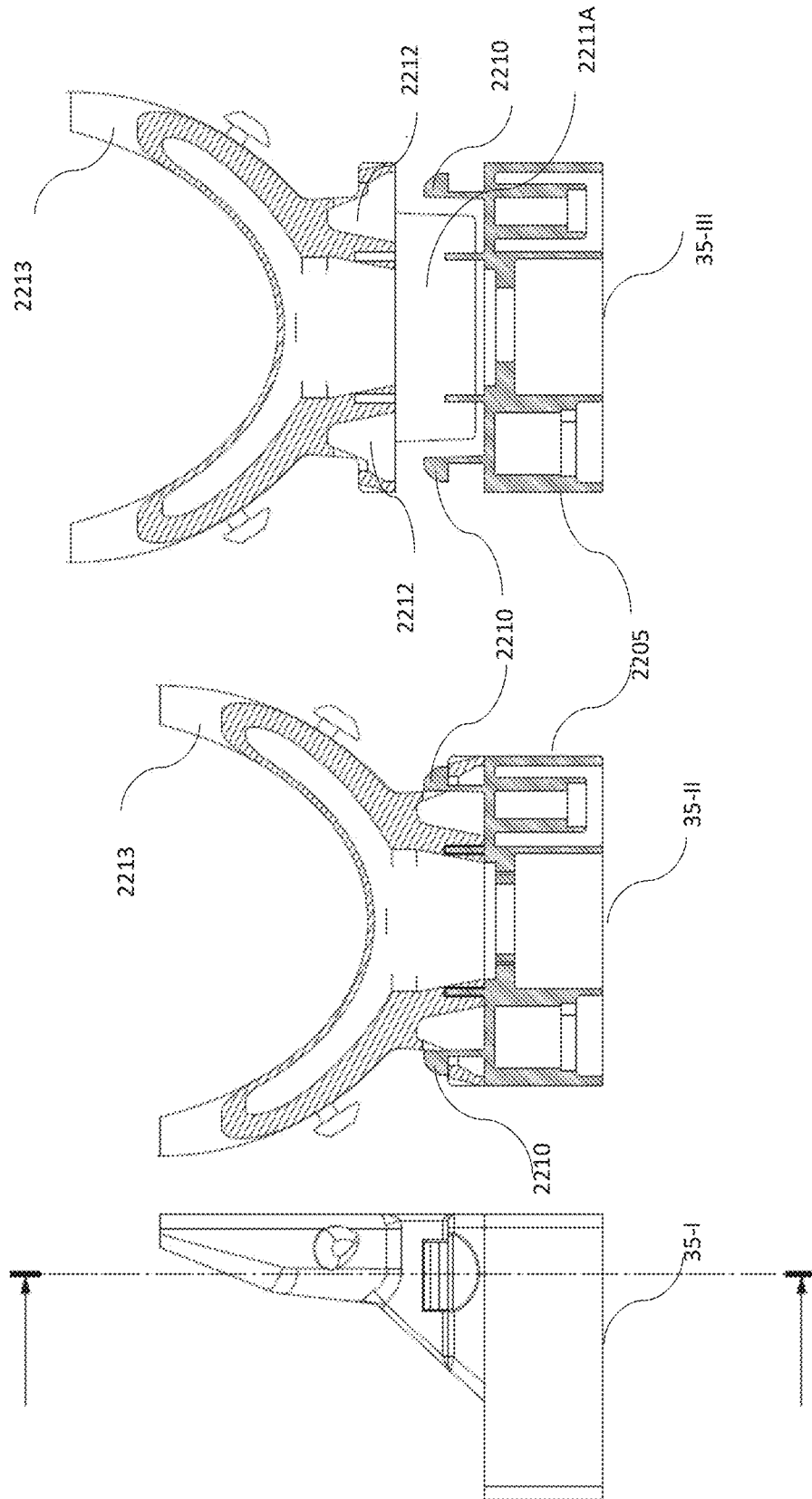


FIG 35A

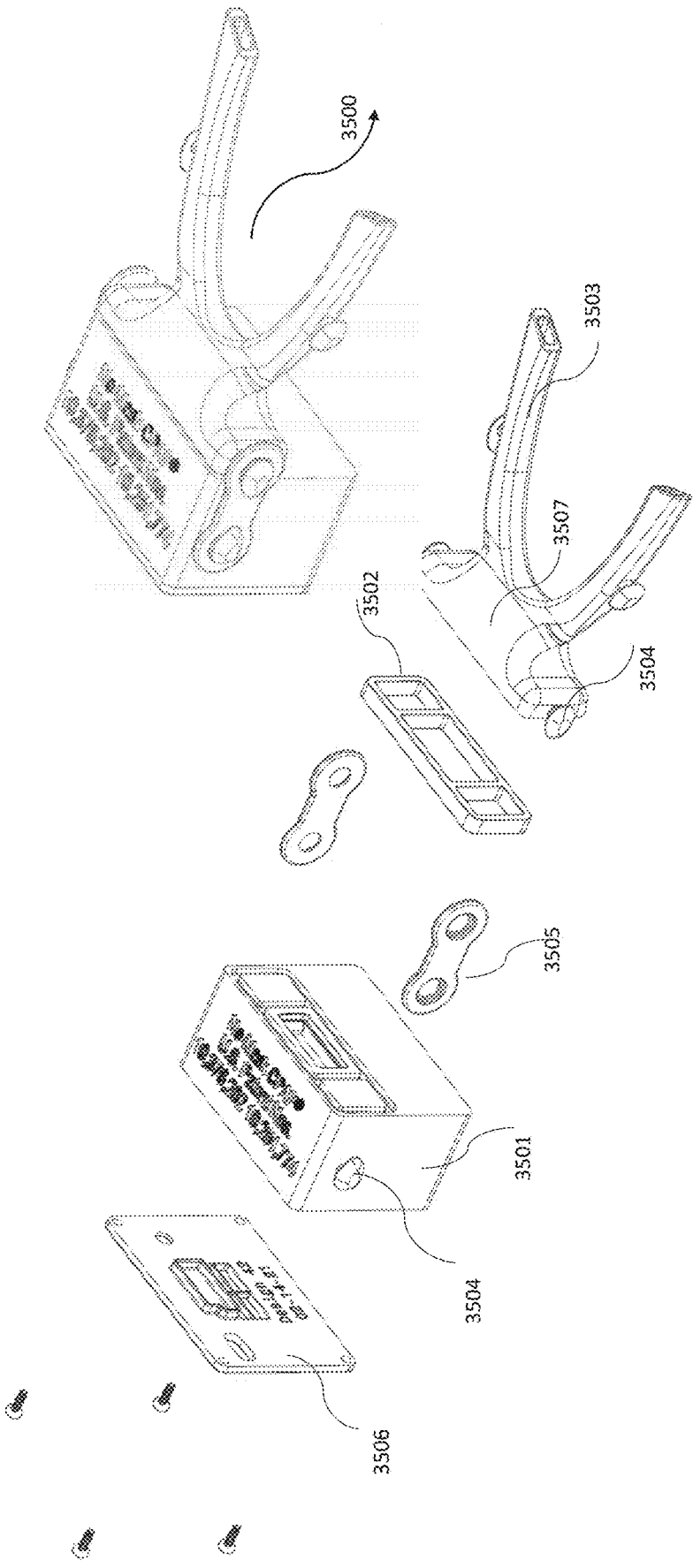


FIG 35B



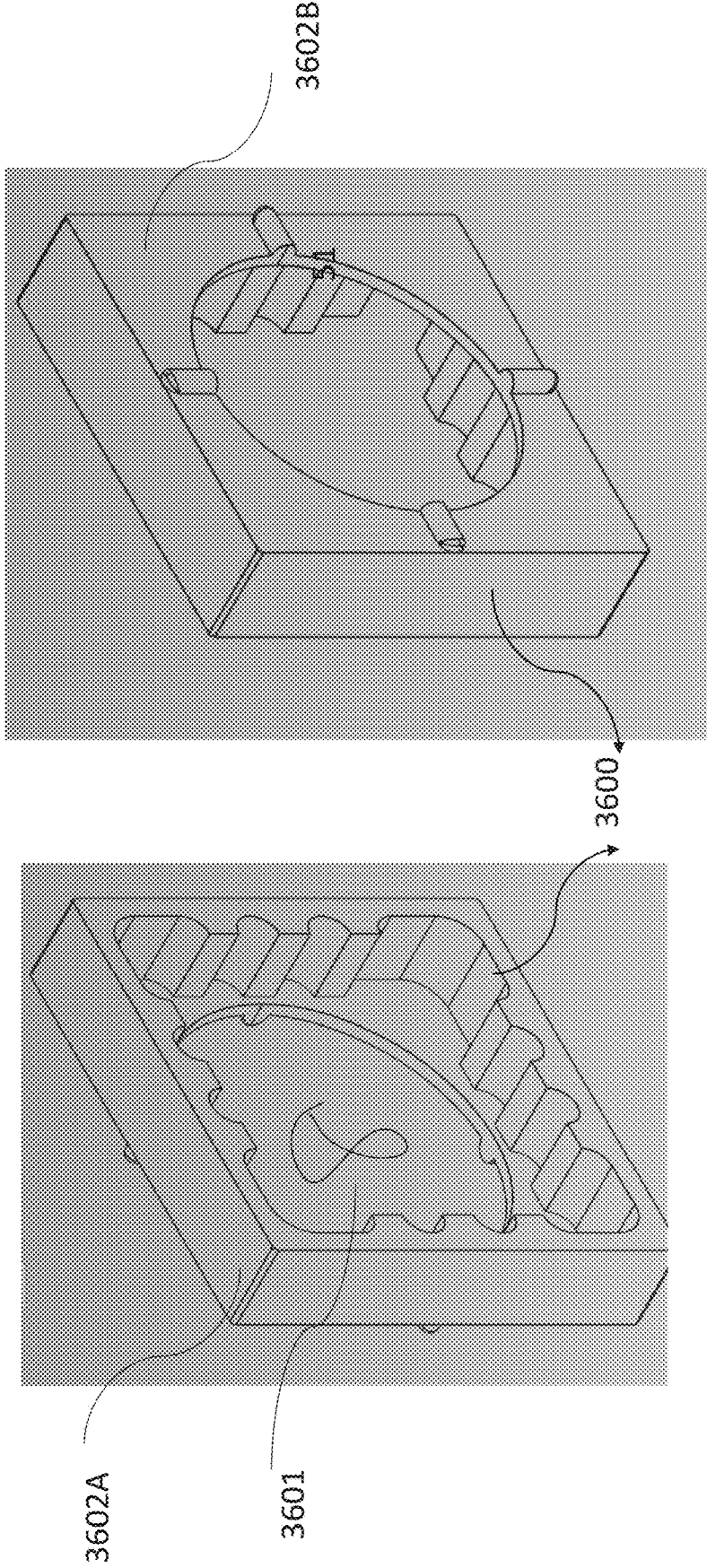


FIG 36B

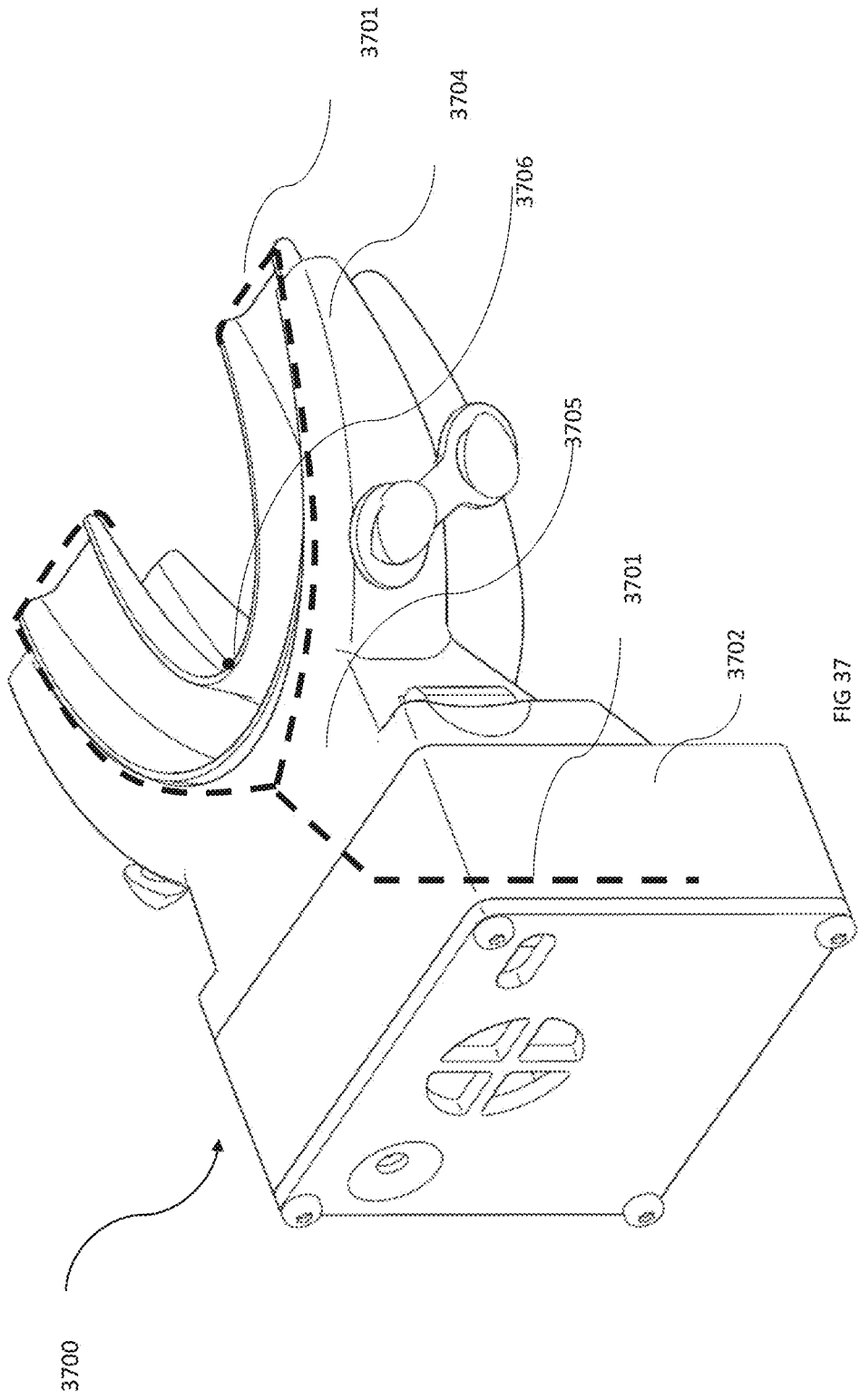


FIG 37

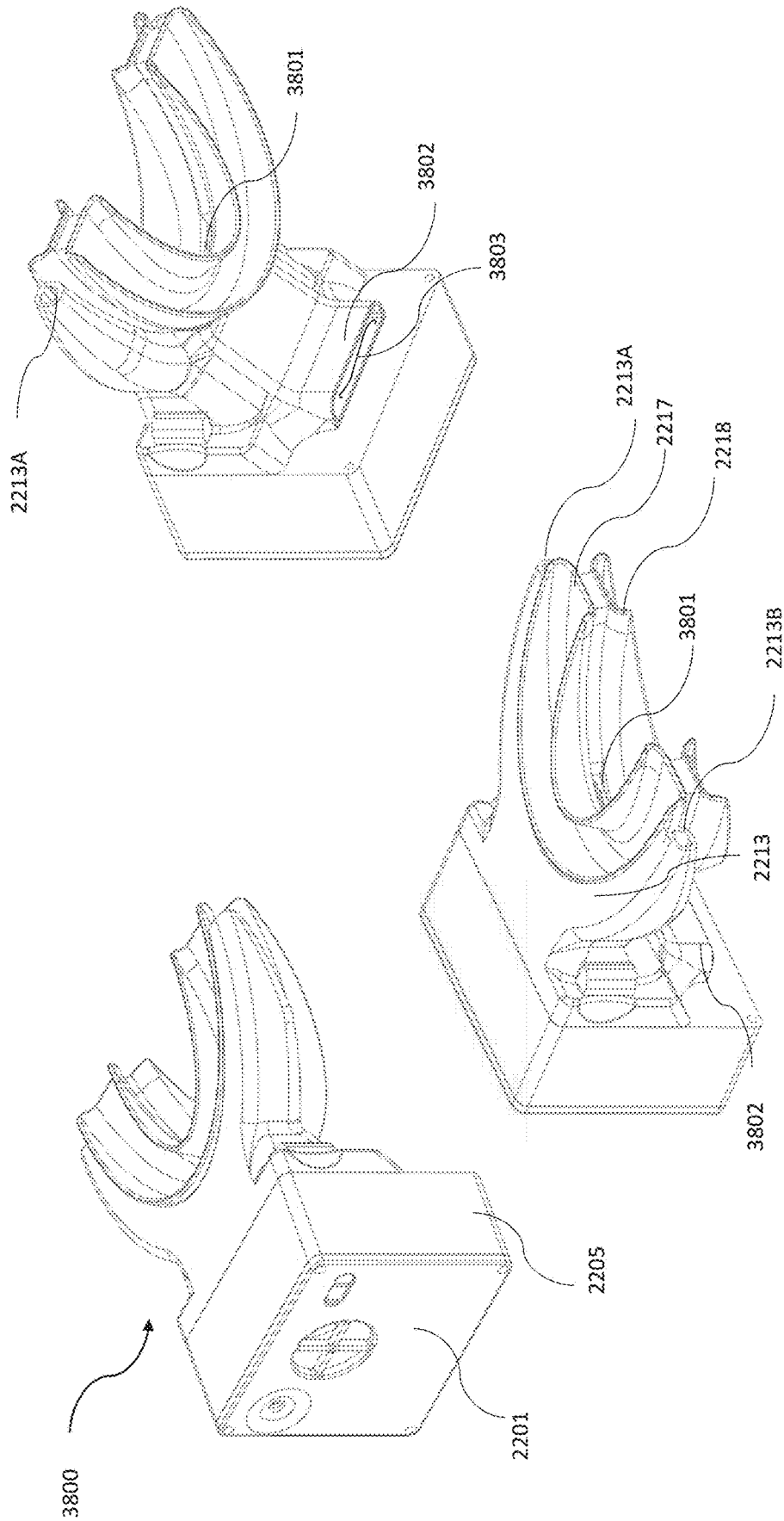


FIG. 38

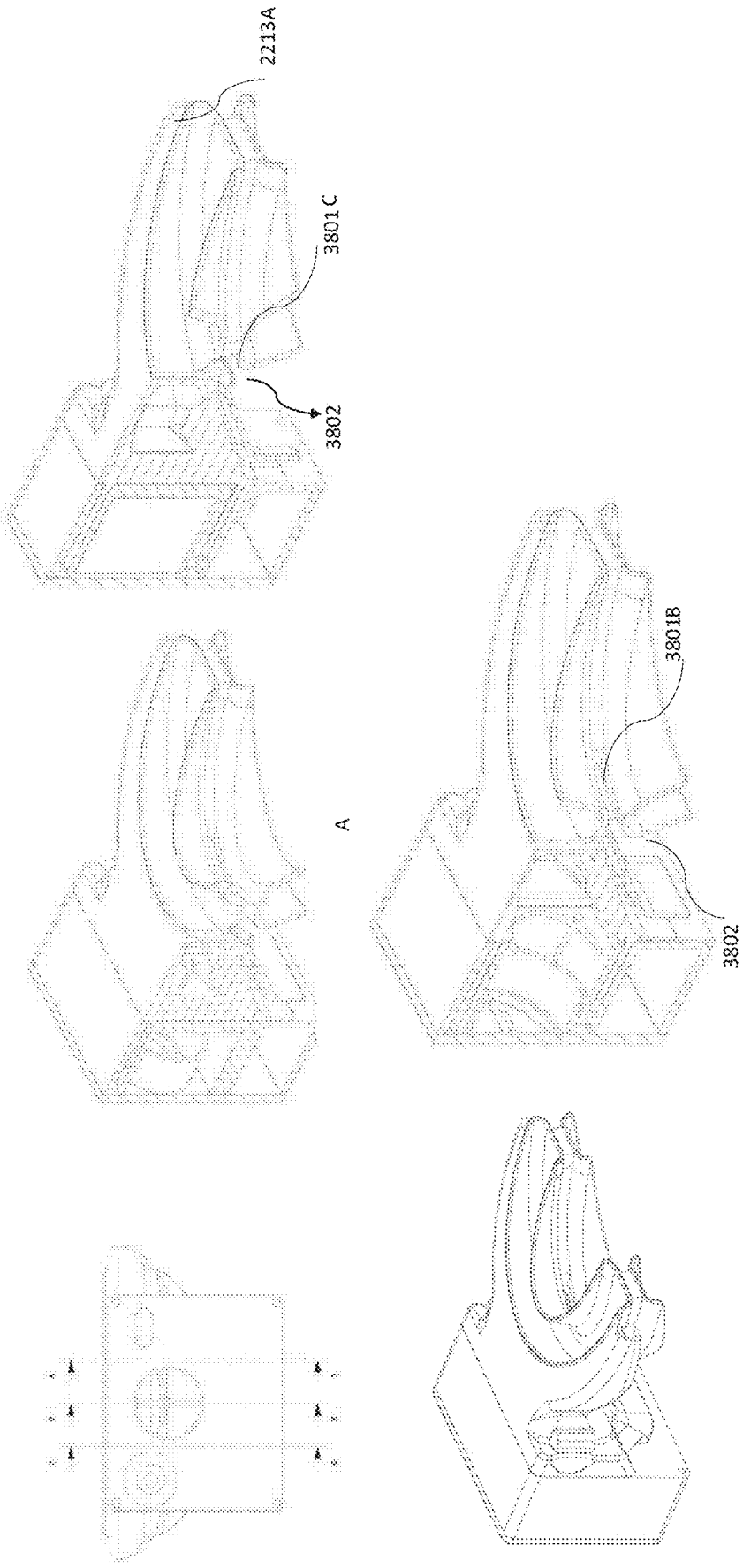


FIG 39

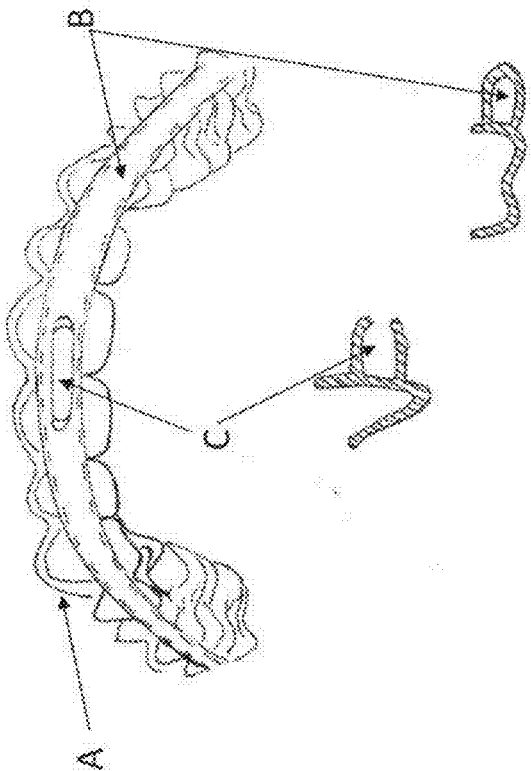


FIG 40



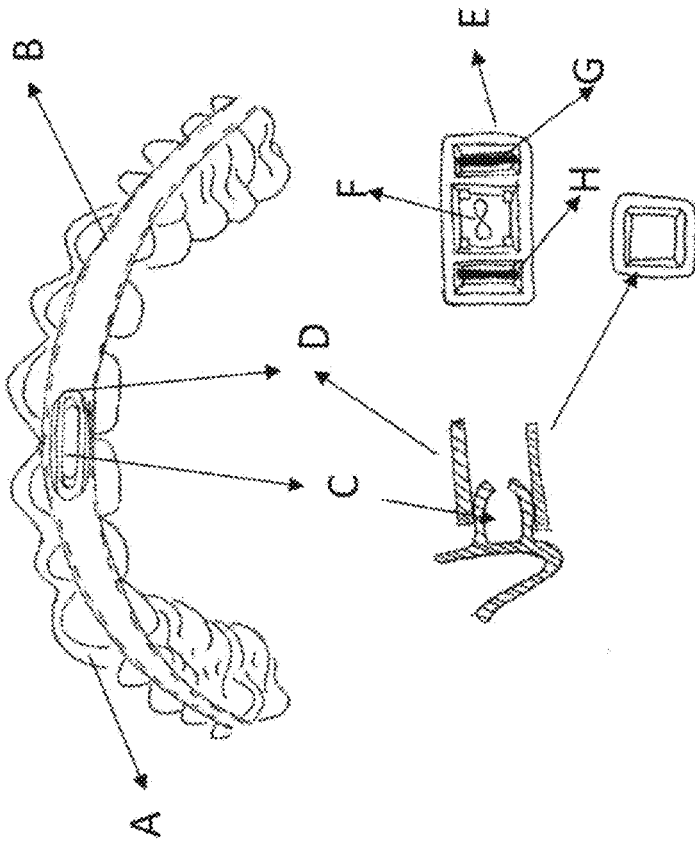


FIG 41

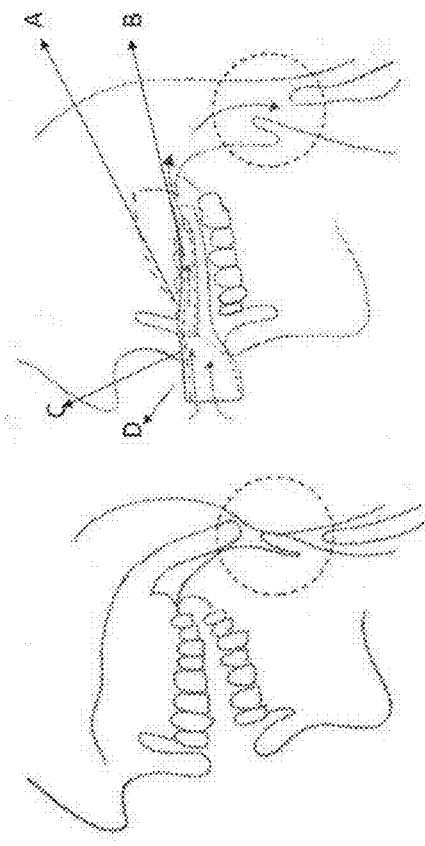


FIG 42

## SLEEP APNEA AND ANTI-SNORING SYSTEM

### CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation-in-part of U.S. patent application Ser. No. 15/383,514 filed on Dec. 19, 2016, which claims the benefit of U.S. Provisional Application No. 62/269,331, filed on Dec. 18, 2015. The entire disclosures of the above applications are incorporated herein by reference.

### FIELD

**[0002]** The teachings are directed towards sleep apnea/anti-snoring devices and more particularly to a cordless and tubeless hybrid sleep apnea/anti-snoring devices for reducing and measuring sleep apnea and snoring.

### BACKGROUND

**[0003]** Obstructive sleep apnea (OSA) is a sleep disorder with partial or complete cessation of breathing during one's sleep. This sleep disorder is currently treated by methods such as a surgery, oral appliance therapy, negative pressure to pull soft palate and tongue forward, implantable devices that keep the airway open during sleep by stimulating the hypoglossal nerve, strips for nose for expiratory positive airway pressure, Positive Air Pressure (PAP) therapy or a combination involving several methods. PAP therapies are also employed to treat other medical and respiratory disorders, such as Cheynes-Stokes respiration, congestive heart failure, and stroke. A common PAP device comprises a flow generator (e.g., a blower) that delivers gas via delivery conduit (hollow tube) to an individual interface. It is also known to deliver the PAP as a continuous positive airway pressure (CPAP), a variable airway pressure, such as bi-level pressure (Bi-PAP) that varies with the individual's respiratory cycle or an auto-titrating pressure (APAP) that varies with the monitored condition of the individual. Nasal, oral-nasal and full-face masks are common interfaces utilized for delivering PAP to the individual's airway.

**[0004]** These masks can be uncomfortable due to improper fit, tight straps to hold mask in place, skin irritation at points of contact, dryness of throat cause claustrophobia, excessive PAP pressure and are a major factor in individual therapy non-compliance. Also the PAP machines can be noisy. Studies show individual non-compliance for PAP therapy from 29 to over 83%.

**[0005]** Obstructive sleep apnea (OSA) is a Sleep disorder with partial cessation(hypopnea) or complete cessation (apnea) of breathing during one's sleep. This sleep disorder is diagnosed and analyzed by a technician monitored overnight sleep study in a sleep laboratory setting (Polysomnography or PSG) with multiple physiological parameters and more recently by Home Sleep Testing devices with limited parameters.

**[0006]** The federal Center for Medicare and Medicaid Services (CMS) has provided guidance for various types of sleep studies based on number of parameters and whether study is attended by Sleep technician or is unattended. A summary of the classification system for sleep studies based on these guidelines is provided below.

**[0007]** Most of the current Home Sleep Testing (HST) devices are worn on chest while current device of invention

is only device which is worn in mouth. It is very comfortable, convenient, small in size and provide for more information due to proximity of several sensors to nose and mouth where actual sleep disturbances events should be measured.

**[0008]** Type I HST devices using in attended sleep studies performed in a sleep lab and monitored by a sleep technician with full sleep staging (i.e monitoring the transition through the various sleep stages). Typically, Type I devices include the following channels (parameters): EEG (electroencephalogram), EMG (electromyogram—chin and Limb), EOG (electrooculogram), respiratory airflow (with oronasal flow monitors), respiratory effort (Thorax and Abdomen), oxygen saturation (oximetry), ECG (electrocardiography), snoring sounds, and body position—additional channels for CPAP/BiPAP levels, CO<sub>2</sub>, pH, pressure etc.

**[0009]** Type II Home sleep test (HST) devices use a portable monitor, performed without any sleep technician monitoring the study, with at least 7 channels or parameters. Type II devices typically include at the very least the following Parameters: EEG, EOG, ECG/heart rate, EMG, Airflow, Respiratory effort, Oxygen saturation. Type III Home sleep tests (HST) use a portable monitor unattended with a minimum of 4channels. Type III devices usually include the following parameters: 2 respiratory movement/airflow, 1 ECG/heart rate, 1 oxygen saturation. Type IV Home sleep test (HST) with Type IV portable monitor, unattended with a minimum of 3 channels. Type IV devices must allow parameters that allow direct calculation of an AHI (Apnea Hypopnea Index) or ROI (Respiratory Disturbance Index) as the result of measuring airflow orthoraco abdominal movement. The ROI is defined as the average number of respiratory disturbances.

**[0010]** Alternately devices that record other information to derive AHI or ROI must be approved by CMS through the review of published peer reviewed medical literature. It is very expensive to perform the traditional attended PSG sleep studies in sleep labs (Type I) to diagnose for OSA. Patients have difficulty getting to sleep in a unfamiliar surrounding with various wires connected to their limbs and head and being continuously watched and monitored. This created a need for a simpler and cheaper way to diagnose for OSA and led to the development of portable sleep monitors—Home Sleep Testing machine (HST) complying with the CMS guidelines and offering results comparable to that of PSG in a home setting.

### SUMMARY OF THE INVENTION

**[0011]** According to the present teachings, a detachable oral sleep treatment device selectively engageable with a patient's lips and teeth, said oral sleep treatment device is presented. The detachable oral sleep treatment device includes a front hollow housing defining a first through passage defining an inlet aperture and an output aperture, said front hollow housing having an exterior surface configured to engage the patient's lips the front hollow housing having a first detachable locking interface adjacent the output aperture. The detachable oral sleep treatment device further includes an air flow generating device disposed within the first through passage, the generating device configured to create an airflow from the inlet aperture through the output aperture the air flow generating device comprises a controller configured to regulate electrical power supplied to the generating device and a battery

disposed within the front hollow housing, said battery being electrically coupled to the airflow generating device and the controller, and a mouthpiece defining first mouthpiece aperture selectively coupled to the front housing, the mouthpiece having first and second curved members together defining a u-shape and having an exterior surface defining a tooth engaging surface, said first and second members defining second and third through passages, said first and second rear mouthpiece apertures disposed adjacent to the retromolar pad members when said mouthpiece is engaged with the patient's teeth. The detachable oral sleep treatment device further includes a vibrational isolating member disposed between air flow generating device located in the front hollow housing to reduce the vibration transmission into the mouthpiece, wherein the vibrational isolating member reduces the noise transmission to mouthpiece which in turn prevents the bone conduction noise through teeth trays in an inner ear canal.

**[0012]** According to the invention above, where the controller is configured to store data related to the plurality of sensors comprising one of a pressure sensor, an airflow sensor and one or more temperature sensors, sound sensor, accelerometer, tilt sensor, and a pulse oximeter.

**[0013]** According to the invention above, further including inhalation and exhalation apertures wherein within the exhalation aperture is disposed a valve that stays closed through it during inhalation, and during inhalation, the air enters in the mouth through the air flow generating device via an air passageway bypassing the tongue, not allowing the muscles to relax and keep oropharynx area open for ease of breathing. During exhalation, the valve opens due to exhalation air pressure or more importantly when nose is congested, allowing air to exhale easily.

**[0014]** According to the invention above, further includes the Infra-red emitter disposed with the mouthpiece configured to provide a signal indicative of air speed and allows to capture the video and photos in the oropharynx area.

**[0015]** According to the invention above, further including active noise cancellation built-in the housing which cancel the airflow noise and vibration noise created by air flow generating device. Which reduces the noise transmission to mouthpiece which in turn prevents the bone conduction noise through teeth trays in inner ear canal.

**[0016]** According to the invention above, the first mouthpiece is configured to engage one of the upper teeth or lower teeth.

**[0017]** According to the invention above, where the mouthpiece second and third through passages are defined at one of underneath and side/surrounding the upper teeth tray.

**[0018]** According to the invention above, where the mouthpiece is selected from the group consisting of a detachable-customized mouthpiece an upper teeth tray 3D printed from a material having a first durometer, an upper teeth tray made from soft material which is thermoformed and adhesively bonded to hard 3D printed air passageway, an upper teeth tray made from boil and bite material bonded to hard 3D printed air passageway to create pre-customized upper mouthpiece defining the first and second rear mouthpiece apertures.

**[0019]** According to the invention above, where the upper teeth trays as described above includes an upper tray 3D printed from hard material an upper teeth tray and a lower teeth tray formed of a single plastics piece.

**[0020]** According to the invention above, where the upper tray is made from soft material which is thermoformed and adhesively bonded to hard 3D printed air passageway.

**[0021]** According to the invention above, where the upper teeth tray made from boil and bite material bonded to hard air passageway.

**[0022]** According to the invention above, where the mouthpiece is attached to lower teeth tray.

**[0023]** According to the invention above, the mouthpiece includes a Mandibular Advancement Devices configured to bring lower jaw forward to further reduce sleep apnea.

**[0024]** According to the invention above, the mouthpiece hinge style sleep apnea device comprising an upper teeth tray and a lower teeth tray formed of a single plastics piece bonded to air passageway of the mouthpiece.

