METHOD, APPARATUS, AND SYSTEM FOR EXPRESSION AND QUANTIFICATION OF HUMAN BREAST MILK

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ABSTRACT

Disclosed herein are devices, systems, and methods for the expression and collection of breast milk. A device in accordance with embodiments comprises an actutable assembly and a breast interface configured to engage a breast and fluidly seal thereagainst. The breast interface comprises a movable member disposed within at least a portion of the breast interface. The device further comprises a tensile element operatively coupling the actutable assembly to the movable member. Actuation of the actutable assembly applies a tensile force to the tensile element, and the tensile element transmits the tensile force to the movable member to move the movable member away from the breast, thereby applying negative pressure to the breast to express milk therefrom.
FIG. 1
Avg. Wolfe: 4 OZ Avg. Duration: 23 min

FIG. 10

FIG. 11
FIG. 14

Pump Performance

mmHg Generated

mmHg Generated

FIG. 14
FIG. 15

mmHg per cc of push

-1.7

-71.1
METHOD, APPARATUS, AND SYSTEM FOR EXPRESSION AND QUANTIFICATION OF HUMAN BREAST MILK

CROSS-REFERENCE


BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention generally relates to medical devices and methods, and more particularly relates to devices and methods for expression and collection of human breast milk.

[0004] The exemplary embodiments disclosed herein are preferably directed at expression of breast milk, but one of skill in the art will appreciate that this is not intended to be limiting and that the devices, systems and methods disclosed herein may be used for other treatments requiring application of a differential pressure.

[0005] Breast pumps are commonly used to collect breast milk in order to allow mothers to continue breastfeeding while apart from their children. Currently, there are two primary types of breast pumps: manually-actuated devices, which are small, but inefficient and tiring to use; and electrically-powered devices, which are efficient, but large and bulky. Therefore, it would be desirable to provide improved breast pumps that are small and highly efficient for expression and collection of breast milk. Additional features such as milk production quantification and communication with mobile devices are further desirable for enhanced user convenience. At least some of these objectives will be satisfied by the devices and methods disclosed below.

[0006] 2. Description of the Background Art

[0007] The following US patents are related to expression and collection of human breast milk: U.S. Pat. Nos.: 6,673,036; 6,749,582; 6,840,918; 6,887,210; 7,875,000; 8,118,772; and 8,216,179.

SUMMARY OF THE INVENTION

[0008] The present invention generally relates to medical devices and methods, and more particularly relates to devices and methods for expression and collection of human breast milk.

[0009] In one aspect, a device for expression and collection of breast milk comprises an actuatable assembly and a breast interface configured to engage a breast and fluidly seal thereagainst. The breast interface comprises a movable member disposed within at least a portion thereof. The device further comprises a tensile element operatively coupling the actuatable assembly to the movable member, wherein the tensile element is disposed within an axial load absorbing member. Actuation of the actuatable assembly applies a tensile force to the tensile element, wherein the tensile element transmits the tensile force to the movable member to move the movable member away from the breast, thereby applying negative pressure to the breast to express milk therefrom. The axial load absorbing member may be axially stiff to absorb reactive forces of the tensile element during application of the tensile force to the tensile element.

[0010] The tensile element may extend continuously between the movable member and the actuatable assembly. The tensile element may comprise a cable, wire, or rope.

[0011] The axial load absorbing member may comprise a tube or coil having an axially stiff geometry to absorb the reactive forces of the tensile element.

[0012] The device may further comprise a tube extending between the breast interface and the actuatable assembly, wherein the tensile element and the axial load absorbing member may be disposed within the tube. The tensile element may be concentrically disposed within the axial load absorbing member, and the axial load absorbing member may be concentrically disposed within the tube.

[0013] The breast interface may further comprise an interface housing having the movable member disposed therein, and the actuatable assembly may further comprise a driving element and an assembly housing having the driving element disposed therein. The tensile element may comprise a first end coupled to the movable member and a second end opposite the first end and coupled to the driving element. The axial load absorbing member may comprise a first end coupled to the interface housing and a second end opposite the first end and coupled to the assembly housing.