**[0025]** According to the present teachings, a detachable oral sleep treatment device selectively engageable with a patient's lips and teeth, said oral sleep treatment device includes a front hollow housing defining a first through passage defining an inlet aperture and an output aperture, said front hollow housing having an exterior surface configured to engage the patient's lips the front hollow housing having a first detachable locking interface adjacent the output aperture. The detachable oral sleep treatment device further includes an air flow generating device disposed within the first through passage, the generating device configured to create an airflow from the inlet aperture through the output aperture the air flow generating device comprises a controller configured to regulate electrical power supplied to the generating device and a battery disposed within the front hollow housing, said battery being electrically coupled to the airflow generating device and the controller. The detachable oral sleep treatment device further includes a mouthpiece defining first mouthpiece aperture selectively coupled to the front housing, the mouthpiece having first and second curved members together defining a u-shape and having an exterior surface defining a tooth engaging surface, said first and second members defining second and third through passages, said first and second rear mouthpiece apertures disposed adjacent to the retromolar pad members when said mouthpiece is engaged with the patient's teeth, and a first vibrational isolating member disposed between the air flow generating device from the front hollow housing to reduce the vibration transmission into the mouthpiece.

**[0026]** According to the invention above, a second vibrational isolating member is disposed between the surfaces of the front housing and the mouthpiece to prevent direct contact of the front housing and the mouthpiece, wherein the front housing is made of a first material having a first durometer and the second vibrational isolating member is made of a second material having a second durometer different than the first durometer.

**[0027]** According to the invention above, where the mouthpiece is selected from the group including of a detachable-customized mouthpiece containing an upper teeth tray 3D printed from a material having a first durometer, an upper teeth tray made from soft material which is thermoformed and adhesively bonded to hard 3D printed air passage way, an upper teeth tray made from boil and bite material bonded to hard 3D printed air passageway; to create pre-customized upper mouthpiece defining the first and second rear mouthpiece apertures.

**[0028]** According to the invention above, where an air flow generating device produces a first air flow rate during inhalation and a second air flow rate during exhalation, creating an expiratory positive airway pressure, maintaining pressure in the airway through the start of the next inhalation.

**[0029]** According to the invention above, where the first detachable locking interface is selected from the group comprising a cantilever snap joint where the load here is mainly flexural, u-shaped snap joints where a variation of the cantilever type, Torsion snap joints where Shear stresses carry the load, and annular snap joints where they are rotationally symmetrical and involve multiaxial stresses.

**[0030]** According to the invention above, where the first detachable locking interface has a snap fit flexible arm that has a decreasing cross-sectional area that decreases linearly up to 30% of a original cross-sectional area.

**[0031]** According to the invention above, where strain in an outer portion of the flexible arm is uniform throughout the length of the flexible arm and wherein the width of the flexible arm is between 3 mm to 15 mm, preferably 10 mm, having a length between 3 mm to 12 mm, the ratio of flexible arm and a thickness of flexible beam arm between 0.5 mm to 3.0 mm.

**[0032]** According to the invention above, where the first detachable locking interface links the housing and mouthpiece together by flexible, semi-solid plastics elastomeric linkages which is held by a plurality of buttons on sides of the housing and mouthpiece.

**[0033]** According to the invention above, where the mouthpiece is detached from the housing using un-linking the flexible, semi-solid linkages from buttons located on both pieces by flanges.

**[0034]** According to the invention above, where the second and third passages having a non-circular cross section which decreases in cross sectional area from the first mouthpiece aperture to first and second rear mouthpiece apertures, that are configured to increase the pressure and air velocity of air passing from the front hollow housing through the second and third passages.

**[0035]** According to the invention above, where the mouthpiece further includes a flexible isolator member disposed between the housing and the mouthpiece to dampen noise transmission to mouthpiece, the flexible isolator being made from a material selected from a seal comprising two shot molding, single or two material 3D printing, injection molding, over molding.

#### DRAWINGS

**[0036]** FIGS. 1A to 1I depict various embodiments of a sleep apnea treatment anti-snoring device attached to upper arch with hollow front housing and hollow side tubes (with or without microprocessor/sensors attached to front hollow housing) to bring air at the end of the throat (pharynx) area according to the present teachings;

**[0037]** FIG. 1J depicts different cross sections of device—from front of the housing to end of inner piece (oropharynx area) according to the present teachings;

**[0038]** FIG. 1K shows further cross section at the center of device as per FIG. 1I cross section;

**[0039]** FIG. 1L shows further cross section at the center of device as per FIG. 1I cross section FIG. 1M shows the

device with cross section areas to be taken for further figures and FIG. 1N depict one cross section of device as per FIG. 1M;

**[0040]** FIG. 1O shows the next cross section as per FIG. 1M;

**[0041]** FIG. 1P depicts the next cross section as per Figure;

**[0042]** FIGS. 1S-1Y represent various views of the device shown in 1O.

**[0043]** FIGS. 1Q and 1R further depict the cross sections to the present teachings;

**[0044]** FIG. 2A to 2C depict a sleep apnea or anti-snoring device with both upper and lower arches, where the upper arch comprises a curved center hollow passageway designs from front of mouth other than hollow tube to keep the tongue down while delivering airflow directly to the oropharynx/throat area according to the present teachings;

**[0045]** FIG. 20 shows hollow tube or hollow passageway design according to FIG. 2 having a lower portion rotated with respect to an upper portion.

**[0046]** FIG. 2E shows an end view of the hollow tube or hollow passage way design shown in FIG. 20;

**[0047]** FIGS. 3A and 3B depict a sleep apnea or anti-snoring device with different designs of strips with two sided adhesive buttons or tapes to keep the individual's tongue forward while still allowing tongue side to side movement according to the present teachings;

**[0048]** FIGS. 4A-4E depict conventional CPAP single piece oral sleep apnea treatment device with micro-blower(s) for continuous positive airflow with microprocessors and sensors according to the present teachings;

**[0049]** FIGS. 5A-5D depict a variety of suitable micro-blowers for use with the teachings;

**[0050]** FIGS. 6A and 6B depict an Auto CPAP (APAP) device with a miniature control module inserted in hollow housing having micro-blower(s) and sensors and microprocessor (micro-chip) etc.;

**[0051]** FIGS. 6C and 6D depict micro fan(s) is mounted vertical, blowing the air straight into housing and hollow tubes. FIG. 6E Show that micro fan(s) can be mounted horizontal and control module can be mounted vertically to each according to the present teachings;

**[0052]** FIG. 7A depict an CPAP or Auto-CPAP (APAP) control module comprising various items inserted in the housing of the device;

**[0053]** FIG. 7B depicts a schematic of the data flow and control module according to one embodiment of the teachings;

**[0054]** FIG. 8A depicts current mandibular advancement device (MAD) and FIG. 8B depicts a combination micro, tubeless, maskless, single piece Oral CPAP device with mandibular advancement capability (Hybrid PAP-MA Oral Device or Hybrid APAP-MA Oral Device);

**[0055]** FIG. 9 depicts one embodiment of a nasal/oral device with or without the MAD CPAP Device;

**[0056]** FIG. 10 depicts thin plastic membrane which depresses the upper arch of mouthguard (at the end, throat area) which expands and stays expanded during airflow from micro blower, stopping soft palates to collapse, allowing more open airway passage;

**[0057]** FIG. 11 depicts exploded view of separate pieces of device to be manufactured;

[0058] FIG. 12 depicts various flows schemes for manufacturing methods for a customized, single piece, micro-oral PAP or APAP device;

[0059] FIGS. 13A-13D depict a customized, single piece, micro-oral PAP device made by a “Boil and Bite” manufacturing process;

[0060] FIGS. 14A-14D depict a customized, single piece, micro-oral PAP device manufactured by “Bite only” micro-cellular foaming injection molding;

[0061] FIGS. 15A and 15B depict a single step manufacturing method for hollow device by injecting material in two cavities, cavities rotation, followed by injecting plastic at intersection of two halves, creating hollow part;

[0062] FIG. 16 depicts micro-holes in the hollow tube (or hollow passage way), blowing air at very low flow rate, but stimulating the tongue to stay forward original position (does not allow to fall back) during sleep. These micro-holes can be near the tongue (lingual area) and/or at the end of throat area (oropharynx area);

[0063] FIG. 17 depicts special microchip embedded into mouthguard for nerve stimulation and a plurality of metal stimulators. It's designed to be in close proximity to the nerves of the tongue muscle. This reduces the tongue falling back during sleep, allowing more open airway passage.

[0064] FIGS. 18A and 18B represent exploded views of components used to form a device according to the teaching of the present invention;

[0065] FIGS. 19A and 19B Represent perspective views of an alternate sleep enhancement medical device;

[0066] FIGS. 20A and 20B represent perspective and top views of a sleep enhancement device according to the present teachings; and FIGS. 21A and 21B represent end views of the device shown in FIGS. 19A and 19B.

[0067] FIGS. 21A and 21B represent perspective front views of a sleep enhancement device according to the present teachings. As can be seen in the treatment or diagnostic device, as described above with respect to FIGS. 18A and 18B can have an integral front section 610 which holds the sensors such as 720 and 725 and can hold the battery and micro blower and associated controller. This portion can be snap or interference fit (but detachable) to a u-shaped body 952 which when mated with support structure 948 defines the side through passages 115. The support structure 948 defines a cavity which supports the bite region 1212. As describes in detail earlier, this bite area 1212 can be a 3D printed representation of the patients tooth region, or can be a boil and bite materials. The support region, also can have several cross flanges 926 which can engage and depress portions of the tongue;

[0068] FIG. 22 depicts the exploded view of detachable oral “Fixed Boil and Bite” sleep apnea mandibular advancement device (MAD) defining air passageways.