[0014] The device may further comprise a driving mechanism releasably coupled with the actuatable assembly, and the actuatable assembly may comprise a driving element. Actuation of the driving mechanism may displace the driving element from a rest position to move the movable member away from the breast, or may replace the driving element to the rest position to move the movable member toward the breast.

[0015] The movable member may comprise a deformable member configured to fluidly seal against the breast. The movable member may comprise a flexible membrane. The flexible membrane may comprise a corrugated region configured to expand and collapse.

[0016] In another aspect, a device for expression and collection of breast milk comprises an actuatable assembly and a breast interface configured to engage a breast and fluidly seal thereagainst. The breast interface comprising a movable member disposed within at least a portion thereof. The device further comprises a tensile element operatively coupling the actuatable assembly to the movable member, the tensile element extending continuously between the movable member and the actuatable assembly. Actuation of the actuatable assembly applies a tensile force to the tensile element, and the tensile element transmits the tensile force to the movable member to move the movable member away from the breast, thereby applying negative pressure to the breast to express milk therefrom.

[0017] The tensile element may comprise a cable, wire, or rope.

[0018] The device may further comprise an axial load absorbing member, and the tensile element may be disposed within the axial load absorbing member that is axially stiff to absorb reactive forces of the tensile element during application of the tensile force to the tensile element. The axial load absorbing member may comprise a tube or coil having an axially stiff geometry to absorb the reactive forces of the tensile element. The device may further comprise a
tube extending between the breast interface and the actuatable assembly, wherein the tensile element and the axial load absorbing member are disposed within the tube. The tensile element may be concentrically disposed within the axial load absorbing member, and the axial load absorbing member may be concentrically disposed within the tube.

[0019] The breast interface may further comprise an interface housing having the movable member disposed therein, and the actuatable assembly may further comprise a driving element and an assembly housing having the driving element disposed therein. The tensile element may comprise a first end coupled to the movable member and a second end opposite the first end and coupled to the driving element. The axial load absorbing member may comprise a first end coupled to the interface housing and a second end opposite the first end and coupled to the assembly housing.

[0020] The device may further comprise a driving mechanism releasably coupled with the actuatable assembly, wherein the actuatable assembly may comprise a driving element. Actuation of the driving mechanism may displace the driving element from a rest position to move the movable member away from the breast, or replace the driving element to the rest position to move the movable member toward the breast.

[0021] The movable member may comprise a deformable member. The movable member may comprise a flexible membrane. The flexible membrane may comprise a corrugated region configured to expand and collapse.

[0022] Other objects and features of the present invention will become apparent by a review of the specification, claims, and appended figures.

INCORPORATION BY REFERENCE

[0023] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0025] FIG. 1 is a perspective view of an exemplary embodiment of a pumping device.

[0026] FIG. 2 is a perspective view of an exemplary embodiment of a pumping device.

[0027] FIG. 3 is a cross-section of an exemplary embodiment of a pumping device.

[0028] FIG. 4 illustrates an exemplary embodiment of an actuable assembly coupled to a driving mechanism.

[0029] FIGS. 5A-5B illustrate an exemplary embodiment of an actueurable assembly coupled to a pendant unit.

[0030] FIG. 6 is a cross-sectional view of an exemplary embodiment of a breast interface.

[0031] FIG. 7 is a cross-sectional view of another exemplary embodiment of a breast interface.

[0032] FIG. 8A is a cross-sectional view of an exemplary embodiment of an integrated valve in an open position.

[0033] FIG. 8B is a cross-sectional view of an exemplary embodiment of an integrated valve in a closed position.

[0034] FIG. 9A is a cross-sectional view of an exemplary embodiment of integrated sensors within a breast interface.

[0035] FIG. 9B is a cross-sectional view of another exemplary embodiment of integrated sensors within a breast interface.