[0069] FIG. 23 depicts exploded view of FIG. 22 oral “Fixed Boil and Bite” sleep apnea mandibular advancement device (MAD) at different angle where it shows air exit location (oropharynx area, back of throat area) from the hollow air passageway (hollow tubes).

[0070] FIG. 24 depicts different cross sections of FIG. 22 detachable oral “Fixed Boil and Bite” Non-mandibular advancement sleep apnea device. If lower teeth tray is attached, it can be shown as MAD device.

[0071] FIG. 25 depicts the exploded view of detachable oral “Adjustable Boil and Bite” sleep apnea mandibular advancement device (MAD) having air passageways. Here

it depicts the outer housing (containing lid, micro-blower, PCB and battery) can be attached and detached from mouthpiece having teeth trays, connecting rods (linkages) and hollow air passageway using snap/unsnap fit structures such as cantilever types. This concept can be without MAD by using upper teeth tray only.

[0072] FIG. 26 depicts exploded view of FIG. 25A oral “Adjustable Boil and Bite” mandibular advancement (MAD) sleep apnea device at different angle where it shows the air exit location (oropharynx area) from the hollow air passageway as part of upper teeth tray. This concept can be without MAD by using upper teeth tray only.

[0073] FIG. 27 depicts the exploded view of detachable oral “Pre-Customized 3D printed sleep apnea mandibular advancement device where mouthpiece is 3D printed having hollow air passage which is located underneath the upper teeth tray which is connected to lower tray by connecting rods (linkages) using buttons. The outer housing can be attached and detached from mouthpiece using cantilever types of snap/unsnap fit structures or other designs. This concept can be without MAD by using upper teeth tray only.

[0074] FIG. 28 depicts different cross sections of oral “Pre-Customized 3D printed” sleep apnea mandibular advancement device shown in FIG. 27.

[0075] FIG. 29 depicts different cross sections of oral “Pre-Customized 3D printed” sleep apnea mandibular advancement device shown in FIG. 27 showing the air entrance from the front of the outer housing through the hollow air passage and air exit in the oropharynx area.

[0076] FIG. 30 depicts the exploded view of FIG. 27 detachable oral “Pre-Customized 3D printed” sleep apnea mandibular advancement device at different angle in which it shows the location of air exit from the hollow air passageway located under the upper teeth tray.

[0077] FIG. 31 depicts the different cross sections of the detachable oral “Pre-Customized 3D printed” sleep apnea mandibular advancement device where mouth piece is 3D printed having hollow air passageway located on the side of the upper teeth tray.

[0078] FIG. 32 depicts exploded view of detachable oral sleep apnea mandibular advancement device having “hinged upper and lower plastics trays” where upper and lower teeth trays are NOT either “boil or bite” type or NOT “Pre-customized 3D printed”.

[0079] FIG. 33 depicts the cross section of hinge structure with dimensions at different locations.

[0080] FIG. 34 depicts the dimensions of snap/unsnap cantilever structure used in all detachable oral sleep apnea devices described in this patent.

[0081] FIG. 35A depicts the cross sections of oral detachable sleep apnea device where outer housing and mouthpiece are snapped together and un-snapped from each other using cantilever type snap beam structure.

[0082] FIG. 35B depicts the expandable oral detachable sleep apnea device where outer housing and mouthpiece are held together using flexible elastomeric plastics linkages and buttons on both pieces while having elastomeric gasket inserted between housing and mouthpiece. Both pieces are removed by detaching the linkages from buttons.

[0083] FIG. 36A depicts the design to isolate, de-couple the micro-blower from the rest of the housing by different techniques of materials and designs. Here it shows passive sound absorption and vibration dampening mechanism by using tapes and/or foam as an enclosure on the micro blower.

The outer housing can also have passive or active sound cancellation technology built in.

**[0084]** FIG. 36B depicts two halves of micro-blower enclosure using sound dampening and/or sound absorbing material.

**[0085]** This enclosure can include a detachable cantilever snap/unsnap type sleep apnea device having micro-blower enclosure in the housing using sound dampening and/or sound absorbing material and soft isolator at all the contact surfaces between housing and mouthpiece.

**[0086]** The detachable sleep apnea device having can include linkages and buttons to attach and detach housing and mouthpiece.

**[0087]** FIG. 37 depicts detachable oral sleep apnea device with electro-stimulation of tongue. The device can be with or without mandibular advancement.

**[0088]** FIG. 38 depicts detachable oral “fixed Boil and Bite” sleep apnea mandibular advancement device having separate hollow air passageway for air inhalation (aided by micro blower) and separate opening for air exhalation (aided by specific design).

**[0089]** FIG. 39 depicts the different cross sections of FIG. 38 showing both air passageways for inhalation and exhalation.

**[0090]** FIG. 40 depicts a diagram showing hybrid sleep apnea device, a combination treatment device, having aligner to treat sleep apnea while correcting teeth at same time. This hybrid device can be with or without mandibular advancement. It can be designed for 24/7 use or for night time use only. This is known as “passive” hybrid device.

**[0091]** FIG. 41 is a diagram showing an example modified detachable hybrid sleep apnea/aligner device where the hollow front outside housing is attached to hybrid sleep apnea device of FIG. 40.

**[0092]** FIG. 42 shows a patient wearing the example detachable hybrid aligner/sleep apnea device of FIG. 41 having front outside housing attached to mouthpiece having hollow tube of the aligner via detachable snap-fit structure.

#### DETAILED DESCRIPTION

**[0093]** The teachings relates to device designs, working function of device, and manufacturing methods for single piece, micro, tubeless, cordless, anti-snoring (AS)/sleep apnea treatment (SA) devices where airflow from the front of the mouth is directed from the device to the back of the mouth, bypassing the soft tissues, palates, tongue etc., directly to the oropharynx or laryngopharynx area, with or without use of micro-blowers. If micro-blowers are not used, the device can have micro-sensors and microprocessors attached to front hollow housing. The sensors can be insert molded in the inner piece of the device. The device can be attached to the upper arch (teeth) or the lower arch (teeth) or to both arches. The design of the device allows for simultaneous nose breathing. The device can be non-customized or customized for the individual. Airflow is directed to the oropharynx area (throat area) from the mouth opening (lips area) using a front hollow housing and hollow tubes (or different hollow passageways designs) bypassing soft tissues. In case of an Auto PAP device, the desired pressure and airflow is achieved (automatically adjusted continuously during sleep) using micro fan(s), sensors and microprocessor having closed loop feedback control system and proprietary algorithm using a compact control module inserted inside the front hollow housing of the oral or oral/nasal

device. Sensors with low energy battery can also be attached to mouthguard during injection molding process for compliance and few data acquisition purposes. The device has the capability to record data within the system using a micro-SD card or to transfer data wirelessly using Bluetooth or cloud to permit live monitoring of the medical condition of the individual and treatment compliance.

**[0094]** In addition to an auto continuous positive air pressure (Auto CPAP) or non-auto continuous positive air pressure (conventional CPAP) controlled mechanism, the oral device can also bring lower jaw forward (mandibular advancement device—MAD) reducing further occurrence of the sleep apnea and snoring significantly, referred to herein as: A. PAP-MAD without micro-blower but with micro sensors and microprocessor or B. CPAP-MAD with micro-blower(s) more micro-sensors and microprocessor or C. Auto-CPAP/MAD with micro-blower(s) having sensors and closed loop control system and proprietary algorithm to have comfortable (auto-adjustable) pressure/air flow during sleep

**[0095]** The device can also be modified to use as a diagnostic sleep apnea device with additional sensors. The device can be controlled wirelessly to set parameters such as pressure, flow rate etc., by any wired or wireless device such as a smart phone, smart notebook etc., using Bluetooth type or other wireless technologies.

**[0096]** The teachings relate to oral or nasal or a combination of oral and nasal device for treatment and diagnosis of obstructive sleep apnea and snoring; having microprocessors and sensors, comprising of following configurations and all devices are with or without mandibular advancement (MAD): 1. Oral Device having micro-blowers and control module—positive airflow (PAP) device 2. Oral Device having micro-blowers and control module—auto control positive airflow (APAP) device and proprietary algorithm for auto adjustment of pressure and/or flow rate 3. Oral/Nasal Device having micro-blowers with positive airflow (PAP or APAP) utilizing nasal passage for air delivery 4. Oral Device without micro blower and with or without microprocessor, sensors and data acquisition system 5. Above oral devices with capability for testing sleep apnea known as HST or OOCST (out of center sleep testing) diagnostic PAP device and capability to treat OSA.

**[0097]** All above configurations without mandibular advancement (MAD) can be provided with upper mouthpiece only (i.e., without the lower mouth piece) or with lower mouth piece only (i.e. without the upper mouth piece). The Non-customized device or customized devices (to fit individual’s teeth) are supplied in different sizes such as small, medium, and large. Both non-customized and customized devices consist of two pieces A and Bas shown below: A. front hollow housing (in which micro fan(s), sensors, microprocessors etc. are inserted after manufacturing) and B. inner mouthpiece with hollow air passageway.

**[0098]** Front housing has snap/un-snap fit concept where front hollow housing section is easily snap-fitted with inner mouthpiece and also can be easily un-snapped (removed from inner mouth piece). Below are manufacturing methods: A. Front hollow housing with is made by injection molding. To prevent air leakage between hollow housing and inner mouthpiece, an elastomeric ring is mounted on front housing or elastomeric ring is molded in one step process as two shot injection molding. B. For inner mouthpiece, the following manufacturing methods are used to achieve predetermined hollow passageways. The inner mouthpiece is divided into

two portion: 1. Partial hollow tube and 2. Mouthguard (upper or lower arch) 1. Multi-step process: 1. Separately injection mold partial hollow tube and mouthguard (or two shot molding of mouthguard where it can be soft/hard material or “boil bite” soft material with hard material) followed by bonding of partial hollow tube and mouthguard to create hollow passage way in inner mouth piece. The bonding can be mechanical, vibration welding, laser welding or adhesively bonding; 2. One step injection molding process where partial walls of tube and mouthguard are molded in two cavities of a single mold, followed by rotating cavities where two halves are aligned and second material is injected at intersection, bonding these two pieces and creating hollow structure. Here, the second material is soft material or “Boil and Bite” material, creating customized oral device in a single step process; 3. Water or gas injection molding to achieve hollow air passageway; and 4. Lost core foam injection molding

**[0099]** Both non-customized and customized devices are manufactured to fit the individual’s teeth (upper arch, lower arch, or both). The customized device provides better fit and more comfort. The customized device is also supplied in 3 different sizes such as small, medium, and large based on internal teeth arch sizes of different individuals.

**[0100]** There are different manufacturing methods for customized devices such as: 3D Printing of Device—This is accomplished by scanning of the teeth or creating an impression of teeth, creating a CAD file of teeth for 3D printing of the device, followed by 3D printing of hard or soft device in a single step. Here, hollow sections such as tubes and hollow housings are manufactured in a single step, due to design freedom of 3D printing process. “Boil and Bite” concepts such as: a) Over-molding of “Boil and Bite” material on 3D printed part (also known as insert molding): This is accomplished by injection molding of soft “Boil and Bite” on hard 3D printed hollow device (part) as an “insert” in injection molding tool. b) Over-Molding of “Boil and Bite” material on previously hollow Injection molded device (part): Injection molding of soft “Boil and Bite” material on previously injection molded hollow device as “an Inert” (here, hollow structure for housing and tubes/hollow air passageway can be manufactured by several methods described above. c) micro-cellular foaming injection molding process where micro-cellular foam material is injected on top of mouthguard.

**[0101]** The device can be single piece construction, if the device does not contain any sensors/microprocessor or sensors/microprocessor and battery are completely sealed, then no need to have snap-fit feature. This single piece construction can be achieved by bonding of two separate injection molded halves at pre-determined line (or separately injection molding housing with partial tube and mouthguard) followed by bonding these two pieces to create hollow structure or by water injection molding or by lost core foam injection molding.

**[0102]** In all cases, it is recommended to replace mouth-piece from front housing or replace “boil and bite” portion of mouth piece once it wears out in order to protect the teeth, keeping correct teeth alignment and not creating TMJ. The front hollow housing with or without microprocessor and sensors can be reused.

**[0103]** For both Non-customized and customized devices, they can be used without micro-blower where air flow is directed from the front to oropharynx area due to hollow

tubes or hollow passage ways. Here, the device can have microprocessor and key sensors to provide feedback on sleep quality and AHI index as well as compliance.

**[0104]** For both Non-customized and customized devices a micro-blower or multiple micro-blowers can be inserted into the front hollow housing of the device. The micro-blower continuously blows air into hollow internal airflow passages attached to the mouth guard, thus working as a conventional CPAP machine, but without any external tubes or wires or cords attached.

**[0105]** For device described above, the device can also be fitted with a control module having microprocessor and sensors for pressure, airflow rate, temperature, pulse rate and oxygen saturation, snoring pattern, position during sleep, respiratory efforts etc. with a closed loop control system (hardware). This embodiment allows for the automatic control of airflow pressure and/or air volumetric flow rate as in Auto CPAP or Bi-CPAP type machines without the need for external tube, wires, cords, fittings using proprietary algorithms built into the device unit command module.

**[0106]** The device brings airflow from the front of the mouth to back of the throat (pharynx area) and can be combined with mandibular advancement (bringing the lower jaw forward) to further assist in mitigating snoring and sleep apnea, referred to herein as PAP-MAD without micro-blower or CPAP-MAD with micro-blower or Auto-CPAP/MAD with closed loop control system.

**[0107]** The device may comprise the capability to record data by micro-SD card or wirelessly transfer data for real time monitoring and treatment compliance. The device can be controlled wirelessly using mobile devices.

**[0108]** One embodiment of the teachings comprises tongue depression design of hollow tube (or any hollow passage design). This serves two purposes: bring the air from outside to back of throat and same time keeping the tongue down, keeping more air passage open at the oropharynx area.

**[0109]** One embodiment of the device comprises of utilizing PVDF sensor technology with airflow and apnea/hypopnea detection already calibrated off the shelf strips (from Dymedix) or standard PVDF film strips that can be mounted in our device with proprietary algorithm to enable CPAP/APAP type operation for all the above PAP devices identified above.

**[0110]** One embodiment provides special design at back of the upper or lower arch of mouthguard which attracts the tongue to stay forward position during, keeping more air passage way open. One embodiment provides curve vertical semi-rigid plastics strip (fish tail shape) attached to hollow side tubes on both side, which pushes upper lip mouth area outward, keeping nasal air way passage open, helping further air coming from nose during sleep, reducing snoring and sleep apnea.

**[0111]** One embodiment of the teachings comprises providing micro-holes in the hollow tube (or hollow passage way), blowing air at very low flow rate, but stimulating the tongue to stay forward original position (does not allow to fall back) during sleep. These micro-holes can be near the tongue (lingual area) and/or at the end of throat area in a hollow tube (left and right) connecting the end of the two sides of hollow tubes of upper or lower arch, directly blowing air to tongue and to soft palates of throat region. Slight disturbance of tongue and soft palate by air from these holes



may be sufficient, not allowing soft tissues to relax, keeping air passageway open during breathing during sleep without waking up an individual.

**[0112]** Other embodiments envisage using nasal or oral-nasal delivery of air flow from device with or without auto control module and micro-blowers. One embodiment of the teachings comprises that the light source and pulse oximeter probe can be mounted outside the lip on vertical plastic strip which is part of hollow housing while the light detector is mounted on the mouthguard. Other concept of wired pulse oximeter can be mounted on ear lobe. Wireless pulse oximeter can be mounted on finger or any other location as done by conventional pulse oximeter. The information can be transferred to Bluetooth of the teachings device or Bluetooth of the smart phone or any such device.

**[0113]** One of the benefit of the device compared to current PAP machine is that there is no need to vent the air during exhalation since device allows to exhale through nose even when the micro blower is continuously blowing air during exhalation.

**[0114]** One embodiment of the teachings comprises special microchip embedded into mouthguard for nerve stimulation. The ultra-small neurostimulator, is mounted on the mouthguard (bonded to mouthguard or insert molded this tiny chip in plastic during injection molding of mouthguard). It's designed to be near the nerves of the tongue muscle for stimulation. This reduces the tongue falling back during sleep, allowing more open airway passage.

**[0115]** Other embodiments envisage using nasal or oral-nasal delivery of air flow from device with or without auto control module and micro-blower(s). One embodiment of the teachings comprises an impact sport guard with additional airflow during the sports activity and protection of teeth. This embodiment is referred to herein as a positive airway pressure impact sports guard with or without micro-blower(s). This is accomplished by front housing having impact absorbing material or a 3-D printed lattice structure to absorb and distribute energy away from the teeth.

**[0116]** One embodiment of the teachings comprises that the light source and pulse oximeter probe can be mounted outside the lip on plastic which is part of hollow housing while the light detector is mounted on the mouthguard. Other concept of wired pulse oximeter can be mounted on ear lobe. Wireless pulse oximeter can be mounted on finger or any other location as done by conventional pulse oximeter. The information can be transferred to Bluetooth of the teachings device or Bluetooth of the smart phone or any such device.

**[0117]** The device can also be configured as a sleep apnea diagnostic device to detect OSA. For this use, the device has various sensors located in the hollow housing and/or the maxillary or mandibular arches which would be capable of measuring and recording oxygen saturation in blood and pulse rate (pulse oximeter), air flow rate, respiratory effort by Bluetooth/wifi enabled effort belts (RIP belts); temperature, position (tilt), Single lead ECG sensor packages with wireless connectivity can be used to monitor and record heart rhythm; also EEG sensors packages can be incorporated to monitor and record brain activity. Also, inside mouth camera can be used to monitor changes in air passage. Proprietary algorithms can be applied to this data to determine AHI which could be correlated to standard Sleep diagnostic tests such as PSG or PG.

**[0118]** The device can be modified to serve as a sleep apnea diagnostic device. For this use, the device has more sensors located in the front outside housing and/or maxillary or mandibular arches such as differential pressure to measure air flow; pulse sensor to measure oxygen saturation in blood, pulse rate, temperature; a position sensor (tilt sensor) to indicate position of body while at sleep, Sound sensor to measure breathing variation and snoring; miniature video camera on the mouthguard to take pictures of inside of mouth during sleep; PVDF based sensor for air flow and temperature measurement; respiratory effort sensor (RIP belt). These data along with heart rate can provide information on AHI (Apnea Hypopnea Index) number for the individual (level of sleep apnea) as well as ability to discriminate between OSA and central apneas. EKG probes can be used for monitoring heart rhythm which can communicate with the device with wireless technology. Also additionally EEG sensors can be incorporated to measure brain activity and provide data on actual sleep time. The device can perform as diagnostic tool (as Home Sleep Testing (HST) or Out of center Sleep Testing (OOCST) for detecting OSA.

**[0119]** The device can also be used to titrate oral appliances such as mandibular advancement (MAD devices) and help select appropriate treatment without extensive sleep lab or home sleep testing. HST can be conducted with different mandibular advancement positions and the Diagnostic results from each overnight sleep study (HST) with different positions compared to select the best position for optimal treatment.

**[0120]** The device can also be configured with PVDF sensors applied to the patients' area above the lips and below the nostrils with a Dymedix sensor (previously calibrated) or with a PVDF film installed in the hollow housing and/or the maxillary or mandibular arches, with airflow and apnea/hypopnea detection capability to provide HST capability. PVDF film has a property that allows it to produce an electrical signal when variation in force, sound, acceleration, pressure, or heat is applied such as by airflow with varying temperatures (breathing in and exhaling), snoring sound, moving while asleep, etc. This signal can be captured and magnified by proper filters and amplifiers to produce waveforms as utilized by PSG/HST diagnostic devices and can be monitored and stored to provide and record indications of snoring, apnea/hypopnea and so on. The PVDF sensor would replace or enhance the sensors already indicated above.

**[0121]** In one embodiment the device can deliver compounds and or excite or stimulate appropriate nerves in the mouth to open air way passages. According to the present teachings, each device within the specification can be used with or without micro blowers. Turning to the figures, FIG. 1A depicts an individual with no sleep apnea treatment device inserted in the mouth. Oropharynx area (upper airway) **15** is almost closed during sleep causing sleep apnea or snoring. In FIG. 1 B, the same individual shown in FIG. 1A is depicted having a sleep apnea treatment device **13** according to the teachings inserted into the mouth, and oropharynx area **15** (airway passage) is less obstructed as air comes from the front of hollow housing of device and is delivered to the oropharynx area, completely bypassing air flow restriction areas such as soft palates, and tongue during sleep, reducing

sleep apnea or snoring. Direct continuous air delivery during inhalation reduces sleep apnea occurrence as the airway passage is less obstructed.

**[0122]** FIG. 1 C depicts a CAD drawing for the device 13. FIGS. 1 D and 1 E shows different designs of device. All FIGS. 1 C, 1 D and FIG. 1 E having an upper arch can be customized using several mentioned methods. FIGS. 1 D and 1 E have sensors and/or microprocessor 127 mounted in the outer housing next to hollow airway passage opening. This sensor helps doctor to determine the patient compliance, sleep information and other parameters real time and/or over long period of time. FIG. 1 C depicts a front top perspective view and FIG. 1 E depicts a rear perspective view of one embodiment of the device of the teachings. As shown in FIG. 1 C and FIG. 1 E, device 13 comprises three main components: hollow front housing 110 with front opening 126 for air entrance and 127 space for microprocessor and sensors (for FIGS. 1 D and 1 E), hollow side tubes 115 which bring air from hollow opening 126 in hollow front housing 110 to oropharynx area 15 as seen in FIG. 1 B and upper arch 100 which can be Non-customized or customized. Upper arch 100 can be made of single material or can comprise soft material 121 touching the teeth and semi-rigid material 122 on outside, facing lower teeth as shown in FIG. 1 F. FIG. 1 G shows the device 13 with strips to keep tongue down. Figure H shows microprocessor and sensors attached to front housing.

**[0123]** Hollow side tubes 115 can be manufactured using the same materials as rest of device 13 or they can be manufactured from material 122 that is slightly more rigid than upper arch 100 material 121 as shown in FIG. 1 F so they do not collapse, restricting the airflow. The rigidity of material also allows withstanding teeth grinding forces during sleep. By using a high modulus material, the wall thickness of hollow side tubes 115 and hollow front housing 110 can be in the range of 0.3 mm to 2 mm, the overall size of device 13 can be reduced, making device 13 more comfortable and increasing internal hollow space for airflow. Hollow side tubes 115 can be coated in their interior surfaces to reduce friction. Hollow side tubes 115 can be made of plastic material having low coefficient of friction, to minimize the air pressure drop from front air entrance area to exit at the back of throat area. Another primary cause of reduced airflow is turbulence, caused by the flow of the air when traveling in an indirect pathway. Where the air flow transitions, there should be a smooth transition curve which will result in less turbulence (smooth transition), so airflow will not be effected (laminar flow rather than turbulent flow). This will reduce the incoming air pressure drop, requiring less pressure need. Less air turbulence will also reduce air flow noise.

**[0124]** Hollow side tubes 115 can also have outer surfaces made of soft material for the comfort of the individual. The inside diameter (cross-section based on design) of hollow side tubes 115 can be constant or the inside diameter can be reduced slowly from front hollow housing connection towards the oropharynx/throat area to increase their velocity, further aiding reduction of obstruction in the upper air passage. This also helps in increase response time when an Auto CPAP concept is used. As cross sectional area decreases, air velocity increases inside hollow side tubes 115. The law of conservation of mass means that the size of hollow side tube 115 can be calculated to provide a desired

air velocity using the following equation:  $V2=(V1*A1)/A2V$  is velocity and A is Area

**[0125]** Device 13 can be designed (figure not shown) to be used with a lower arch (lower teeth) only rather than an upper arch 100 as shown in FIGS. 1 C and 1 E. In this embodiment, the front hollow housing 110 (for air flow) and hollow side tubes 115 are attached to the lower arch of the mouth guard, eliminating the need for the upper arch mouth guard.

**[0126]** FIG. 1 J shows few cross sections of device from front of the housing to oropharynx area (towards throat area) as per FIG. 11. The cross section of hollow tubes or hollow air passage ways is determined by AHi index of an individual and required air flow rate and pressure.

**[0127]** FIGS. 1 S-1 V shows different designs of hollow tubes and hollow passageways 115. The hollow passage ways can be in the form of tubes—round, oval, rectangular or any other size and dimension based on required airflow and pressure determined by hand calculation or by computational fluid dynamics (CFO). The hollow passage ways can be buccal side, lingual side or at occlusal area (between the upper and lower teeth). The hollow passage ways can be reduced in dimension from front to back. The length of hollow air passage way can be varied.

**[0128]** As shown in FIG. 1 M, the hollow passage way 115 can have micro holes 116 at predetermined area from front to back just to excite tongue to stop it falling back, keeping air passage way open. The hollow passage way from two side tubes can be connected at the throat area having other hollow tube, creating “C” hollow section and there are holes only in tube at throat area to provide controlled air flow and pressure to reduce sleep apnea. FIG. 1 L and FIG. 1 N depict cross sections of one embodiment of a sleep apnea treatment or anti-snoring device 14 without micro-blowers having both upper and lower arches 100, 101 where hollow side tubes 115 are connected with upper arch 100. FIG. 1 L and FIG. 1 N depict a CAD drawing while FIG. 1 M depicts the CAD drawing of an alternative design having micro holes which apply air to the tongue or soft pallet or throat area. Upper arch (maxillary) 100 and lower arch (mandibular) 101 of the device 14 have dimensions fitting upper and lower teeth of the wearer such that the device 14 does not move the lower jaw forward as would a MAD (mandibular advancement device).

**[0129]** Buttons or any snap fit design or matching tabs design on arches can be used to keep upper arch 100 and lower arch 101 of the device 14 together during sleep. Hollow front housing 110 comprises an opening 126 in the front of the device 14 where air enters and exits during breathing (inspiration and expiration). Hollow front housing 110 can be of any shape (rectangular, oval, square, round etc.) and is not limited to the shape depicted in FIGS. 1 B to 1 L. The size of hollow front housing 110 depends on the person's mouth opening size. For Non-customized devices, the size of hollow front housing 110 is designed in such a way that it will cover majority of the population having different facial dimensions, and can be manufactured in small, medium and large sizes. For customized devices, the device substantially fits the individual's teeth, but it is not necessary to cover all teeth as long as device does not come out during sleep.

**[0130]** FIG. 10-1 R show the sections of the device (fitting upper and lower arches/teeth) with front hollow housing opening having micro-sensors and microprocessor. FIG. 1 N

depicts an individual with full sleep apnea device while 1 P depicts the device with a front portion removed. As described in detail below with respect to FIGS. 18A and 18B, thus allowing for disinfection of only the mouth portion, unsnapping the front hollow housing after the use of device.

[0131] The non-customized or customized device can be a single piece construction made out of semi-solid material, elastomeric material or hard/soft (soft in contact with teeth) materials. The device can be made by injection molding or/and two shot over-injection molding or insert injection molding processes or thermoforming processes, followed by bonding technologies as described earlier. Single piece design or two piece snap fit design with tubes (hollow air passage way), compact construction, fit, finish and comfort are the key factors used in the design, selection of materials and manufacture of the device.

[0132] FIGS. 1 Q depict air entrance opening 126 in hollow front housing 110 and air exit opening 130 from upper arch hollow side tubes 115 during inspiration. FIG. 1 R depicts a cross section of device 14. FIG. 1 Q depicts device 14 with hollow front housing 110 and hollow side tubes 115 attached to upper arch 100. Hollow front housing 110 can be completely detached and easily attachable at intersection 135, snap fit connection. FIGS. 1 S-1 Y represent various views of the device shown in 10.

[0133] Further the top of housing part 110 can be split into 2 snap fit components if needed, permitting easy assembly and access for the electronics including micro blower that will be mounted inside the hollow front housing 110.

[0134] The snap fit design (connect and disconnect of hollow housing from inner mouthpiece) is essential to clean the device after every night and also to replace the inner mouthguard after few months as it wears out due to teeth grinding forces. Patient has to order only inner mouthpiece and connect with original front housing to function like new device, reducing cost. For the customized "Boil and Bite" soft portion can be changed after certain usage if "boil and bite" is mechanical attached to rigid arch, further reducing the cost to patient and frequent change reduces the bruxism or jaw deformation.

[0135] FIGS. 2A-2C depict one embodiment of a device 24 having air entrance opening 226 comprising a curved hollow air tube 230 connected from hollow front housing 210 directly to the center of upper arch 200, bringing air directly from the outside of the mouth to the back of the mouth. FIG. 2A, FIG. 28 and FIG. 2C and FIG. 20 and FIG. 2E are CAD drawings showing different views of the device 24. In this embodiment, the mouth has to be kept open slightly to permit the hollow air tube 230 to pass the teeth area and this is accomplished by putting tabs or spacer on bottom of upper arch and top of bottom arch or using the tube 230 to create this separation allow pass-through. Here, spacer between upper and lower arch is built in (molded) allow the center hollow tube pass through when device is inserted in the mouth, without touching the teeth. FIG. 2C depicts hollow tube without spacer can be used to separate upper and lower arch to direct the air flow from front of mouth to throat area. It works as spacer as well as hollow air passage way.

[0136] Curved hollow air tube 230 can be curved slightly downward so that it can apply pressure downward on the tongue such that the tongue does not fall backward during sleep, helping to keep the upper air way passage open (oropharynx area of mouth) and reducing the sleep apnea.

Further the tube 230 will be flexible in the lateral domain to permit small sideways movement of the tongue for comfort. Curved hollow airtube 230 can be of any shape, round, square, rectangular. Curved hollow air tube 230 can be made of single material or multi-material where outside material is softer than internal material for individual's comfort. This concept can be used with or without mandibular advancement and with or without CPAP or Auto-CPAP having micro blower(s). The center hollow air passageway can be hollow spoon shape so that it can apply pressure on downward on the tongue, larger surface area than just the abovementioned hollow tube, further preventing the tongue to fall backward, helping even more air way passage open, and further reducing sleep apnea.

[0137] In one embodiment, curved hollow air tube 230 can be used along with hollow side tubes 215. FIGS. 3A and 38 depict one embodiment of device 34 to keep the tongue forward (not allowing the tongue fall back). If the device 34 is made to fit only the upper arch teeth or lower arch teeth, then multiple strips 340 can be joined accordingly as shown from left to right of the mouth guard arches 300, 301 (not shown in figure). Strips 340 can be straight, concave or convex. Strips 340 can be made of polymeric elastomer material. To stop the tongue from falling back, two sided pressure sensitive or moisture sensitive or any other chemistry type adhesive tape 350 in the form of small buttons or other shapes like rectangular tape can be used to cover the strip in whole or in part. Before placing the sleep apnea device 34 in the mouth, the adhesive buttons or tape 350 can be placed on one or more strips 340 by removing release paper on one side of the adhesive tape or buttons 350. Then, the other side of the adhesive buttons or tape 350 is exposed by removing release paper and the device 34 is inserted in the mouth. The adhesive of the adhesive buttons or tape 350 bonds to the tongue. The elasticity of adhesive and design of the adhesive buttons or tape 350 will allow some movement of the tongue from left to right or right to left, but will keep the tongue in a forward position, stopping the tongue from falling backward and keeping the airway passage open. Directional elasticity of the adhesive can allow significantly more movement of tongue from left to right or right to left compared to inward movement towards throat, not falling back. This will increase comfort level during sleep as some movement of tongue is allowed. It is also possible to hold the tongue in a forward position by putting the adhesive buttons or tape 350 at the back wall 315 of hollow front housing 310/arch 300, 301.

[0138] FIGS. 4A-4E depict a device 44 having micro-blower(s) 445 with continuous positive airflow (oral CPAP device) concept without automatic feedback control of pressure, flow rate, temperature, but with built-in microprocessor and sensors in device for compliance and monitoring purpose. FIG. 4A depicts a cross section of device 44 having Nanofan(s) or micro blower(s) 445 with sensors/microprocessors etc. 455 is the direction of flow in the interior 414 of hollow front housing 410. Here, micro blower(s) is attached horizontally to front housing, bringing the air flow from bottom of the hollow housing. While FIGS. 48 and 4C shows device where micro-blower(s) is mounted vertically, bringing the airflow directly from front housing to hollow tubes or hollow air passage way. This is most preferable way of mounting the micro blower(s) since this attachment provides less resistance to air flow and less flow turbulence. This design also provides ease of device manufacturing. But,

in few types of micro-blowers, vertical mount may not be feasible. Sensors, microprocessors, USB drive, batteries etc. Are inserted in open chamber 460 of the front housing next to micro blower opening in FIGS. 48 and 4C. Device 44 is depicted in FIGS. 4A, 48 and 4C having micro blower(s) 445 in the interior 414 of hollow front housing 410 having sensors, microprocessor, batteries and USB card, Blue tooth port etc. The mounting of these sensors and other items are discussed in FIG. 7. The dimensions of the walls of the hollow front housing 410 depend on the type of material and manufacturing process. The dimensions of opening 426 of hollow front housing 410 vary depending on the type and number of micro blowers 445 that are used. When micro-blowers 445 are inserted when opening 426 is in the front of hollow front housing 410, micro-blowers 445 have a tight fit with the inner wall of hollow front housing 410. Elastomeric/rubber gasket can be used to prevent or minimize air leakage. As shown in FIG. 4A, micro-blowers 445 rest on bottom walls on both sides of hollow front housing 410 having bottom opening 455 for air entrance. Gasket material can be used to seal the front opening 426 of the hollow front housing 410 around the wall of micro-blower 445.

[0139] The front or bottom opening 455 of hollow front housing 410 allows for airflow for micro-blowers 445. This way, during inhalation, as micro-blowers 445 turn on, air comes in from the bottom opening 455 of hollow front housing 410, exits hollow front opening 410, moves other side of micro-blower(s) and then moves into hollow side-tubes 415, directing air directly at the oropharynx area. It is possible to increase the pressure or velocity of incoming air by reducing the size of the hollow side tubes 415 from the entrance at the hollow front housing 410 to the exit in the oropharynx area. It is also possible to change the pressure and flow rate of incoming air by changing the voltage supply to the micro-blower(s). The arrows in FIGS. 4A, 48, 4C, 40 and 4E show the airflow directions from opening of the hollow front housing 410 through microblowers 445 to the hollow side tubes 415 to oropharynx area (throat area) and can have a 3 to 5 times the tidal volume. Only difference is that micro-blower(s) are mounted vertically, directing the air flow straight into the hollow tubes or hollow passage way in case of FIG. 48 and FIG. 4C. FIG. 48 shows embodiment with micro-blower mounted vertically and allowing for straight air flow to back of mouth. FIG. 40 depicts a person wearing this kind of oral CPAP device.

[0140] The design of device 13 envisages placement of the micro-blower at center FIG. 4A and FIG. 4C or on the side of front hollow housing as shown in FIG. 48. When the blower is placed on the side as opposed to the center, the dimensions on both tubes or either hollow passage on device inside the mouth will be adjusted to get even flow rates from both hollow passage discharges of air at back of mouth (oropharynx area).

[0141] This continuous positive airway pressure oral device (PAP or CPAP), provides unobstructed breathing by delivering a constant flow of air through the sidetube(s) or center tube(s) or any other hollow air passage designs connected to the front hollow housing, directly to upper air passage way. The oral device with housing is designed such a way that when individual wears it, it is secured to the lips so that little or no air escapes from the front. Also, the micro-blower(s) are constantly running, so exhalation will mostly occur through nose. Due to this constant level of airflow during inspiration, air pressure, air flow and air

velocity increases in the oropharynx (throat area) so the upper airway does not collapse during inhalations while sleeping. Air flow from the micro-blower can be adjusted by control module as required.

[0142] Although this is not an Auto-CPAP type device but only a CPAP type device, the device can adjust the micro-blower output to match inspiration and expiration cycles based on temperature sensors, if needed but constant running of micro-blower(s) is preferred.

[0143] A variety of suitable micro-blowers are shown in FIGS. 5A-5D. Depending on the individual's requirement (based on sleep study), a specific microblower type and size can be selected to have fixed volumetric air flow rate up to 30 liters per minute and/or air pressure of up to 30 cm H2O (3000 pascal). It is possible to change (set) the pressure and volumetric flow rate of the same micro-blower manually. A CFO (computation flow analysis) will be used to determine and demonstrate the efficacy of the device under various design parameters and biological physiologies.

[0144] Micro-blowers with different mechanisms can be used including but not limited to the following: The micro-blowers can be based on concepts such as Piezo nano fan 570 shown in FIG. 5A. The Piezo nano fan consists of blades made of stainless steel, brass or even Mylar. Attached to the blades is a patch of piezoelectric ceramic material. Piezoelectric material deforms in the presence of a voltage field. Positive and negative electrical voltage affect the material differently. As a positive voltage is applied, the ceramic can expand, causing the blade to move in one direction. A negative electrical voltage can cause the ceramic material to contract and move the blade back in the opposite direction. The fan's speed can be adjusted by changing the frequency of the current. The nano fan or micro blower can be based on axial air gap technology 571 as shown in FIG. 58 with almost no power loss. One can use roots blower 572 as shown in FIG. 5C, a more positive displacement pump. One can use a micro-blower concept using-Air Multiplier 573 as shown in FIG. 50 (powerful airflow, no blade). The Air Multiplier is a blower with an unusual characteristic in that it does not have any visible blades. It appears to be a circular tube mounted on a pedestal. The shallow tube is only a few inches deep.

[0145] One can use centrifugal fans, of which there are 3 major classes—forwardly curved, backwardly curved or straight-bladed. They generally move less air but at a higher pressure. Some fans are called compressors if they turn at sufficient speed to materially compress the air they are moving. Centrifugal fans are usually mounted in a housing that looks like a snail shell. The inlet is in the center and the discharge is the opening of the shell at the outer edge of the scroll. When the blower is integrated with a housing and a motor, it then becomes a blower.

[0146] One can use a plurality, such as hundreds, of Nano blowers instead of micro-blowers inserted into the hollow housing of the device. In case of an SAT (sleep apnea treatment) or AS (Anti-snoring) device with several nano-blowers, it is possible to generate the full range of treatment pressures up to and in excess of a treatment number of 20 cm pf H2O, because of the strength of the electrostatic force that drives the nano-blower plates, like bellows, open and closed, together and apart. Each nanoblower can push a small amount of air at significant pressure, and hundreds of nanoblowers work in parallel to achieve the required volume to effectively treat the particular individual's sleep apnea.

Due to significantly less air leakage and pressure drop, the individual may not need to have this high treatment number of pressure 20 to 30 cm of H<sub>2</sub>O (current CPAP machine—30 cm of H<sub>2</sub>O or up to 3000 pascal), but can be achieved in case if it is needed. To reduce cost, these micro or nano-blowers can be manufactured by “roll to roll” (R2R) or similar low cost, high volume manufacturing processes. Since, oral CPAP innovation directs air directly from front of the housing to oropharynx area, bypassing the tongue and soft pallets, the pressure required is significantly low compared to current CPAP devices. CFO data shows that 2 cm of H<sub>2</sub>O can be sufficient, not 20 to 30 cm of H<sub>2</sub>O required for traditional current CPAP machines. This is a great advantage since it will significantly reduce the numbers of Nano blowers compared to nose mounted CPAP device, or less powerful or less number of other micro-blowers described above.

**[0147]** The dimension (sizes and shapes) of the hollow front housing of the device depends on the type and size of micro-blower(s) and also for a specific individual and face size or there can be three sizes offered (small, medium and large). For example, a micro-blower is shown having dimension of 17 mm×17 mm×8 mm fan, having volumetric airflow of 30 liters per min (500 ml per second). Tidal volume (air volume displaced during inspiration or expiration) without extra effort is 500 ml during inspiration (for breathing). A typical respiratory rate for an adult at rest is 12 to 20 breath per minute, meaning each breath (in and out) is 3 to 5 seconds. For example, given 2.5 seconds inspiration time (breath), tidal volume is 500 ml. For inspiration time of 2.5 seconds, air volume taken in is 500 ml (200 ml per second).

**[0148]** If this micro-blower is used (having capacity of 1 CFM=30 liter per min=500 ml per sec), air volume can be 1250 ml (500 ml×2.5 sec) per inhalation, increasing the airflow rate by 2.5 times then required in normal case. For patient suffering for sleep apnea, this will open the air passage in the oral cavity significantly and prevent the collapse of soft tissues in oropharynx and larynx, preventing mild to moderate sleep apnea and snoring. By using hollow tubes taking air directly to pharynx area, air is brought in faster where needed, even further reducing sleep apnea and snoring event of patient. If one micro-blower does not perform as needed, more than one micro-blower in series can be used to get more airflow and pressure.

**[0149]** FIGS. 6A and 68 depict an Auto CPAP (APAP—Automatic positive air pressure) device 64 with Miniature Auto Control Module 605 inserted in hollow front housing 610 along with micro-blower(s) 645 and sensors 646. 605 can be mounted horizontally or vertically depending on the type of micro-blower(s) used. FIG. 6C depict micro-blower (s) 645 and automotive control module are mounted vertically in front housing. Control module 605 is data-capable and records all information on events and compliance. Control module 605 having a microprocessor with several sensors 646 and micro-blower(s) 645 is placed directly in hollow front housing 610 of a single piece and may provide variable flow depending on the response measures and calculated by the controller. Micro, oral device 64 having very small space in comparison to current Auto CPAP devices where the control module 605 along with blower/motor 645 is located remotely from the individual and airflow is brought through a hose or tube to the nose or mouth or both. Vertical mount of micro blower may allow to reduce overall size of the device.

**[0150]** The microprocessor or micro-chip in control module 605 is in communication with airflow (differential pressure), temperature, tilt, sound sensors and pulse oximeter 646 to provide continuous feedback of changes in any parameters to microprocessor. Sensors 646 not only can be attached to control module 605 but also to the mouth guard (inside arch 600), further increasing the capability of device 64 for sleep apnea and also other purposes such as diagnostic device as well as compliance information. Based on the history and AHI index, the microprocessor automatically adjusts air flow rate/pressure to improve the comfort level of the patient. To reduce further discomfort and also keep air passage way open for longer time, micro blower(s) may not be supplying air flow continuously. This is achieved by using a thermistor sensor in 646 which monitors the individual’s breathing and send an output that reduces the flow of the device 64 internal blower when the individual starts to exhale. The exhalation temperature is higher than inhalation temperature. The resulting lowered resistance prevents the individual from feeling as though he is “fighting” against the machine when breathing, reducing discomfort. The control module can be mounted inside the front hollow as shown in FIGS. 6A and 68 or also can be mounted on the top portion or bottom or side portion of the housing. Also it can be split into multiple PCB’s with varying configuration. Pressure sensors can be used monitor the pressure delivered to the individual in all type of PAP machine types.

**[0151]** Analog Temperature Sensor (breathing timing sensor) is a small package thermistor which can be used for a fast response. This sensor can be placed in a location where it can be contacted with exhaled air. Analog temperature sensors provide a signal to the microprocessor indicating the start of the exhalation and inhalation cycle. The exhalation temperature is higher than room temperature, indicating start of exhalation, giving feedback to microprocessor to control micro-blowers. Start of inhalation is sensed by temperature or/and air pressure sensor.

**[0152]** A customized or Non-customized oral Auto CPAP type (automatic positive airway pressure) device continuously monitors the sensor parameters and utilizing proprietary algorithms automatically varies the air flow or pressure as per individuals need. APAP adjusts the air flow (pressure) to improve upper airway passage opening to a comfortable level, not too much pressure or airflow then required.