[0036] FIG. 10 illustrates an exemplary embodiment of a pendant unit and a mobile device.

[0037] FIG. 11 illustrates an exemplary embodiment of a pendant unit in communication with a mobile device.

[0038] FIG. 12 is a cross-sectional view of an exemplary embodiment of a breast interface with a mechanical deformable member.

[0039] FIG. 13 is a cross-sectional view of an exemplary embodiment of a mechanical driver for a mechanical deformable member.

[0040] FIG. 14 is a graph illustrating the pump performance of an exemplary embodiment compared to a commercial device.

[0041] FIG. 15 is a graph illustrating the pumping efficiency of an exemplary embodiment compared to a commercial device.

DETAILED DESCRIPTION OF THE INVENTION

[0042] Specific embodiments of the disclosed devices and methods will now be described with reference to the drawings. Nothing in this detailed description is intended to imply that any particular component, feature, or step is essential to the invention. One of skill in the art will appreciate that various features or steps may be substituted or combined with one another.

[0043] The present invention will be described in relation to the expression and collection of breast milk. However, one of skill in the art will appreciate that this is not intended to be limiting, and the devices and methods disclosed herein may be used in other applications involving the creation and transmission of a pressure differential, such as in the treatment of sleep apnea and/or other remote pressure needs.

[0044] FIG. 1 illustrates an exemplary embodiment of the present invention. Pumping device 100 includes breast interfaces 105, a tube 110, and a controller or pendant unit 115 operatively coupled to breast interfaces 105 through tube 110. Breast interfaces 105 include resilient and conformable flanges 120, for engaging and creating a fluid seal against the breasts, and collection vessels 125. The device may optionally only have a single breast interface. Pendant unit 115 houses the power source and drive mechanism for pumping device 100, and also contains hardware for various functions, such as controlling pumping device 100, milk production quantification, and communication with other devices. Tube 110 transmits suitable energy inputs, such as mechanical energy inputs, from pendant unit 115 over a long distance to breast interfaces 105. Breast interfaces 105 convert the energy inputs into vacuum pressure against the breasts in a highly efficient manner, resulting in the expression of milk into collection vessels 125.

[0045] One of skill in the art will appreciate that components and features of this exemplary embodiment can be combined or substituted with components and features of any of the embodiments of the present invention as
described below. Similarly, components and features of other embodiments disclosed herein may be substituted or combined with one another.

[0046] Hydraulic Pumping Device

[0047] Hydraulic systems can reduce pumping force requirements, and therefore also reduce the size of the pumping device, while maintaining high pumping efficiency. In a preferred embodiment, the pumping device can utilize a hydraulic or pneumatic pumping device to generate a pressure differential against the breast for the expression and collection of milk.

[0048] Exemplary hydraulic pumping devices are depicted in FIGS. 2 and 3. FIG. 2 illustrates a pumping device 150 with a syringe 155 fluidly coupled to breast interface 160 by tube 165. Syringe 155 is coupled to tube 165 through a three-way valve 170. Breast interface 160 contains an exit port 175. The syringe 155 drives a fluid 180 contained within tube 165 against or away from a flexible member contained within breast interface 160 to create the pressure differential necessary for milk expression from the breast.

[0049] FIG. 3 illustrates another embodiment of a pumping device 200. The actuable assembly 205 includes an assembly housing 210, a driving element 215, radial seals 220, and a shaft 222. Driving element 215 is operatively coupled to a pendant unit, such as pendant unit 115, through shaft 222. The tube 225 contains a fluid 230 and is fluidly coupled to the actuable assembly 205 and the breast interface 235. The breast interface 235 consists of an interface housing 240, a flexible membrane 245, a reservoir 250, a sealing element 255, an expression area 260, and a drain port 265. The sealing element 255 includes deformable portion 270. The drain port 265 is coupled to a collection vessel 275 and includes a flap valve 280.