**[0153]** Through the use of firmware (proprietary algorithm) on the control module, the device automatically controls the air pressure and airflow rate by continuously changing air micro-blower’s speed using closed loop control system. It is not necessary that individual has to have all teeth, so long as the device can be held in the individual’s mouth by a few teeth. The device has a fast-response micro-blower(s), pressure transducer and microprocessor. The device control module discerns stoppage or blockage of breathing from data being collected from the various sensors and will accordingly adjust the air flow (pressure) from the micro-blower to varying preset values as per the proprietary algorithm. As discussed in connection with devices without microblowers, the Auto-CPAP device with micro-blower can be attached to upper arch or lower arch, or attached to both arches with or without moving lower jaw forward (like a MAD device). There is also an air filter (washable or disposable) that can be attached in front of the micro-blower to filter dirt. Hypoallergenic disposable filters are made of non-woven acrylic and polypropylene fibers with a poly-

propylene carrier. The combination of materials helps block very fine particles, and some filters claim to have anti-microbial agents. The hollow housing can be made of plastics having anti-microbial agents (with or without controlled release).

**[0154]** The micro blower and microprocessors etc. can be powered by coin type or other types of micro-battery or rechargeable (electric or USB type) coin cell or other types of micro-battery such as a polymeric micro-battery. Data storage and transfer can be achieved by a variety of technologies, thus eliminating need for any cord or wires. Two such technologies include Bluetooth® and micro-SD card. The device may incorporate Bluetooth® technology such that the device is continuously synced (or synced whenever desired) with any other Bluetooth® enabled mobile device such as smart cell phone, tablet, computer etc. The mobile device can then up link through the Internet to send the data from the device to an Internet server. The device can then provide sleep apnea related data to a device having an appropriate app, which data can then be analyzed and stored on the device and/or can be communicated/shared with doctors or other medical professionals or other third parties via email or via cloud. Using a smart phone or similar devices, it is also possible to send input to control module of the device to set up initial required air flow (pressure) etc. for individual as needed.

**[0155]** Micro-SD card: The micro-SD card can store all sleep apnea data during sleep and can be downloaded to a device such as a smart phone or computer at a later time. Other configurations of the device can include Wi-Fi capable. Additionally, the control module may have the capability to manual control if needed and OLEO to show the state of the system. The control module may use an algorithm that learns from individual's breathing pattern and reduces device pressure on exhalation (expiration). Sound output from the device will be between 12 to 18 dBA during normal operation. By CPAP industry standards that are considered to be exceptionally quiet. Auto-off function puts the display backlight to sleep Functions offered on current CPAP devices can also be incorporated into this oral CPAP device or on mobile app to a connected mobile device with display for power status, pressure and ramp time. It also gives audio visual feedback when programming ramp and pressure settings.

**[0156]** FIG. 7A depicts the cross section of an Auto-CPAP (APAP) front hollow housing with micro blower **760** and control module **735** consisting of various elements inserted in the hollow front housing of a device that is in communication with mobile devices **770** to download (sync) the data. Elements include but are not limited to: LCD and touch screen control **700** and on/off switch **701** Bluetooth® sensor **705** and microSD card **710**, pressure sensor **715**, airflow sensor **720**, temperature sensor **725**, sound sensor **730**, and tilt (position) sensor **732**, microprocessor with firmware **740**, rechargeable battery with USB port **745**, material or fabric with high water absorption capability during exhalation and desorption during inhalation **755**, micro-blowers **760** and air filter **765**. The sensors may be positioned differently than shown inside the mouth in the mouthguard or alternate locations as required. **770** depicts a mobile device in communication with Bluetooth® or other wireless communication link **775** mounted with a sleep apnea device comprising a control module. **785** depicts the respiratory belt (RIP) belt. **780** depicts pulse oximeter that will also communicate with

the control module via Bluetooth or other wireless methods. A material **755** is incorporated after the microblower to absorb moisture of exhalation.

**[0157]** FIG. 78 depicts a schematic of the control module of a device to treat sleep apnea and snoring. The device has proprietary firmware/algorithm to operate indifferent modes such as CPAP, Auto CPAP, *8i*-CPAP etc. Method of operation of a single piece tubeless Auto CPAP oral device: The control module is programmed with firmware/algorithm to perform the following operations as shown in FIG. 78. The individual puts the oral device in his/her mouth, fitting it well, and then turns the on/off switch **701**. The device can also be turned on using a connected device such as a smartphone **770** via Bluetooth® **705**. The start of inhalation can be detected by setting a predetermined value for temperature sensor **725** (less than body temperature) or air pressure sensor **715** (atmospheric pressure). Air enters when the micro-blower **760** starts during inspiration via a signal given by the microprocessor **740**, based on input from temperature sensor **725** and/or pressure sensor **715**. The air is filtered by filter **765** before entering in the hollow front housing **610**. A material **755** incorporated into the control module area **605** has high water absorption capability from the surroundings. If needed, this material **755** can be soaked in water and incorporated in the hollow front housing **610** before sleep to achieve a level of humidity.

**[0158]** This material **755** does not affect the air flow due to its location in the hollow front housing **610**, but at the same time it picks up moisture during exhalation. Moisture is then released in air during inspiration, the amount of moisture depending on-air flow rate and temperature. The humidity level does not alter the pressure level or change the therapeutic value of CPAP device, it just improves the comfort. Due to the relatively tight seal of the device at the lips, there is little or no leakage and the individual can also breathe through the nose. Also, since the micro blower(s) are continuously running, air is always entering thro' mouth during inhalation and exhalation. As air always enters thro' mouth via micro blower, person more likely to exhale through nose, thus there is no need for tight seal of oral device at mouth.

**[0159]** The RIP Belt **785** and Pulse Ox **780** will continuously send data about respiratory effort and oxygen saturation as well as Pulse rate via wireless methods to the control module and which can then be recorded on the storage device. Sensors read pressure and flow rate values and once they deviate from predetermined set values, they provide input to the microprocessor **740** of the control module **605** which in turn changes the micro-blower **760** speed up or down (changing the power supply level). The control module **605** is operable to determine the occurrence of an apnea from a reduction in respiratory airflow below a threshold, and if an apnea has occurred, to determine the duration of the apnea and to cause the flow generator (micro-blowers **760**) to increase the treatment pressure/flow rate by an amount which is an increasing function of the duration of the apnea, and a decreasing function of the treatment pressure/flow rate immediately before the apnea.

**[0160]** The start of expiration can be detected by temperature sensor **725** or airflow sensor **720** or sound sensor **730**. During expiration, the speed of micro-blower **760** can be reduced to decrease resistance to airflow during expiration, for increasing comfort. Data-recording devices such a micro SD card can be used to record multiple variables from the

sensors described in FIG. 7 or can be wirelessly uploaded to servers. This will help to determine optimum pressure, but the most common measurement is individual's "Apnea/Hypopnea Index" or "AHI", where the goal is to get AHI to 5.0 or lower.

**[0161]** The same Auto CPAP device can also be used as 8iPAP/VPAP by changing the algorithm of the firmware on the control module to have different modes of operation during sleep as described below. 8ilevel-PAP (8ilevel Positive Airway Pressure) provides two levels of pressure: IPAP (inspiratory Positive Airway Pressure) and a lower EPAP (Expiratory Positive Airway Pressure). 8ilevel or variable level machines (8iPAP/VPAP) blows air in two levels, one for inhalation (IPAP) and one for exhalation (EPAP). This method is used in situations where marked difficulty breathings present.

**[0162]** These devices can be available a) either in a range of air flow/pressure values so that individual will be able to obtain the device with the treatment number appropriate for him/her, much like contact lenses or b) device will be made adaptive so that they will self-adjust (like some current high-end APAP machines) to provide the exact pressure for effective treatment

**[0163]** FIGS. 8A-88 depict the same concepts for the devices as above in FIGS. 6A-6D and 7A-7B but the single piece micro oral tubeless device **84** has capability of bringing the lower jaw forward (mandibular advancement) in the same manner as MAD devices **80** as seen in FIG. 8A currently in the market by opening of the mouth upper airway passage area (oropharynx area). As seen in FIG. 8A, current MAD devices **80** lack a hollow front housing, microblowers or hollow side tubes in the mouth guard upper and lower arches **800**, **801**. Oral MAD CPAP device **84** shown in FIG. 88 and FIG. 88 consists of CPAP module **805** (same as **605** in FIG. 6A) incorporated in hollow front housing **810**, with hollow side tubes **815** (same as **115** in FIG. 1 D) to deliver air directly to oropharynx area and design mechanism **880** as an example to bring the lower jaw forward.

**[0164]** The lower jaw, mandibular, can be moved forward by other mechanisms available in the market. The single piece micro oral MAD/CPAP device design mechanism **880** allows the mandible to be advanced in increments of 1 mm or less with a protrusive adjustment range of at least 5 mm. In addition, reversal of the advancement is possible. The protrusive setting is verifiable. It maintains a stable retentive relationship to the teeth, implants or edentulous ridge and retains the prescribed setting during use. This concept of mandibular advancement (MAD) can be used for customized or Non-customized device and also for CPAP, Auto-CPAP, Bi-PAP devices etc., along with other features/concepts described for other embodiments of the teachings as described herein. The current MAD devices on market, essentially only bring the lower jaw forward by methods such as Herbst, TAP, EMA (strap) etc.

**[0165]** These current devices do not have any capability of measuring any parameters of air flow during sleep or providing any titration data or functioning as a CPAP or APAP. Teachings Device shown in **88** has all the capabilities (including the electronic package of command module and sensors) of all embodiments described earlier plus the capability of mandibular advancement using various methods as shown in FIG. 8A including variations to those indicated above (Herbst, TAP and EMA) to achieve this.

**[0166]** This oral device can have electrical stimulation capability for providing mild shocks to the soft palates and tongue. When the electronic sensors detect blockage of air passage (by soft palates relaxing or when the tongue falls back and blocks the airway passage), the device can provide a mild electrical stimulation, and alleviate the blockage of airway passage from persisting further due to above events.

**[0167]** It has been proven that side sleeping position reduces the sleep apnea events by more than 20%. When individual moves from side position to subprime position, the tilt sensor records it and the built-in proprietary algorithm (software) sends a signal to thin plastic sheet (or a patch on face) attached to the device and touching to lip(s) to vibrate. This reminds individual to sleep on side. The individual slowly adjusts to this and over few nights adjusts to sleep on side without waking up. One of the appliance designs is very simple that it will be just upper mouthguard with outside housing having tilt sensor to remind the individual to sleep on side.

**[0168]** This device can be used as impact sport guard with additional airflow during play and protection of teeth. It is referred to as a positive airway pressure impact sports guard without micro-blower(s). Such impact sport guards have a hollow housing in the front with two hollow side tubes attached to upper arch of the device. They can also be used for people in contact and non-contact sports acting as a protection mouthguard as well as a device to increase air intake, just like breathing deeply without the thought and effort. The impact blow abrasion and dissipation characteristics are achieved by making device using additive manufacturing (3D printing) technologies with lattice structure.

**[0169]** FIG. 9 depicts a nasal/oral device **94** with CPAP/MAD or Auto CPAP Device/MAD. This nasal/oral device **94** can also be used without mandibular advancement (without MAD). Internal hollow tubes inside the mouth (on upper or arches) can be blocked or eliminated in the oral device (no air flow going through the mouth), but two hollow flexible conduits **916** are connected to two nostrils from the top of the hollow front housing **910** of oral device in which micro-blowers **945** are attached; or the airflow can be from both nose and mouth if the internal mouth tubes are left open. This can be achieved by nasal elastomeric housing **990** (Like nasal pillows used in CPAP machines) snug fitting the nose where conduit **916** are coming out from the oral PAP device **94**. The end of each of the two tubes **916** has an expandable elastomeric attachment or nasal cannula **995** or nose pillows for each nostril, snug fitting inside the nostrils which holds the two tubes **916** and nose housing **990** in place during sleep.

**[0170]** The nasal cannula can also be kept in place by using strip around the ears. The oral device **94** has two functions: 1. the hollow front housing **910** with microblower **945** delivers air flow to nose by itself or along with the airflow through the mouth during inspiration instead of inside mouth 2. The oral device **94** holds the nose housing **995** with control module, micro-blowers **945** and sensors and tubes **916**, the whole air delivery system, in place as device is attached to teeth (upper or lower or both upper and lower arches). This oral device **94** can have a mechanism to bring lower jaw forward (MAD device), further opening the air passage way in mouth.

**[0171]** This device **94** allows reduction of sleep apnea by providing natural airflow through nose (natural breathing) in

combination with lower jaw movement (nose CPAP or APAP with MAD Device). The elastomeric housing **990** snug fitting the nose have micro holes allow and controls the airflow during the expiration. Airflow from the hollow front housing **910** can also be controlled during the expiration by reducing the speed of micro-blowers **945** if expiration should be slowed down. Note for Nasal airflow the technique to increase humidity is described earlier in FIG. 7 while inhaling will be used.

**[0172]** Micro-Nasal PAP device: In a specific embodiment of the device, it can be attached directly to nose with microprocessors and sensors. This nasal micro PAP device has external housing, snug fitting with nose with two hollow tubes going into nostril. The external housing has micro blowers or nano-blowers with similar concepts of control module with pressure and flow rate sensors as described previously for the oral PAP devices (FIGS. 4A-4D or FIG. 68). It is a stand-alone single unit like oral device but attached to the nose instead of mouth. The device has no external tubes or cords.

**[0173]** A fabric or film with directional nano pores structure can be disposed in front of the oral or nasal device to slow expiration. The device can have breathable antimicrobial fabric or film with directional nano pores structure with or without micro-blower SA or AS device. This fabric can be placed in front of the hollow box where air enters into the mouth or nose during inhalation. This fabric can be adhesively bonded, or can be permanent or preferably removed every day to wash or insert same one or new one (every month) before using device. As the individual breathes in, the fabric or film's nanostructure design opens the pores, allowing the individual to breathe in normally. Then, as the individual breathes out, expiration is slowed as the nano structure pores closes slightly to create a gentle pressure that naturally opens the airway and relieves snoring or mild to moderate sleep apnea.

**[0174]** The data acquisition capability of the oral devices of the various configurations described above (FIG. 7A and FIG. 78 allows it to be used as a diagnostic device for sleep apnea for diagnosis of Sleep Breathing Disorder—specifically obstructive sleep apnea and allows to set parameters for current CPAP machines or device of current invention. This oral HST device can essentially function as a stand-alone HST (Home Sleep Testing) or OOCST (Out of Center Sleep Testing) device such as Resmed's Apnea link or Itamar's Medibyte and so on. In the present system, it can be used to set parameter of oral sleep apnea device of current teachings.

**[0175]** The device is a multi-channel screening tool, that can measure all or selected parameters such as airflow through mouth or nose, snoring, oxygen saturation, pulse, temperature, body position, respiratory effort during sleep, EKG, EEG by various sensors that are built into the device or linked via wired or wireless technologies such as Bluetooth or Wi-Fi.

**[0176]** The acquired data from this device can be used to calculate apnea hypopneaindex (AHI) based on the sleep time recorded based on proprietary algorithm which can generate a comprehensive sleep study report with a custom app or software. This AHI determination with other parameters recorded would permit prescribing/specifying appropriate CPAP/APAP/BiPAP treatment option (setting appropriate pressure (and/or air flow rate) for PAP or pressure range (and/or air flow rate) for APAP devices as well as

MAD (Mandibular Advancement Device) treatment option (setting the position of the lower jaw advancement). The device can also have a miniature/nano IR or thermal imaging video camera which can help detect changes in the airway passage during sleep.

**[0177]** In one embodiment of the device, it can be used to validate the mandibular advancement device (MAD) setting used for treatment of OSA and snoring (OS/SA). In this version, the device would have all sensors mentioned above or limited sensors and built in capability on the control module to discriminate the efficacy of the MAD treatment and validate the lower jaw advancement setting selected. If used limited sensors, it would have 3 indicators that would indicate if the efficacy of the MAD treatment made a positive difference (ie reduce the OSA/AHI or reduced snoring) or made no difference or made a negative difference and made the symptoms worse. The indicator can be a color coded system (such as green/yellow/red) or light up different labelled lights to depict the 3 outcomes. The efficacy of MAD device can be also be shown as actual AHI index number.

**[0178]** The devices can be of any constructions/concepts as described previously but not limited to: 1. only upper arch or lower arch device or device with both arches 2. Both upper and lower teeth arch without bringing lower jaw forward 3. Both upper and lower teeth arch where lower arch is adjustable to bring lower jaw forward, 4. Center hollow tubes/hollow passage ways or strips or any other design to keep tongue down.

**[0179]** The various embodiment of the device described above also work as nightguard to prevent bruxism, teeth grinding and also treat TMJ in addition to reduces snoring and sleep apnea.

**[0180]** FIG. 10 depicts thin plastic bag attached to upper arch of mouthguard (at the end, throat area) which expands and stays expanded during air flow from microblower, stopping soft palates to collapse, allowing more open airway passage. If device has no micro blower, during normal breathing this bag will expand during inhalation and collapse during exhalation but stays in place due to specific bag design and support design with upper arch. It is also possible to have dome same semi-rigid plastic bonded with upper arch which will not allow the soft palate to relax, keep in place during sleep.

**[0181]** The Non-customized device or customized devices (to fit individual's teeth) are supplied in different sizes such as small, medium and large. The device can be made by snap-fitting injection molded hollow front housing with rest of the part-hollow side tubes and upper and lower arches (mouthguard). This way hollow front housing can be easily detached from rest of the device after sleep to clean the mouthguard or when required such as repairing or replacement.

**[0182]** FIG. 11 depicts an exploded view of device as separate pieces which are snap fitted together after manufactured. **1110** is front housing and **1120** is inner mouth piece. **1111** is partial hollow tube and **1112** is base of mouthguard. While **1113** is "boil and Bite" piece on top of base piece of mouthguard **1112** for customization.

**[0183]** FIG. 12 depicts several manufacturing methods for device. Both noncustomized and customized devices consist of two pieces A and B as shown below: front hollow housing **1210** (in which micro fan(s), sensors, microprocessors etc. are inserted after manufacturing); and an inner mouth piece



with hollow air passage way. The front housing has snap/un-snap fit concept where front hollow housing section is easily snap-fitted with inner mouth piece and also can be easily un-snapped (removed from inner piece).

**[0184]** The systems can be formed using the following methods. The front hollow housing **1210** is made by injection molding. To prevent air leakage between hollow housing and inner mouth piece, an elastomeric ring is mounted on front housing or elastomeric ring is molded in one step process as two shot injection molding. For the inner mouth-piece **1220**, the following manufacturing methods are used to achieve predetermined hollow passage ways. The inner mouth piece is divided into two portions: 1. Partial hollow tube **1211** and 2. Base piece of Mouthguard **1212** (upper or lower arch) A multi-step process can be used which includes separately injection mold partial hollow tube **1211** and base piece of Mouthguard **1212** followed by bonding these two pieces to create hollow passage way in inner mouth piece **1220**.

**[0185]** One can also make partial hollow tube **1211** and base piece of Mouthguard **1212** by thermoforming process followed by bonding these two pieces to create hollow passage way in inner mouth piece **1220**. Thermoforming process allows for customization. Bonding of these two pieces can be done by ultrasonic welding, laser welding or mechanical bonding or combinations of these technologies or adhesive bonding or other bonding technologies, creating the thin device with hollow side tubes. The wall thickness can be as low as 0.5 mm in several areas. One step injection molding process where partial walls of tube **1211** and base mouthguard **1212** are molded in two cavities of a single mold, followed by rotating cavities where two halves are aligned and second material **1213** is injected at intersection, bonding these two pieces and creating hollow structure. Here, the second material **1213** is soft material or same as “Boil and Bite” material **1213**, creating customized oral device in a single step process. (see FIG. **15**). Water or gas injection molding to achieve hollow air passageway. Lastly, lost core foam injection molding can be used to for the passages.

**[0186]** Both non-customized and customized devices are manufactured by similar processes as described above except for customizations (to fit the teeth perfectly) is achieved by processes such as 3D printing (hard or hard/soft materials), “boil and bite” concept and micro-cellular foaming injection molding processes and thermoforming of aplastic sheet on a tooth model. The device can be single piece construction, if it device does not contain any sensors/microprocessor or sensors/microprocessor and battery are completely sealed, then no need to have snap-fit feature. This single piece construction can be achieved by bonding of two separate injection molded halves at pre-determined line (or separately injection molding housing with partial tube and mouthguard) followed by bonding these two pieces to create hollow structure or by water injection molding or by lost core foam injection molding. 3D printing or additive manufacturing can be used to form the components or single piece device.

**[0187]** FIGS. **13A-13D** depict a customized cross sections of the device using “Boil or Bite” concept to fit individual teeth. FIG. **13A** and FIG. **13B** depict portions of a device **134A**, having both upper and lower arches **1300**, **1301** with hollow front housing **1310** and hollow side tubes **1315** attached to upper arch **1300**. FIG. **13C** and FIG. **13D** depict

a device **134B** having upper arch **1300** only with hollow front housing **1310** and hollow side tubes **1315**. Upper and lower arch portions touching the teeth are made of material which will soften on boiling in water, due to glass transition temperature of lower than 1 OOC and will form to the shape of teeth upon biting in the mouth. The arch portions may be made of single soft material or soft and hard material. Soft material is used for “Boil and Bite” and hard material provides the support during bite. The hollow front housing **1310** and hollow side tubes **1315** (and bottom of upper and lower arch portions) are made of high temperature plastics which do not soften at all at 1 OOC (boiling point of water) due to their glass transition temperature greater than 1 OOC. This way, after “Boiling and Biting” the device **134A**, **134B**, the individual can customize the device to fit his/her teeth and still air flow will not be affected as rest of the dimensions of device will not be changed during boiling and biting (hollow tubes and the hollow housing dimensions).

**[0188]** The “Boil and Bite” devices can be manufactured by two methods. 1. First, “Boil and Bite” soft portions of the upper and lower arches are injection molded (or two shot injection molded from soft/hard material) and this portion is inserted in a second tool where it is over-molded with high temperature plastics material forming rest of the part having hollow side tubes and hollow front housing or 2. “Boil and bite” portions of upper and lower arches and rest of the device (hollow side tubes and hollow front housing and bottom arch) are injection molded separately as shown in FIG. **13A** or **13C**, then mechanically snap-fitted to make a single device shown in FIG. **13B** or **13D**. Later concept 2 may be better approach for individual since “Boil and Bite” portion requires to be replaced every six months to preserve the bite. For individual, the second concept eliminates to buy whole unit, they must only buy a “boil and bite” portion, when needed, saving money.

**[0189]** FIGS. **14A-14D** show a customized, single piece, micro oral PAP device **144** manufactured by micro-cellular foaming injection molding. Device **144** illustrates a concept for temporarily customizing device **144** during sleep, allowing good grip by teeth and increasing comfort level. As shown in FIG. **14A**, a soft material **121** is used for the portion of the device **144** touching the teeth which is made out of microcellular foam **1400**. The microcellular foam **1404** can be open cell structure with regular elastomeric polymer or closed cell structure with highly elastomeric material. Soft material **121** may alternatively comprise polymeric gel material.

**[0190]** As shown in FIG. **14B**, the individual inserts the device **144** in the mouth, and upon biting on the device, the applied pressure deforms the elastomeric structure of micro-cellular foam **1404**, allowing the impression of teeth on the inside **1423** of the soft microcellular foam **1404**. This way, device **144** stays in place during sleep. To take device **144** out from mouth upon waking up, the individual has to apply vertical downward force on device **144**. Once device **144** is removed from the individual’s mouth, the microcellular foam **1404** returns to its original shape and is ready for the next night to again form a customized device. FIG. **14C** shows device **144** with microcellular foam **1404**, while FIG. **14D** depicts cross section A-A of a portion of upper arch **1400** showing the microcellular foam **1404** taking the shape of the individual’s teeth after bite.

**[0191]** FIG. **15** depict a single step manufacturing method for hollow device by injecting material in two cavities,

cavities rotation, followed by injecting plastic at intersection of two halves, creating hollow part.

[0192] FIG. 16 depicts micro-holes in the hollow tube (or hollow passage way), blowing air at very low flow rate, but stimulating the tongue to stay forward original position (does not allow to fall back) during sleep. These micro-holes can be near the tongue (lingual area) Fig. and/or at the end of throat area (oropharynx area. The microholes in the hollow tube at end connected to two side tubes of an arch, directing the airflow at the end of oropharynx (directly at throat region). This can significantly help in keeping airway open compared to providing airflow by just two sides tubes. These holes can be pointed into any direction desired by the treating physician.

[0193] FIG. 17 depicts special microchip embedded into mouthguard for nerve stimulation. Optionally, the device as an impact sport guard with additional airflow during play and protection of teeth. Energy absorbing and dissipation away from the teeth is achieved by selecting right plastic material and internal design of the part wall like honeycomb or lattice like structure. This embodiment is referred to herein as appositive airway pressure impact sports guard with or without micro-blower(s).

[0194] FIGS. 18a-218 represent alternate views of sleep apnea measurement and treatment devices described above in the descriptions of FIGS. 1-17. FIGS. 18a and 18b represent exploded views of components used to form a device according to the teaching of the present invention. The device can be formed of several injection molded or 3D printed components. These components can be snap or interference fit together, adhesively, or thermally bonded. As can be seen in FIGS. 18a and 18b, the treatment or diagnostic device, as described above can have a detachable front section 610 which holds the sensors such as 720 and 725 and can hold the battery and micro blower and associated controller. This portion can be snap or interference fit to a u-shaped body 952 which when mated with support structure 948 defines the side through passages 115. The support structure 948 defines a cavity which supports the bite region 1212. As describes in detail earlier, this bite area 1212 can be a 3D printed representation of the patients tooth region, or can be a boil and bite materials. The support region also can have several cross flanges which can engage and depress portions of the tongue.

[0195] FIGS. 19A through 20B represent perspective views of an alternate sleep enhancement medical device. The treatment or diagnostic device, as described above can have a fixed (shown) or detachable front section 610 which holds the sensors such as 720 and 725 and can hold the battery and micro blower 760 and associated controller. This portion can be integral to a u-shaped body 952 which defines the side through passages 115. The u-shaped body 952 defines a cavity which supports the bite region 1212. The support region also can have several cross flanges which can engage and depress portions of the tongue. One of these cross flanges 950 can be hollow and define a plurality of micro or macro holes 954 which allow the distributed flow of air into the lingual region 15.

[0196] FIGS. 21A and 21 B represent perspective front views of a sleep enhancement device according to the present teachings. As can be seen in the treatment or diagnostic device, as described above with respect to FIGS. 18A and 18b can have an integral front section 610 which holds the sensors such as 720 and 725 and can hold the

battery and micro blower and associated controller. This portion can be snap or interference fit to a u-shaped body 952 which when mated with support structure 948 defines the side through passages 115. The support structure 948 defines a cavity which supports the bite region 1212. As describes in detail earlier, this bite area 1212 can be a 3D printed representation of the patient's tooth region or can be boil and bite materials. The support region also can have several cross flanges 926 which can engage and depress portions of the tongue.

[0197] FIG. 22 shows exploded view of detachable "Fixed Boil and Bite" sleep apnea mandibular advancement device (MAD) device 2200 where outside housing 2200 A (containing lid 2201, micro-blower 2206, PCB 2207, battery 2208 and screws 2201A) can be attached and detached from mouthpiece 2200B using cantilever types of snap-fit structures 2210. The mouthpiece 2200B has teeth trays 2217 and 2218 and air passageway 2213. The housing 2200A have same or similar design concept for most the sleep apnea devices discussed in this patent. The lid 2201 has three openings. Opening 2204 is for on/off switch 2209, opening 2203 is for air entrance by micro blower 2206 and opening 2202 is for USB for charging of rechargeable battery. Opening 2203 may contain micro-fabric to filter dust without affecting the air flow rate. Once the micro-blower 2206, PCB 2207 and battery 2208 are inserted in the opening of the partial housing 2205, the lid 2201 is placed on top of this housing 2205 using screws 2201A to complete the outside housing piece 2200A. This provides detachable housing 2200A, the configuration is same for most of the devices with different designs shown in this invention. Only design of mouthpiece 2200B are different for different innovative concepts and due to customization of individual. The design of mouthpiece is such that it provides maximum lip seal and easily fits with the outside detachable housing 2200A. The housing 2200A can be 3D printed or injection molded from most of rigid or semi-rigid plastics materials. It can be also soft inner/rigid outer two-layer structure materials for sound dampening of micro-blower or it can be soft/hard structure where all contact surfaces between the housing and mouthguard are made of soft material for micro-blower's vibration noise decoupling from housing to mouthpiece. The micro blower 2207 can be attached using screws to the housing and/or sound dampening foam tapes and/or elastomeric enclosure can be mounted surrounding the micro blower for noise isolation. The battery 2208 is snug fit with foam or any other design structure in the housing to avoid any rattling but 10% gap is maintained between the walls due to expansion when running of battery for a long time. To make the "boil and bite" device, first the person boils the water, then dip the fixed boil and bite EVA inner upper and lower trays 2171 and 2218 which are already bonded with rest of the mouthguard piece 2213 in water for certain time till it softens, followed by dipping in cold water for few seconds for surface cooling. Then bonded upper and lower trays are fitted on teeth and customization is done similar to commercial boil and bite EVA nightguards in the market. Here, upper and lower tray 2217 and 2218 of the mouthpiece can be thermoformed with plastic film on the patient's teeth model to make customized device, followed by bonding to 2213 to eliminate boil and bite concept.

[0198] As shown, the outside of mouth housing (containing lid, micro-blower, PCB and battery) known as "outer housing" can be attached and detached from the inner

mouthpiece having teeth trays and hollow air passageways using cantilever types or other types of snap-fit or detachable structures. This figure shows cantilever type snap-unsnap design. The outside of mouth housing has same or similar design concept for most the sleep apnea devices described in this invention. One can use “customized” Thermoformed EVA type elastomeric material bonded to hollow air passageway instead of boil and bite concept. Here, “pre-customized” upper and lower teeth trays are made by dual soft and hard material. The soft material is thermoformed over patients’ model and these thermoformed customized teeth trays are bonded with already pre-customized 3D printed upper air passageway made from hard material. The soft material stays in touch with teeth providing comfort, ease of fitting by doctor. It also helps in absorbing noise created by micro blower vibration or air flow. It also depicts the customized 3D printed of soft and hard material in a single step 3D printing process.

[0199] FIG. 23 shows the exploded view of detachable “Fixed Boil and Bite” sleep apnea mandibular advancement device 2200 at different angle. Here, 2213A and 2213B show the hollow air passageway section 2213 for the exit of air in the oropharynx area (throat area).

[0200] FIG. 24 shows different cross sections of the device 2200 of FIG. 23. As shown in cross section view B-B, air enters via micro-blower 2207 in the air passageway channels 2213 and air exits on both sides of the air passageway as shown as 2213A and 2213B. Other cross sections show the opening of the air passageway 2213.

[0201] FIG. 25 depicts the exploded view of detachable “Adjustable Boil and Bite” sleep apnea mandibular advancement device (MAD) 2300 where housing 2200A (containing lid, micro-blower, PCB and battery) can be attached and detached from mouthpiece 2300B having teeth trays 2217 and 2218 by snap fit or other concepts. First, the upper teeth tray 2217 is bonded to upper mouthguard 2213 with adhesive 2216. First the person boils the water, then dip the upper mouthguard 2213 with teeth tray 2217 in water for certain time till it softens, followed by dipping in cold water for few seconds for surface cooling. Then the upper tray 2217 is fitted on teeth and customization is done like commercial boil and bite EVA nightguards in the market. The lower tray 2218 is also customized the same way. After customization of upper and lower trays, they attached with connecting rods (linkages) 2219 on both sides on trays by mounting on anchors (buttons) 2214. This makes device adjustable, allowing advancement of lower jaw forward as needed by selecting the length of linkage 2219. The angles of anchors are critical, and dentist decides based on patient’s teeth and jaw’s structure.

[0202] The upper tray 2217 and lower tray 2218 can also be “pre-customized by thermoforming” manufacturing process with plastic film such as EVA on the patient’s teeth model. The customized upper tray 2217 is then bonded to upper mouthguard 2213 using 2216 adhesive. Then, upper mouthguard 2221 having thermoformed tray 2217 and lower thermoformed tray 2218 are attached with connecting rods (linkages) 2219 on both sides on trays by mounting on anchors (buttons) 2214. This makes device adjustable, allowing advancement of lower jaw forward as needed by selecting the length of linkage 2219.

[0203] One can also use the above devices without lower teeth tray, meaning no need to have MAD device, use of only upper mouthguard 2221 having upper teeth tray 2217.

The air from the air passageway 2213 stimulates the soft tissues, not allowing them to relax, keeping air passage open in throat area without need of lower jaw advancement. This helps in sleep apnea and snoring treatment.

[0204] FIG. 26 shows the exploded view of FIG. 25 device “adjustable boil and bite” 2300 device at different angle. The 2213A and 2213B shows the opening from which air exits in the oropharynx area of the throat.

[0205] FIG. 27 depicts the exploded view of detachable “pre-customized” sleep apnea mandibular advancement device 2400 where housing 2200A (containing lid, micro-blower, PCB and battery) can be attached and detached from mouthpiece 2200B having teeth trays, connecting rods (linkages) 2419 and air passageway 2413 using cantilever types snap-fit structures 2210 and 2212. The housing 2200A is 3D printed or injection molded using one of several plastics. To manufacture pre-customized 3D upper mouthguard 2421 with teeth tray 2417 and hollow air passageway 2417, the teeth impression of the person or digital scan of the teeth with intra oral device is taken. From this CAD file of the upper teeth with upper teeth tray 2417 and hollow air passageway 2417 is created, known as upper mouthguard 2422. Then upper mouthguard 2421 is 3D printed using several additive manufacturing processes in the market using medical grade FDA approved plastics. Similarly lower teeth tray 2421 is manufactured. It is also possible to manufacture upper mouthguard 2422 and lower teeth tray by other non-additive manufacturing technologies.

[0206] One can also use the above devices without lower teeth tray 2421, meaning no need to have MAD device, use of only upper mouthguard 2422 having upper teeth tray 2417 and air passageway 2413. The air from the air passageway 2413 stimulates the soft tissues, not allowing them to relax, keeping air passage open in throat area without need of lower jaw advancement. This helps in sleep apnea and snoring treatment.

[0207] FIG. 28 depicts the cross-section views of “Pre-Customized” 2400 device of FIG. 27. 2413 is hollow air passage underneath and connected to the upper tray 2417. There are six cross sections of this device 2400 shown. Cross section E-E shows the hollow openings of the air passage 2417.

[0208] FIG. 29 depicts different cross sections of the “Adjustable 3D Printed” sleep apnea device of FIG. 27 with air flow passage connected to underneath of the upper tray of device 2400. Air enters through 2412 and exits at 2413A and 2413B locations of the oropharynx area, back of throat.

[0209] FIG. 30 depicts the exploded view of “customized” 2400 device at different angle. Air exits at 2413A and 2413B locations of the oropharynx area, back of throat.

[0210] FIG. 31 depicts “Pre-Customized” sleep apnea device 2500 having hollow air passageway 2513 on both sides of the upper tray 2517. Lower teeth tray 2518 is connected to upper teeth tray 2517 by two linkages 2519 on both sides of the hollow tubes using buttons. The figure also depicts the different cross sections. Cross section F-F shows the hollow openings 2513A and 2513B of the air passageway 2513.

[0211] The “customized” upper and lower teeth trays can be 3D printed similarly as described in FIG. 27. If trays are thermoformed, then upper tray is bonded to air passageway 2513. The outer housing can be attached and detached from mouth piece using cantilever types or other snap/unsnap fit structures. Here the design can be modified where “pre-

customized" upper and lower teeth trays, each is made from dual materials, meaning soft and hard material. The soft material is thermoformed over patients' model and this soft thermoformed upper tooth tray bonded with already pre-customized 3D printed hard upper mouthpiece having hollow air passageway. The soft material stays in touch with teeth providing comfort, ease of fitting by doctor. The soft material also helps in absorbing noise created by micro blower vibration or air flow noise. The upper and lower teeth trays can be customized 3D printed from soft and hard material in a single step 3D printing process where soft material is in contact with teeth.

[0212] Instead of soft boil and bite material or soft thermoformed material, one can apply soft coating for all rigid or semi-rigid plastics upper and lower trays in case of all different types of oral customized 3D printed sleep apnea MAD or non-MAD devices described above. The soft coating is applied in the inner surface of rigid or semi-rigid teeth trays to provide comfort and reduce noise transferred from teeth to jaws to ear canal due to noise created by micro blower vibration or due to air flow.

[0213] FIG. 32 depicts exploded view of detachable "Hinge type" oral sleep apnea mandibular advancement device 2600 having "hinged upper and lower plastics trays" where upper tray 2617 and lower teeth tray 2618 are NOT either "boil or bite" type or NOT "Pre-customized 3D printed" to fit the teeth. It is not customized to fit patient's teeth but to hold the upper and lower teeth in position. The upper and lower teeth trays can be injection molded from soft or semi-rigid plastics or thermoformed on teeth model from soft or semi-rigid plastics. The mandibular advancement is achieved by selecting the size of trays 2617 and 2618 as one piece such as small, medium, and large. The hinge structure helps to hold the device in place on upper and lower teeth, advancing the lower jaw forward based on size of the plastic trays 2617 and 2618 as one piece, attached to hollow air passageway 2613 of the upper mouthpiece by adhesive 2616. This upper mouthpiece 2613 with air passageway is 3D printed or manufactured by any of several plastics technologies to fit small, medium, and large upper trays. 2201 is a lid and 2205 is a housing which is common design for all the devices.

[0214] The upper and lower teeth trays can be injection molded from soft plastics or thermoformed from soft plastics on teeth model to make the trays customized to the person. The mandibular advancement is achieved by selecting the size of trays such as small, medium, and large and the hinge structure helps to hold the device in place on upper and lower teeth, advancing the lower jaw forward based on size of the plastic tray attached to hollow air passageway of the upper mouthpiece. This upper mouthpiece with air passageway is 3D printed or manufactured by any of several plastics technologies to fit small, medium, and large upper trays.

[0215] FIG. 33 depicts the cross section of living hinge which connect the upper and lower trays 2617 and 2618 as a single piece. 33A is a living hinge gap between the walls and dimensions can be 0.020 inches to 0.060 inches or more. 33B is a radius and dimensions can be 0.020 inches or more. There is at least 0.005-inch radius to all corners. The dimension of 33C is 0.0 inches to 0.006 inches or more. The thickness of living hinge 33D is from 0.002 inches to 0.015

inches or more. The wall thickness of upper and lower trays 2617 and 2618 is in the range between  $-0.012$ " to 0.12 inch thick or more.

[0216] In all above different types of sleep apnea or anti-snoring devices, the micro blower is continuously running. The micro blower can be set at constant speed (air flow rate) or can be set at one speed during inhalation and different speed during exhalation. The advantage of micro blower running continuously during exhalation that it restricts the airflow during exhalation, which creates expiratory positive airway pressure and maintain pressure in the airway through the start of the next inhalation. This helps keep airway open little longer during exhalation, improving the sleep apnea treatment.

[0217] FIG. 34 depicts the one of several structures for snap fit designs of the housing 2205. There are several types of snap fits designs can be used. The most important are: Cantilever snap joints—The load here is mainly flexural, U-shaped snap joints—A variation of the cantilever type, Torsion snap joints—Shear stresses carry the load, Annular snap joints—These are rotationally symmetrical and involve multiaxial stresses. For example, in this diagram, the detachable sleep apnea appliance is shown using the cantilever beam type snaps for snapping and unsnapping of outside housing and mouthpiece. Front housing 2205 shows two cantilever type snaps 2210 while 2212 are two openings in the mouthpiece in which 2210 snaps in. To unsnap the front housing and mouthpiece, the person pushes in both snaps 2210 by hands and pull-out the two pieces in opposite direction with hands, once both snaps 2210 are out of both openings 2212. The design and dimensions of snaps are very critical for 3D printing as well as for injection molding manufacturing process. The thickness of the optimal snap fit arm (flexible beam) decreases linearly up to 30% of the original cross-sectional area. The strain in the outer fibers is uniform throughout the length of the cantilever. The width of the flexible snap beam  $b$  can be 3 mm to 15 mm, preferably 10 mm for nylon, length  $L$  of the flexible snap beam can be 3 mm to 8 mm preferably, the ratio of flexible snap arm width to length can be 1 to 3 or more or it can also be 3 to 1 depending on the plastics material and other snap dimensions. The thickness  $t$  of flexible beam arm can be 0.7 mm to 1.5 mm or more. There is a relationship between  $b$  width,  $y$  length and  $t$  thickness of the flexible portion of snap arm that it allows to flex or bend the cantilever to snap in the opening of the mouthpiece and apply constant load, so the two pieces housing and mouth pieces stay snap in, does not come out during any movement during sleep. At the same time, the arm area of the snap should be flexible enough that when normal force is applied on the rigid catch (top portion of snap)  $C$ , the mouthpiece and housing should be detached easily. The angle of the right catch  $C$  can be 20 degrees to 50 degrees. The height  $Y$  of the rigid catch  $C$  can be 2 mm to 5 mm or more.

[0218] FIG. 35A shows how the outer housing 2205 and mouthpiece 2213 which are snapped and unsnapped (detached) of the detachable sleep apnea device 35-I. Housing and mouth pieces can be of several different designs as described in this invention. The cross section of device is taken as shown in FIG. 35-1 FIG. 35-II shows the sleep apnea appliance in snapped position. Once both pieces are snapped in, it is a complete device with which patient sleeps. Here, 2210 is cantilever beam type snap of housing 2205 which is snapped in the opening 2212 of the mouthpiece

**2213.** FIG. 35-III shows the sleep apnea appliance in un-snapped position, meaning housing and mouthguard are detached. The patient detaches the two pieces when awakes in the morning. The mouthpiece is cleaned with soap and water while rechargeable battery in the housing is charged with USB located on the PCB and power supply. This figure does not show the lower mouthpiece which is connected to upper mouthpiece by linages (straps) as described for MAD devices. But device can have lower tray to use as MAD device. The device is mounted to upper teeth and connected to lower teeth by lower teeth tray which is adjusted as needed to bring lower jaw forward to reduce sleep apnea level.

**[0219]** FIG. 35B depicts the view of the expandable oral detachable sleep apnea **3500** device where attaching and detaching the outer housing **3501** and mouthpiece **3502** take place by different mechanism compared to snap and unsnap joints described in FIG. 35 A. The outer housing **3501** and mouthpiece **3507** held together by buttons **3504** on both pieces using semi-flexible or hard linkages **3505**. Length of linkage is patient specific as outer portion of mouthpiece varies from patient to patient. It is very important to have ease of mounting housing and mouthpiece together and once both pieces are attached, they should be held together tightly during sleep without air leakage at the interface. This is achieved by selection of right material of the linkages and also distance between the buttons on housing and mouthpiece. If length of linkage is X, then distance between buttons on housing and mouthpiece should be 1.1X to 2.0X depending on the softness of linkage material. There is a flexible gasket **3502** between housing and mouthpiece to dampen the micro blower's noise transmission to mouthpiece **3507**. The **3503** is air passageway of upper mouthpiece. The lower mouthpiece can be used to make the MAD device.

**[0220]** FIG. 36A depicts one of the concepts of isolating the micro-blower (micro blower) from the rest of the outer housing. In other word, decouple the micro blower from the rest of the system so noise does not transmit, and it dampens the noise. There are different ways to reduce the airborne noise and structural noises. Airborne noise is created by the interaction of the vibrating surface with the surrounding air. It can be reduced by adding absorbers, barriers, and layers to absorb or reflect sound energy. Structural noise is produced by mechanical vibration energy that travels throughout the structure of the product as well as materials which comes in contact. Structural noises are controlled by controlling the vibration that causes it. A low friction surface positioned between parts is one way to manage vibration. Isolation of vibration is another. Another way to manage the structural noise is to change the vibration mode of the structure by adding a vibration dissipating dampening material. To reduce the vibration noise of micro blower **3601**, **3602** vibration dampening tape or isolator is inserted at all sides of the micro blower which come in contact of housing chamber **3604**). This vibration dampening tape or isolator **3602** provide a visco-elastic layer between two rigid surfaces (micro-blower and walls of housing) while bonding them together. Vibration that occurs in either panel places this tape or isolator material in elongation mode, but elongation is constrained by the rigidity of the panels (micro blower and housing walls). As a result, vibration energy is turned into heat energy through constrained layer damping, resulting in micro blower's noise reduction.