[0050] Actuable assembly 205 displaces fluid 230 contained within tube 225, which can be a flexible line. Fluid 230 occupies reservoir 250 within breast interface 235 and is coupled with flexible membrane 245. Flexible membrane 245 transmits vacuum pressure from fluid 230 to the deformable portion 270 of sealing element 255. When a breast is engaged into and fluidly sealed with breast interface 235 by sealing element 255, displacement of the actuable element 215 produces substantial vacuum pressure against the breast through flexible membrane 245 and deformable portion 270, resulting in the expression of breast milk into expression area 260. The expressed milk drains through drain port 265 into collection vessel 275. Drain port 265 is configured with a flap valve 280 to provide passage of milk while maintaining vacuum pressure in expression area 260.

[0051] The fluid for the hydraulic pumping device can be any suitable fluid, such as an incompressible fluid. In many embodiments, the incompressible fluid can be water or oil. Alternatively, the fluid can be any suitable gas, such as air. Suitable incompressible fluids and gases for hydraulic systems are known to those of skill in the art.

[0052] One of skill in the art will appreciate that components and features of any of the exemplary embodiments of the hydraulic pumping device can be combined or substituted with components and features of any of the embodiments of the present invention as described herein.

[0053] Actuation Mechanism

[0054] Many actuation mechanisms known to those of skill in the art can be utilized for the actuable assembly 205. Actuable assembly 205 can be a piston assembly, a pump such as a diaphragm pump, or any other suitable actuation mechanism. The optimal configuration for actuable assembly 205 depend on a number of factors, such as: vacuum requirements; size, power, and other needs of the pumping device 200; and the properties of the fluid 230, such as viscosity, biocompatibility, and fluid life requirements.

[0055] FIG. 3 illustrates an exemplary embodiment in which actuable assembly 205 is a piston assembly and driving element 215 is a piston. Actuable assembly 205 includes radial seals 220, such as O-rings, sealing against assembly housing 210 to prevent undesired egress of fluid 230 and to enable driving of fluid 230.

[0056] FIG. 4 illustrates another exemplary embodiment of an actuable assembly 300 including a pair of pistons 305.

[0057] In preferred embodiments, the actuable assembly includes a driving element powered by a suitable driving mechanism, such as a driving mechanism residing in pendant unit 115. Many driving mechanisms are known to those of skill in the art. For instance, the driving element, such as driving element 215, may be actuated electromechanically by a motor, or manually by a suitable user-operated interface, such as a lever. Various drive modalities known to those of skill in the art can be used. In particular, implementation of the exemplary hydraulic pumping devices as described herein enables the use of suitable drive modalities such as direct drive and solenoids, owing to the reduced force requirements of hydraulic systems.

[0058] Referring now to the exemplary embodiment of FIG. 4, the pistons 305 include couplings 310 to a crankshaft 315. The crankshaft 315 is operatively coupled to a motor 320 through a belt drive 325. The crankshaft 315 drives the pair of pistons 305 with the same stroke timing in order to apply vacuum pressure against both breasts simultaneously, a feature desirable for increased milk production. Alternatively, the crankshaft 315 can drive the pair of pistons 305 with any suitable stroke timing, such as alternating or offset stroke cycles.

[0059] The driving mechanism can be powered by any suitable power source, such as a local battery or an AC adaptor. The driving mechanism can be controlled by hardware, such as onboard electronics located within pendant unit 115.

[0060] FIG. 5 illustrates an exemplary embodiment of an actuable assembly 350 that includes releasable coupling 355. Preferably, actuable assembly 350 is releasably coupled to a pendant unit 360 and the driving mechanism housed therein. The coupling can be a mechanical coupling or any suitable quick release mechanism known to those of skill in the art. The releasable coupling mechanism allows for flexibility in the configuration and use of the pumping device. For instance, user comfort can be improved through the use of differently sized breast interfaces for compatibility with various breast sizes. Additionally, this feature enables a common pumping device to be used with interchangeable breast interfaces, thus reducing the risk of spreading pathogens. Furthermore, the releasable coupling enables easy replacement of individual parts of the pumping device.