**[0221]** FIG. 36B depicts two halves of micro blower enclosure **3602** using sound dampening and/or sound absorbing material. The micro blower is completely enclosed in both halves **3601A** and **3602B**. The design of enclosure is based on the type of material and type of micro blower **3601**.

**[0222]** In one embodiment, the micro blower speed is set to lowest level for initial few minutes (for example 30 minutes or so) and then slowly ramped up to desired high micro blower speed. This allows the patient to go to sleep easily as there will be very little or no noise while going to sleep. This provides comfort level to the patient and increase the compliance level. The device also has a provision to see the level of battery charged and level of micro blower speed at any point by pushing on/off button few times. The speed of the micro blower can be adjusted by adjusting the micro-switches on the PCB or using USB of the PCB which connected to laptop or cell phone to set the desired micro blower speed. In later case, patient can never be able to change the speed of micro blower.

**[0223]** The detachable cantilever snap/unsnap type sleep apnea device. The mechanism of snap and unsnap is same as described earlier. The innovation is that this type of device has two concepts of dampening the micro blower vibration or any other sound transmitting from the housing **3600A1** to mouthpiece **3600A2**. The purpose is to reduce or eliminate airborne or vibration noise created by micro-blower and also transmission of any noise due to jawbone conduction in inner ear. To reduce the vibration noise at the source, the micro blower **3601** is completely enclosed in both halves **3601A** and **3602B**. These are several designs can be used to keep micro blower in place during the operation while it has minimum contacts with the enclosure, as if micro blower is hanging in the air while rotation. With the use of enclosure sound dampening material having shore hardness of 10 A to 90 A, most of the noise due to micro blower vibration is dampened. The design of these enclosure halves is also based on type of micro blower **3601** and enclosure material. To reduce the transmission of any noise from the housing to mouthpiece, the soft isolator **3605** is either inserted in the mouthpiece as a separate piece (two piece soft/hard construction) or housing is manufactured by two shot molding (one piece soft/hard construction) where soft isolator **3605** is molded in with hard plastics material of the housing in a single step process.

**[0224]** The detachable sleep apnea device having linkages and buttons to attach and detach housing and mouthpiece. The mechanism of attaching and detaching the housing **3600B1** and mouthpiece **3600B1** is completely different compared to previous devices having cantilever type snaps. The concept is similar as described in FIG. 35B. The outer housing **3600B1** and mouthpiece **3600B2** are held together by buttons **3610** on housing and **3611** on mouthpiece using semi-flexible or hard linkages **3609**. Length of linkage is patient specific as outer portion of mouthpiece varies from patient to patient. It is very important to have ease of mounting the housing and mouthpiece together before the device is inserted in the mouth and once both pieces are attached, they should be held together tightly during sleep without air leakage at the interface. This is achieved by selection of right material of the linkages (softness in the range of 10 A shore hardness to 90 A shore hardness and also distance between the buttons on housing and mouthpiece. If length of linkage **3609** is X, then distance between buttons

on housing and mouthpiece should be 1.1X to 2.0X depending on the softness of linkage material selected. The other innovation of **3600B** sleep apnea device is having two concepts of dampening the micro blower vibration or any other sound transmitting from the housing **3600B1** to mouthpiece **3600B2**, same as described above. The purpose is to reduce or eliminate airborne or vibration noise created by micro-blower and also transmission of any noise due to jawbone conduction in inner ear. To reduce the vibration noise at the source, the micro blower **3601** is completely enclosed in both halves **3601A** and **3602B**. These are several designs can be used to keep micro blower in place during the operation while it has minimum contacts with the enclosure, as if micro blower is hanging in the air while rotation. With the use of enclosure sound dampening material having shore hardness of 10 A to 90 A, most of the noise due to micro blower vibration is dampened.

[0225] The design of these enclosure halves is also based on type of micro blower **3601** and enclosure material. To reduce the transmission of any noise from the housing to mouthpiece, the soft isolator **3605** is either inserted in the mouthpiece as a separate piece (two piece soft/hard construction) or housing is manufactured by two shot molding (one piece soft/hard construction) where soft isolator **3605** is molded in with hard plastics material of the housing in a single step process. It has micro-blower enclosure in the housing using sound dampening and/or sound absorbing material and soft isolator at all the contact surfaces between housing and mouthpiece.

[0226] FIG. 37 depicts electrostimulation or electro-excitation of tongue and soft tissues, so tongue does not fall back (relax) and soft tissues in back of throat does not relax. This is achieved by connecting electric wire **3701** to PCB **3702** (not shown) located in the housing **3700**. This electric wire passes through hollow opening-air passageway **3704** of the upper mouthpiece **3705**. Position sensor **3706** senses the initial position of the tongue when the sleep apnea device is inserted in mouth before the sleep. During the sleep, if tongue falls back, tongue will not touch the sensor, which is sensed by sensor and data is transferred to PCB. The PCB immediately gives minor shock to the tongue using wire **3701** which is located at the exit of hollow tube and always touching to tongue as shown. Once tongue comes forward, touches the sensor, the minor electric shock is stopped. In other words, the minor shock teaches the tongue to stay always in forward position, not falling back and keeping the air passage open in throat area (oropharynx area).

[0227] FIG. 38 depicts the "Fixed" customized boil or bite, or "Customized 3D printed" sleep apnea device having different inhalation and exhalation ports. The exhalation port **3801** and **3802** is in between the upper **2217** and lower teeth tray **2218**. Opening port **3801** is inside the mouth while opening port **3802** is outside the mouth where exhalation air from port **3801** comes out to atmosphere via port **3802**. During inhalation, the micro-valves or flapper type film valve **3803** connected to port **3802** stays closed due to its design (outside air pressure during inhalation keeps valve closed). The air enters in the mouth through the micro-blower via air passages **2213A** and **2213B** bypassing the tongue which does not allow the muscles to relax and keep oropharynx area open for ease of breathing reducing sleep apnea events. During exhalation, the micro-valves or flapper type film valve **3803** opens due to exhalation air pressure, allowing the exhalation air to escape very easily in case

nostrils are congested. Here, the resistance of the valve can be adjusted by design and type of material if needed in such a way that it restricts the airflow during exhalation, which creates expiratory positive airway pressure and maintain pressure in the airway through the start of the next inhalation. This helps keep airway open little longer during exhalation, improving the sleep apnea treatment.

[0228] The same concept of use of valve to allow air to atmosphere during exhalation can be used for all types of MAD devices described in this invention (boil and bite or customized 3D printed devices) providing the air opening in the upper teeth tray where this air opening is not connected to hollow air passageway. The purpose of the opening is to allow controlled exhalation in addition to controlled exhalation by continuous micro blower, creating expiratory positive airway pressure and maintain pressure in the airway through the start of the next inhalation. This helps keep airway open little longer during exhalation, improving the sleep apnea treatment.

[0229] FIG. 39 depicts FIG. 38 with different cross sections showing how the hollow opening **2213A** of air passageway coming from micro-blower is separated from openings **3801** and **3802** connected between upper tray and lower tray.

[0230] In one of the embodiments, the sleep apnea treatment device may function as "Hybrid Device" meaning sleep apnea treatment and aligner concepts built in a single device. The straightening of the teeth is achieved by connecting the upper and lower aligners together while sleep apnea events are reduced during air inhalation via hollow air passageway connected to upper aligner. The hybrid device can and with or without moving the lower jaw forward (MAD device). It is claimed to have "daytime aligners" and "nighttime aligners (modified daytime aligners)". The patient wears both the upper and lower aligners during the daytime to correct teeth positioning. In the daytime, when the patient is awake, no sleep apnea occurs. The thickness of the aligners wall can be from 0.5 mm to 2.5 mm while thickness of sleep apnea device's hollow air passageway can be from 0.5 mm to 3 mm. Both daytime or nighttime sleep apnea/aligner hybrid device can be with or without detachable housing containing micro blower, PCB, sensors, rechargeable battery etc.

[0231] FIG. 40 shows an example "nighttime passive 3D-printed hybrid sleep apnea/aligner device". The upper aligner labeled "A," is connected to tube B having "C" shape creating hollow structure for air passageway. The aligner A is 3D printed or thermoformed using plastics films. Only the upper aligner has the hollow tube B, creating hybrid device, while the lower aligner does not have hollow air passageway (not shown in figure). The hollow tube B can injection molded, thermoformed or 3D printed, and it is bonded to aligner A via several technologies. The hollow tube B on the aligner A goes from front of the mouth area (lips area) to throat area meaning at the oropharynx or laryngopharynx area. In the center position of the hollow tube B (center of lips area), there is an opening C through which air enters during inhalation.

[0232] To use same hybrid system for "daytime aligner device", the opening C is closed with the detachable plug or opening C can be closed by using a simple detachable Snap-On lid. The opening C is in flush with the tube B such a way that it does not interfere with the patient's daytime activity such as talking, breathing, and the opening C also

allows the patient's mouth to close completely and comfortably. The daytime aligner functions normally as designed to straighten the teeth. In another scenario, the lower aligner can be modified instead of the upper aligner, with a hollow tube B. This example aligner system modifies only one aligner, either the upper or the lower aligner, with hollow tube B. Which aligner to be modified (upper or lower) can be defined by the patient's mouth and teeth geometry. The patient wears both the upper and lower aligners during the daytime to correct teeth positioning. In the daytime, when the patient is awake, no sleep apnea occurs.

**[0233]** The thickness of the A aligners can be from 0.5 mm to 2.5 mm while thickness of the B shape section of sleep apnea device's hollow air passageway can be from 0.5 mm to 3 mm.

**[0234]** FIG. 41 shows the design of a "Active hybrid nighttime 3D-printed sleep apnea/aligner device" with a sleep apnea treatment device, with or without capability of moving the lower jaw forward. In this implementation, the same day time aligner shown in FIG. 40 is modified so that the patient attaches a detachable hollow front housing D, snap-fit on the front center hollow opening C (center of lips area) of hollow tube B. This modified design with snap-fitted detachable front hollow housing D brings outside air through the hollow housing D as the patient breathes, to hollow center C and through hollow tubes (air passageway) B to the back of the mouth, bypassing the soft tissues, palates, tongue etc., directly to the oropharynx or laryngopharynx area, not allowing tongue to fall back and/or not allowing muscles along with soft fatty tissues in the upper mouth and throat areas to relax during sleep, thus keeping air passage open, and reducing or preventing sleep apnea and snoring. This example aligner system not only keeps the air passage opens during sleep, but simultaneously corrects teeth positioning during sleep without need of bringing the lower jaw forward.

**[0235]** As shown in FIG. 41, the detachable snap-fit front housing D can be replaced with other innovative front devices, such as housing E, which is divided into three sections of a hollow housing. The center of the housing E has micro-blower(s) F with very high RPM (up to 20,000 RPM) to bring air continuously from the front to connection C, to hollow tubes B, and all the way back to the oropharynx or laryngopharynx area (throat area). The housing E has two side openings G and H as shown in FIG. 41. G is a rechargeable battery. H is a compact control module consist of PCB containing microprocessor, Bluetooth, and optional micro-SD card, and can also contain several sensors such as airflow sensor, pressure sensor, pulse oximeter (to measure the pulse rate and oxygen saturation), temperature sensor, accelerometer, tilt sensor and sound sensor.

**[0236]** A target air pressure and airflow are achieved to keep the patient's air passage open, to treat the sleep apnea (airflow is automatically adjusted continuously during sleep) by controlling the speed of micro blower(s). This automatic control of the micro blower's speed is achieved by utilizing feedback from the sensors and microprocessor having a closed loop feedback control system with control logic, using a compact control module with PCB "H" inserted inside the front hollow housing E in FIG. 41. The collected data also provides compliance for treating sleep apnea and for use of the aligner device itself, during sleep. The example device has the capability to record data within the system using a micro-SD card or to transfer data wirelessly

using Bluetooth or cloud to permit live monitoring of the medical condition of the individual, and treatment compliance.

**[0237]** The functionality of the example aligner to straighten teeth during the night is not affected using the sleep apnea treatment modification of the aligner system, which does not require bringing the lower jaw forward. The housing contains of micro blower, control module (PCB) with microprocessor, Bluetooth, micro-SD card, several sensors, and rechargeable battery. This is known as "active" hybrid device.

**[0238]** FIG. 42 depicts the patient wearing the example of hybrid aligner/sleep apnea device on upper teeth, using the devices of FIG. 41 with front hollow housing D attached to the hollow tube of B of the aligner A, via snap-fit structure C as described previously with detachable sleep apnea devices FIG. 35A and FIG. 35B.

**[0239]** In one of the embodiments, the blower speed can be controlled independently during inhalation and exhalation using thermistor or thermocouple which is incorporated in the air passageway of the device either in the housing or in the mouthpiece. The exhalation temperature is higher compared to inhalation. The micro blower speed is higher (pre-set based on patient) during exhalation compared to inhalation which creates pressure when one exhales to keep airway open for longer time. The use of thermistor also helps for tracking the use of device by patient, known as compliance. There is a flash memory on the PCB which records the temperature during sleep and this information is transferred via USB or via Bluetooth to the cell phone or other electronic device.

**[0240]** In one of the embodiments, only micro blower and on/off switch are mounted in the outer housing of the device while the rechargeable battery and PCB inserted in a box and are mounted on the body by several means such as used in medical wearable devices in the market. The micro blower's wire is connected to wire on PCB. This type of oral sleep apnea device can be one piece or detachable device. The benefit of this concept is that it reduces the weight of the housing and provides more comfort to the patient. Also, it will make sleep apnea device very small due to smaller outer housing.

**[0241]** In one of the embodiments, only micro-blower and PCB are inserted in the housing. Here, micro-blower is powered by household electricity using electric wire adapter instead of rechargeable battery. This adapter is connected to USB mounted on the PCB or directly connected to micro blower. The micro blower speed is monitored by PCB or by outside adapter having controller. This makes device smaller and lightweight. The device is safer as device is not using rechargeable battery.

**[0242]** In all sleep apnea devices described above, the micro blower's speed can be pre-set by doctor based on patient's sleep apnea study (in-laboratory or in home using HST). The micro blower's speed can be adjusted slowly to a level where patient's sleep apnea is reduced to an acceptable level. This is done in combination of MAD adjustment (lower jaw advancement) which can be as little as possible for the comfort of the patient. It is also possible that micro blower speed or air flow rate may be sufficient to excite the tongue and the soft tissues, not allowing them to relax, eliminating the MAD device completely, meaning there is no need to have lower teeth tray and connectors.

[0243] In one of the embodiments, the Infra-red (IR) or optical camera with light mounted on the mouthpiece of the sleep apnea device where airflow exits from one of the hollow air passage channels. The Infra-red camera or optical camera is mounted at the end of hollow tube so one can continuously capture the video or photos to see what is happening in the throat area (oropharynx area). This information can provide data on patient's sleep pattern, movement of soft tissues, constrained or opening of the air passage. Airflow rate can be adjusted automatically by micro blower's speed if air passage in oropharynx area become narrow using closed loop feedback control system. A sophisticated algorithm (software) is developed to calculate the oropharynx opening area, by capturing the images by cameras.

[0244] In one of the embodiments, it shows another way to reduce mouth dryness while sleeping with the device is to use wicking polyester or any other synthetic polymer fabric having yarns attached to mouthpiece which absorbs the moisture of exhalation, moisture only stays on surface. Exhalation air has more moisture compared to inhalation air. During inhalation, this moisture from surface of the fabric will be released in the mouth, keeping mouth moist. Moisture-wicking fabrics include synthetic fibers such as polyester or nylon, and any material that has been treated with a solution to prevent water absorption. Polyester and nylon are water-resistant because they are made from materials with a chemistry that is similar to plastic. Instead of water being absorbed by the fiber it sits on, water droplets stay on the surface during exhalation and move around the fabric by running along the weave. Eventually, the water droplets reach the outside of the fabric where, if exposed to the inhalation air, they evaporate, keeping mouth moist during sleep.

[0245] In one of the embodiments, a design structure can be created in front of micro-blower using 3D printed metamaterial. This can help in reducing micro blower noise significantly. A metamaterial is any material engineered to have a property that is not found in naturally occurring materials. This is called passive noise cancellation.

[0246] In one of the embodiments, the temperature sensor at the end of the hollow opening of the air passageway, measures the inside temperature of the mouth. The temperature data are stored on the flash of PCB mounted in the outer housing. Recording the temperature data helps doctor and insurance companies to find out compliance level by the patient as mouth temperature is same as body temperature, different than room temperature and it fluctuates during sleep.

[0247] In one of the embodiments, the outer housing of oral sleep apnea device contains a digital accelerometer as part of PCB that continually monitors a patient's sleep position. When using the device, if a patient turns to the supine position, it will react with a soft vibration of a patch as part of the housing which is in contact with upper or lower lip that continues until the patient returns to a non-supine position. The PCB records the digital data on PCB which can be transferred to cell phone via Bluetooth so patient can see the percentage of supine sleep from the previous night of sleep with an indication of either an increase or decrease in percentage of supine sleep, number of vibrational feedback instances from the previous night of sleep, trend report with indication of average percentage supine sleep in the previous 7 days and a graphical visualization of the trendline.

[0248] And the relationship between width, length and thickness of the flexible portion of snap arm that it allows to flex or bend the cantilever to snap in the opening of the mouthpiece and apply constant load, so the two pieces (housing and mouthpieces) stay snap, does not come out during any movement during sleep. At the same time, the arm area of the snap should be flexible enough that when normal force is applied on the rigid catch (top portion of snap), the mouthpiece and housing should be detached easily by applying inward pressure using figure to detach. The angle of the right catch can be 20 degrees to 50 degree. The height of the rigid catch can be 2 mm to 5 mm or more.

[0249] According to the teaching of the FIGS. 22-42, a detachable apnea device is presented is engageable with a patient's lips and teeth, the oral sleep treatment device including a front hollow housing defining a first through passage defining an inlet aperture and an output aperture, the front hollow housing having an exterior surface configured to engage the patient's lips the front hollow housing having a first detachable locking interface adjacent the output aperture. The detachable apnea device includes an air flow generating device disposed within the first through passage, the generating device configured to create an airflow from the inlet aperture through the output aperture the air flow generating device comprises a controller configured to regulate electrical power supplied to the generating device and a battery disposed within the front hollow housing, the battery being electrically coupled to the airflow generating device and the controller. The detachable apnea device mouthpiece defining first mouthpiece aperture selectively coupled to the front housing, the mouthpiece having first and second curved members together defining a u-shape and having an exterior surface defining a tooth engaging surface, the first and second members defining second and third conical through passages, the second and third passages having a non-circular cross section which decreases in cross sectional area from the first mouthpiece aperture to first and second rear mouthpiece apertures, that are configured to increase the pressure and air velocity of air passing from the front hollow housing through the second and third passages, the first and second rear mouthpiece apertures disposed adjacent to the retromolar pad members when the mouthpiece is engaged with the patient's teeth.

[0250] The detachable apnea device includes a vibrationally isolating member disposed between the air flow generating device from the front hollow housing to reduce the vibration transmission into the mouthpiece.

[0251] As shown in FIGS. 22-42 the detachable apnea device includes a first mouthpiece configured to engage one of the upper teeth or lower teeth. The mouthpiece defines second and third conical through passages are defined at one of underneath and side/surrounding the upper teeth tray. Optionally, the mouthpiece is selected from the group consisting of a detachable customized mouthpiece containing a 3D printed upper tray, a bonding layer between the hollow air passageway on which pre customized thermoformed plastics teeth tray is bonded to create pre-customized upper mouthpiece defining the first and second rear mouthpiece, and a teeth tray is pre-manufactured by thermoforming process or by 3D printing. Optionally, the mouthpiece is attached to lower teeth tray.

[0252] The device can contain a Mandibular Advancement Devices configured to bring lower jaw forward to further reduce sleep apnea. Additionally, the device can include be



a hinge style sleep apnea device. The upper teeth tray and a lower teeth tray can be formed of a single plastics piece connected by a hinge structure. It can be formed by one of injection molding process and a thermoforming process. The upper tray can be bonded to the mouthpiece with adhesive. Optionally, the hinge structure comprises a living hinge gap between the walls and dimensions 0.020 inches to 0.060 inches, the radius is greater than 0.020 inches, the wall thickness of living hinge is between 0.007" to 0.015" thick and the wall thickness of upper and lower trays is between 0.012" to 0.12 inch thick.

**[0253]** The device can have a continuously running motor at constant speed micro blower where the micro blower produces a first air flow rate during inhalation and a second air flow rate during exhalation, creating an expiratory positive airway pressure maintaining pressure in the airway through the start of the next inhalation. The first detachable locking interface is selected from the group comprising a cantilever snap joint where the load here is mainly flexural, u-shaped snap joints where a variation of the cantilever type, Torsion snap joints where Shear stresses carry the load, and annular snap joints where they are rotationally symmetrical and involve multi-axial stresses.

**[0254]** The first detachable locking interface has a snap fit flexible arm that has a decreasing cross-sectional area that decreases linearly up to 30% of a original cross-sectional area. The strain in an outer portion of the flexible arm is uniform throughout the length of the flexible arm and where the width of the flexible arm is between 3 mm to 15 mm, preferably 10 mm, having a length between 3 mm to 8 mm, the ratio of flexible arm and a thickness of flexible beam arm between 0.7 mm to 2.0 mm. The first detachable locking interface links the housing and mouthpiece together by flexible, semi-solid plastics elastomeric linkages which is held by a plurality of buttons on sides of the housing and mouthpiece.

**[0255]** The upper and lower trays can be separated by detached by un-linking the flexible, semi-solid linkages from buttons located on both pieces by flanges. Additionally, a flexible isolator member disposed between the housing and the mouthpiece to dampen noise transmission to mouthpiece, the flexible isolator being made from a material selected from a seal comprising two shot molding, two material 3D printing, and two-piece construction where isolator is inserted in the housing separately.

**[0256]** The device can include a vibrationally isolating member disposed between the air flow generating device from the front hollow housing to reduce the vibration transmission into the mouthpiece. The member can be formed of a low durometer material disposed between the front hollow housing and the mouthpiece which dampens any vibrations created by micro blower and transmitted from housing to mouthguard. The soft contact layer prevents the noise transmission to mouthpiece which in turn prevents the bone conduction noise through teeth trays in ear canal.

**[0257]** The mouth piece can include an adjustable boil and bite mouthpiece defining the second and third conical through passages and a micro blower having a first blower speed level during device start-up and a second blower speed level after a predetermined amount of time. The controller can include a circuit to determine a level of battery charge and a level of air flow generating device speed. Additionally, a position sensor located at the forward tongue

area of upper mouthpiece senses the position of the tongue in forward position and a shock inducing circuit.

**[0258]** Additionally, the device can include an inhalation and exhalation apertures where within the exhalation aperture is disposed a valve that stays closed through it during inhalation, and during Inhalation, the air enters in the mouth through the air flow generating via an air passageway bypassing the tongue, not allowing the muscles to relax and keep oropharynx area open for ease of breathing, reducing sleep apnea events and snoring. During exhalation, the valve opens due to exhalation air pressure, allowing exhalation air to escape, where the resistance of the valve can be adjusted.

**[0259]** Optionally, a thermocouple can be incorporated the front hollow housing, where the exhalation temperature is higher compared to inhalation temperature or the temperature of the patient's mouth. The thermocouple provides a signal indicative of the temperature of airflow. The thermocouple can include an Infra-red (IR) emitter disposed with the mouthpiece configured to provide a signal indicative of airspeed. The device can include a moisture wicking material which absorbs the moisture of exhalation. The system can include a 3D printed acoustic metamaterial to reduce the noise of micro blower significantly. The device can contain a digital accelerometer that a patient's sleep position.

**[0260]** Optionally, the sleep apnea treatment device which functions as hybrid device that functions as a sleep apnea and an aligner device in a single device. Optionally, the sleep apnea treatment device can include an accelerometer which can determine a patient's sleep position.

**[0261]** Rigid or semi-rigid plastic examples suitable for use in manufacturing the devices include, but are not limited to: Commodity thermoplastics such as polyvinylchloride, polyolefin and polystyrene: polyvinyl chloride having properties such as but not limited to: density of 1.2 to 1.4 g/lee, tensile strength in range of 40 to 55 Mpa, tensile elongation in range of 20 to 100%, flexural modulus in range of 2.0 to 5 GPa; polyolefin such as polyethylene and polypropylene materials having properties such as but not limited to: density in range of 0.86 to 0.98 g/lee, tensile strength in range of 20 to 60 Mpa, tensile elongation in range of 50 to 150%, flexural modulus in range of 1.5 to 2.0 GPa, notched impact strength in range of 50 to 200 Jim; polycarbonate having properties such as but not limited to: density of 1.2 g/lee+ 1-0.1, tensile strength in range of 50 to 85 Mpa, tensile elongation in range of 40 to 140%, flexural modulus in range of 2.0 to 2.6 GPa, impact strength in range of 300 to 1000 Jim; acrylics such as polymethylmethacrylate (PMMA), acrylic copolymers and acrylic multipolymer blends having properties such as but not limited to: density in range of 1.1 to 1.2 g/lee, tensile strength in range of 30 to 75 Mpa, tensile elongation in range of 4 to 30%, flexural modulus in range of 1.5 to 4.0 GPa, notched impact strength in range of 100 to 300 Jim; Rigid thermoplastics polyurethanes (TPU) can be polyester, polycarbonate or polyether based TPU having properties such as but not limited to: density with the range of 1.05 g/lee to 1.20, shore D hardness of 35 D to 850, tensile strength @ break 35 to 70 MPa, tensile elongation in range of 50 to 300%, flexural modulus in range of 0.5 to 2.5 GPa; Polyesters including PBT or PET having properties such as but not limited to: density in range of 1.2 to 1.4 g/lee, tensile strength @ break in range of 40 to 70 Mpa, tensile elongation in range of 40 to 100%, flexural modulus in range of 2.0 to 3.5 GPa, notched impact strength in range of 35 to 70 Jim; ABS having properties such as but not limited to: density in

range of 1.00 to 1.05 glee, tensile strength @ break in range of 30 to 50 Mpa, tensile elongation in range of 5 to 30%, flexural modulus in range of 2.0 to 3.0 GPa, notched impact strength in range of 250 to 350 J/m; Nylons or polyamides such as PA 6, PA 66, PA 11, PA 12, PA 46, PA 610, having properties such as but not limited to: density in range of 1.00 to 1.2 glee, tensile strength @ break in range of 45 to 85 Mpa, tensile elongation in range of 30 to 200%, flexural modulus in range of 1.0 to 3.0 GPa, notched impact strength in range of 25 to 120 J/m; Polyether ether ketone (PEEK) having properties such as but not limited to: density in range of 1.30 to 1.35 glee, tensile strength @ break in range of 90 to 150 Mpa, tensile elongation in range of 10 to 40%, flexural modulus in range of 4.0 to 4.5 GPa, notched impact strength in range of 55 to 65 J/m; Composites of above plastics with glass fiber, carbon fiber and other fillers polymeric alloys comprising blends of polymers such as polycarbonate alloys with polybutylene terephthalate (PBT), and polyethylene terephthalate (PET) for improved chemical resistance, PC/ABS copolymer alloys for ease of processability, PC/TPU, PC/ABS, PC/SMA, PBT/PET/ASA alloys, PA/TPU and several combinations of all the plastics described above; thermosets comprising photopolymers made out of methacrylated oligomers, monomers, acrylated monomers, low molecular weight polymers or elastomers to reduced brittleness having properties such as but not limited to: density in range of 1.10 to 1.20 glee, tensile strength @ break in range of 40 to 65 Mpa, tensile elongation in range of 10 to 40%, flexural modulus in range of 2.0 to 4.0 GPa, notched impact strength in range of 10 to 40 J/m and shore D hardness of 50 to 800; Soft and elastomeric plastics include, but are not limited to: soft polyurethanes, EVA (ethylene vinyl acetate), TPE such as SEBS, elastomeric nylons, silicones elastomers, biopolymers (PLA—polylactic acid), thermoplastics or thermoset elastomers.

**[0262]** The devices can be formed of copolyester produced when more than onediacid or dial is used in the polyester polymerization process, such as PETG (polyethylene terephthalate glycol), PCTG (Polycyclohexylene dimethylene-terephthalate glycol) with properties such as but not limited to: density in range of 1.2 to 1.7 glee, tensile strength @ break in range of 25 to 30 Mpa, Tensile elongation in range of 110 to 300%, flexural modulus in range of 1.8 to 2.2 GPa, notched impact strength in range of 100 J/m to no break; soft polyurethanes (TPU elastomers) having properties such as but not limited to: density with the range of 1.05 glee to 1.30, shore 0 hardness of 30 0 to 750, tensile strength @ break 15 to 50 MPa, tensile elongation in range of 300 to 800%, flexural modulus in range of 0.03 to 0.15 GPa. compression set 10 to 45%, tear strength 80 to 180 Nlmm; EVA (ethylene vinyl acetate) having properties such as but not limited to: density with the range of 0.93 glee to 0.96 glee, shore 0 hardness of 30 0 to 500, tensile strength @ break 3 to 35 MPa, tensile elongation in range of 300 to 800%, elastic modulus in range of 0.015 to 0.08 GPa; and silicones elastomers having properties such as but not limited to: density with the range of 1.12 glee to 1.2 glee, shore A hardness of 30 A to 70 A, tensile strength @ break 8 to 15 MPa, tensile elongation in range of 300 to 800%, compression set 10 to 20%, tear strength 30 to 40 Nlmm.

**[0263]** Additionally, the material can be formed of TPE such as SEBS having properties such as but not limited to: density with the range of 1.15 glee to 1.25 glee, shore 0 hardness of 350 to 750, tensile strength @ break 10 to 45

MPa, tensile elongation in range of 200 to 375%, compression set 5 to 30%, tear strength 80 to 100 Nlmm. Polymeric materials can also be blended with fillers such as carbon fibers, carbon nanotubes, glass microsphere, silica, etc., to obtain the desired properties of a mouth guard.

**[0264]** The invention relates to oral or nasal or a combination of oral and nasal sleep apnea diagnostic device as Home Sleep Testing (HST) device for the diagnosis of obstructive sleep apnea (OSA) and snoring; having micro-processors and sensors, comprising of following configurations: 1) Basic HST unit for standard OSA testing. This configuration without mandibular advancement (MAD) can be provided with upper mouth piece only (i.e. without the lower mouth piece) or with lower mouth piece only (i.e. without the upper mouth piece); 2) HST unit with mandibular advancement (MAD)—this is to validate specific mandibular advancement setting and treatment of sleep apnea with or without innovative oral CPAP sleep apnea device or current CPAP device; 3) HST unit to be used in conjunction with current CPAP for determining the efficacy of a pressure setting; 4) HST device as sleep apnea diagnostic as well as treatment device: In addition to device performing as diagnostic tool (as Home Sleep Testing (HST) or Out of center Sleep Testing (OOCST) for detecting OSA, the same device can also be used as sleep apnea treatment and/or anti-snoring device.

**[0265]** The device can be fitted with a mix of sensors to measure air flow; SpO<sub>2</sub> (oxygen saturation in blood), heart rate (beats/min) and respiratory effort. These parameters would be sufficient to perform a sleep study conforming to the guidelines by CMS or AASM for a Type III or Type iV study. Additional sensors can be included to measure temperature; body positions while at sleep, Sound (breathing) variation and snoring, Single channel ECG (heart), EEG for brain activity etc. Actual sleep time is not measured by current HST devices while in one embodiment the device can have built-in sensors or wirelessly communicating sensors like heart rate, breathing monitoring, position sensor for body movement during sleep, temperature along with proprietary algorithm helps in measuring actual (true) sleep time which is very important for accurate (true) AHI number, a measure of severity of sleep apnea.

**[0266]** In one embodiment, the device would be fitted with a differential pressure sensor to measure airflow and pressure (or alternately with a PVDF calibrated strip), a novel pulse ox sensor from lips for oxygen saturation and heart rate (alternately could be a standard pulse oximeter with Bluetooth capability), and a photo phlethysmo graphic (PPG) sensor to measure respiratory effort (alternately could be a standard RIP belt to acquire the same parameter).

**[0267]** All these parameters can be continuously acquired and stored on a memory SD card built into the unit (device) or wirelessly transferred using Bluetooth, wifi, cloud or other similar technologies to a mobile device or to cloud based server. This data can then be analyzed by automated computer algorithms for episodes of breathing irregularities while sleeping—such as apneic or hypopneic events and summarized to provide AHI/ROI information. The ROI is defined as the average number of respiratory disturbances. The device can be controlled wirelessly using mobile devices.

**[0268]** In another embodiment, the device can be enhanced by addition of sound sensor to measure breathing patterns and snoring variation, thermistor for temperature of

air flow and breathing pattern, miniature video camera mounted on the mouthguard to take pictures of inside of mouth during sleep and a processing unit to capture and analyze these parameters to provide a far more comprehensive sleep study report compared to a Type III or Type IV HST device.

**[0269]** Both of above embodiments can be adapted to validate Mandibular Adjustment (MAD) setting by providing oral component with mandibular adjustments (lower jaw advancement) in specific fine increments. Also, the device of present invention can be concurrently used with CPAP and validate efficacy of pressure setting for the CPAP treatment.

**[0270]** The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the embodiments is described above as having certain features, any one or more of those features described with respect to any embodiment of the disclosure can be implemented in and/or combined with features of any of the other embodiments, even if that combination is not explicitly described. In other words, the described embodiments are not mutually exclusive, and permutations of one or more embodiments with one another remain within the scope of this disclosure.

**[0271]** Spatial and functional relationships between elements (for example, between modules) are described using various terms, including “connected,” “engaged,” “interfaced,” and “coupled.” Unless explicitly described as being “direct,” when a relationship between first and second elements is described in the above disclosure, that relationship encompasses a direct relationship where no other intervening elements are present between the first and second elements, and also an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”

**[0272]** In the figures, the direction of an arrow, as indicated by the arrowhead, generally demonstrates the flow of information (such as data or instructions) that is of interest to the illustration. For example, when element A and element B exchange a variety of information but information transmitted from element A to element B is relevant to the illustration, the arrow may point from element A to element B. This unidirectional arrow does not imply that no other information is transmitted from element B to element A. Further, for information sent from element A to element B, element B may send requests for, or receipt acknowledgements of, the information to element A.

**[0273]** In this application, including the definitions below, the term ‘module’ or the term ‘controller’ may be replaced with the term ‘circuit.’ The term ‘module’ may refer to, be part of, or include processor hardware (shared, dedicated, or

group) that executes code and memory hardware (shared, dedicated, or group) that stores code executed by the processor hardware.

**[0274]** The module may include one or more interface circuits. In some examples, the interface circuits may include wired or wireless interfaces that are connected to a local area network (LAN), the Internet, a wide area network (WAN), or combinations thereof. The functionality of any given module of the present disclosure may be distributed among multiple modules that are connected via interface circuits. For example, multiple modules may allow load balancing. In a further example, a server (also known as remote, or cloud) module may accomplish some functionality on behalf of a client module.

**[0275]** The term code, as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, data structures, and/or objects. Shared processor hardware encompasses a single microprocessor that executes some or all code from multiple modules. Group processor hardware encompasses a microprocessor that, in combination with additional microprocessors, executes some or all code from one or more modules. References to multiple microprocessors encompass multiple microprocessors on discrete dies, multiple microprocessors on a single die, multiple cores of a single microprocessor, multiple threads of a single microprocessor, or a combination of the above.

**[0276]** Shared memory hardware encompasses a single memory device that stores some or all code from multiple modules. Group memory hardware encompasses a memory device that, in combination with other memory devices, stores some or all code from one or more modules.

**[0277]** The term memory hardware is a subset of the term computer-readable medium. The term computer-readable medium, as used herein, does not encompass transitory electrical or electromagnetic signals propagating through a medium (such as on a carrier wave); the term computer-readable medium is therefore considered tangible and non-transitory. Non-limiting examples of a non-transitory computer-readable medium are nonvolatile memory devices (such as a flash memory device, an erasable programmable read-only memory device, or a mask read-only memory device), volatile memory devices (such as a static random access memory device or a dynamic random access memory device), magnetic storage media (such as an analog or digital magnetictape or a hard disk drive), and optical storage media (such as a CD, a DVD, or a Blu-ray Disc).

**[0278]** The apparatuses and methods described in this application may be partially or fully implemented by a special purpose computer created by configuring a general purpose computer to execute one or more particular functions embodied in computer programs. The functional blocks and flowchart elements described above serve as software specifications, which can be translated into the computer programs by the routine work of a skilled technician or programmer.

**[0279]** The computer programs include processor-executable instructions that are stored on at least one non-transitory computer-readable medium. The computer programs may also include or rely on stored data. The computer programs may encompass a basic input/output system (BIOS) that interacts with hardware of the special purpose computer, device drivers that interact with particular devices of the

special purpose computer, one or more operating systems, user applications, background services, background applications, etc.

**[0280]** The computer programs may include: (i) descriptive text to be parsed, such as HTML (hypertext markup language), XML (extensible markup language), or JSON (JavaScript Object Notation) (ii) assembly code, (iii) object code generated from source code by a compiler, (iv) source code for execution by an interpreter, (v) source code for compilation and execution by a just-in-time compiler, etc. As examples only, source code may be written using syntax from languages including C, C++, C#, Objective-C, Swift, Haskell, Go, SOL, R, Lisp, Java®, Fortran, Perl, Pascal, Curl, OCaml, Javascript®, HTML5 (Hypertext Markup Language 5th revision), Ada, ASP (Active Server Pages), PHP (PHP: Hypertext Preprocessor), Scala, Eiffel, Smalltalk, Erlang, Ruby, Flash®, Visual Basic®, Lua, MATLAB, SIMULINK, and Python®.

**[0281]** None of the elements recited in the claims are intended to be a means plus-function element within the meaning of 35 U.S.C. § 112(f) unless an element is expressly recited using the phrase “means for” or, in the case of a method claim, using the phrases “operation for” or “step for.”

**[0282]** Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

**[0283]** The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

**[0284]** When an element or layer is referred to as being “on,” “engaged to,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like

fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

**[0285]** Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

**[0286]** Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

**[0287]** In the foregoing description, the teachings have been described with reference to specific exemplary embodiments thereof. It will be apparent to those skilled in the art that a person understanding these teachings may conceive of changes or other embodiments or variations, which utilize the principles of this teachings without departing from the broader spirit and scope of the teachings. The specification and drawings are, therefore, to be regarded in an illustrative rather than a restrictive sense.

What is claim is:

1. A detachable oral sleep treatment device selectively engageable with a patient’s lips and teeth, said oral sleep treatment device comprising:

a front hollow housing defining a first through passage defining an inlet aperture and an output aperture, said front hollow housing having an exterior surface configured to engage the patient’s lips the front hollow housing having a first detachable locking interface adjacent the output aperture;

an air flow generating device disposed within the first through passage, the generating device configured to create an airflow from the inlet aperture through the output aperture the air flow generating device comprises a controller configured to regulate electrical power supplied to the generating device and a battery disposed within the front hollow housing, said battery being electrically coupled to the airflow generating device and the controller;

a mouthpiece defining first mouthpiece aperture selectively coupled to the front housing, the mouthpiece having first and second curved members together defining a u-shape and having an exterior surface defining a

- tooth engaging surface, said first and second members defining second and third through passages, said first and second rear mouthpiece apertures disposed adjacent to the retromolar pad members when said mouthpiece is engaged with the patient's teeth; and
- a vibrational isolating member disposed between air flow generating device located in the front hollow housing to reduce the vibration transmission into the mouthpiece, wherein the vibrational isolating member reduces the noise transmission to mouthpiece which in turn prevents the bone conduction noise through teeth trays in an inner ear canal.
2. The device of claim 1 wherein the first mouthpiece is configured to engage one of the upper teeth or lower teeth.
3. The device of claim 1 wherein the mouthpiece second and third through passages are defined at one of underneath and side/surrounding the upper teeth tray.
4. The device of claim 1 wherein the mouthpiece is selected from the group consisting of a detachable-customized mouthpiece an upper teeth tray 3D printed from a material having a first durometer, an upper teeth tray made from soft material which is thermoformed and adhesively bonded to hard 3D printed air passageway, an upper teeth tray made from boil and bite material bonded to hard 3D printed air passageway to create pre-customized upper mouthpiece defining the first and second rear mouthpiece apertures.
5. The device of claim 1 wherein the mouthpiece is attached to lower teeth tray.
6. The device of claim 1 comprising a Mandibular Advancement Devices configured to bring lower jaw forward to further reduce sleep apnea.
7. The device of claim 1 comprising hinge style sleep apnea device comprising an upper teeth tray and a lower teeth tray formed of a single plastics piece bonded to air passageway of the mouthpiece
9. A detachable oral sleep treatment device selectively engageable with a patient's lips and teeth, said oral sleep treatment device comprising:
- a front hollow housing defining a first through passage defining an inlet aperture and an output aperture, said front hollow housing having an exterior surface configured to engage the patient's lips the front hollow housing having a first detachable locking interface adjacent the output aperture;
- an air flow generating device disposed within the first through passage, the generating device configured to create an airflow from the inlet aperture through the output aperture the air flow generating device comprises a controller configured to regulate electrical power supplied to the generating device and a battery disposed within the front hollow housing, said battery being electrically coupled to the airflow generating device and the controller,
- a mouthpiece defining first mouthpiece aperture selectively coupled to the front housing, the mouthpiece having first and second curved members together defining a u-shape and having an exterior surface defining a tooth engaging surface, said first and second members defining second and third through passages, said first and second rear mouthpiece apertures disposed adjacent to the retromolar pad members when said mouthpiece is engaged with the patient's teeth; and
- a first vibrational isolating member disposed between the air flow generating device from the front hollow housing to reduce the vibration transmission into the mouthpiece.
10. The device of claim 9 further comprising a second vibrational isolating member disposed between the surfaces of the front housing and the mouthpiece to prevent direct contact of the front housing and the mouthpiece, wherein the front housing is made of a first material having a first durometer and the second vibrational isolating member is made of a second material having a second durometer different than the first durometer.
11. The device of claim 10 wherein the mouthpiece is selected from the group consisting of a detachable-customized mouthpiece containing an upper teeth tray 3D printed from a material having a first durometer, an upper teeth tray made from soft material which is thermoformed and adhesively bonded to hard 3D printed air passage way, an upper teeth tray made from boil and bite material bonded to hard 3D printed air passageway; to create pre-customized upper mouthpiece defining the first and second rear mouthpiece apertures.
13. The device of claim 10 wherein an air flow generating device produces a first air flow rate during inhalation and a second air flow rate during exhalation, creating an expiratory positive airway pressure, maintaining pressure in the airway through the start of the next inhalation.
14. The device of claim 10 wherein the first detachable locking interface is selected from the group comprising a cantilever snap joint where the load here is mainly flexural, u-shaped snap joints where a variation of the cantilever type, Torsion snap joints where Shear stresses carry the load, and annular snap joints where they are rotationally symmetrical and involve multiaxial stresses.
15. The device of claim 10 wherein the first detachable locking interface has a snap fit flexible arm that has a decreasing cross-sectional area that decreases linearly up to 30% of a original cross-sectional area.
16. The device of claim 15 wherein strain in an outer portion of the flexible arm is uniform throughout the length of the flexible arm and wherein the width of the flexible arm is between 3 mm to 15 mm, preferably 10 mm, having a length between 3 mm to 12 mm, the ratio of flexible arm and a thickness of flexible beam arm between 0.5 mm to 3.0 mm.
17. The device of claim 9 wherein the first detachable locking interface links the housing and mouthpiece together by flexible, semi-solid plastics elastomeric linkages which is held by a plurality of buttons on sides of the housing and mouthpiece.
18. The device of claim 17 is detached by un-linking the flexible, semi-solid linkages from buttons located on both pieces by flanges.
19. The device of claim 9 wherein said second and third passages having a non-circular cross section which decreases in cross sectional area from the first mouthpiece aperture to first and second rear mouthpiece apertures, that are configured to increase the pressure and air velocity of air passing from the front hollow housing through the second and third passages,

20. The device of claim 1 further comprising a flexible isolator member disposed between the housing and the mouthpiece to dampen noise transmission to mouthpiece, the flexible isolator being made from a material selected from a seal comprising two shot molding, single or two material 3D printing, injection molding, over molding.

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