[0061] One of skill in the art will appreciate that components and features of any of the exemplary embodiments of the actuation mechanism can be combined or substituted with components and features of any of the embodiments of the present invention as described herein.
Flexible Membrane

In many embodiments such as the embodiment depicted in FIG. 3, the flexible membrane 245 is located within breast interface 235 and disposed over at least portion thereof, forming reservoir 250 between the interface housing 240 and the flexible membrane 245. Preferably, the flexible membrane 245 deforms substantially when subject to the negative pressures created when the fluid 230 is displaced from reservoir 250 by actuated assembly 205. The amount of deformation of the flexible membrane 245 can be controlled by many factors, (e.g., wall thickness, diometer, surface area) and can be optimized based on the pumping device (e.g., pump power, vacuum requirements).

FIG. 6 illustrates an exemplary flexible membrane 370 with a specified thickness and diometer.

FIG. 7 illustrates another embodiment of flexible membrane 375 with corrugated features 380 for increased surface area.

Suitable materials for the flexible membrane are known to those of skill in the art. In many embodiments, the flexible membrane can be made of a material designed to expand and contract when subject to pressures from the coupling fluid such as silicone, polyether block amidates such as PEBAX, and polychloroprenes such as neoprene. Alternatively, the flexible membrane can be fabricated from a substantially rigid material, such as stainless steel, nitinol, high diometer polymer, or high diometer elastomer. In these embodiments, the rigid material would be designed with stress and/or strain distribution elements to enable the substantial deformation of the flexible membrane without surpassing the yield point of the material.

FIGS. 8A and 8B illustrate preferred embodiments of a breast interface 400 in which an exit valve 405 is integrated into the flexible membrane 410 to control the flow of expressed milk through exit port 415. The exit valve 405 is opened to allow fluid flow when the flexible membrane 410 is relaxed, as shown in FIG. 8A, and is closed to prevent fluid flow when the flexible membrane 410 is deformed, as shown in FIG. 8B. The exit valve 405 enables substantial vacuum pressure to be present in pressure area 420 during extraction, while allowing milk to drain during the rest phase of the pump stroke. While many conventional breast pump valves function on pressure differentials alone, the exit valve 405 can preferably be configured to also function on the mechanical movement of flexible membrane 410. Incorporation of an integrated exit valve 405 with mechanical functionality as described herein can improve the sealing of the breast interface 400 during vacuum creation. Furthermore, the implementation of an exit valve integrated with the flexible membrane 410 such as exit valve 405 reduces the number of parts to be cleaned.

Milk Collection and Quantification System

With reference to FIG. 3, expressed milk drains through exit port 265 in flexible membrane 245 into a collection vessel 275. Collection vessel 275 can be any suitable container, such as a bottle or a bag. In many embodiments, collection vessel 275 is removably coupled to flexible membrane 245. Collection vessel 275 can be coupled directly or remotely via any suitable device such as extension tubing.

In many instances, it can be desirable to track various data related to milk expression and collection, such as the amount of milk production. Currently, the tracking of milk production is commonly accomplished by manual measurements and record-keeping. Exemplary embodiments of the device described herein may provide digital-based means to automatically measure and track milk production for improved convenience, efficiency, and accuracy.

FIGS. 9A and 9B illustrate exemplary embodiments of a breast interface 450 with one or more integrated sensors 455. Sensors 455 are preferably located in the vessel 460, but may also be located in exit valve 465, or any other suitable location for monitoring fluid flow. In a preferred embodiment, at least one sensor 455 is integrated into a valve that is opened by fluid flow and detects the length of time that the valve is opened. The sensor signal can be interrogated to quantify the fluid flow. Suitable sensors are known to those of skill in the art, such as accelerometers, hall effect sensors, and photodiode/LED sensors. The breast interface can include a single sensor or multiple sensors to quantify milk production.

FIG. 10 illustrates an exemplary embodiment of pendant unit 500 in which milk expression data is shown on a display screen 505. In many embodiments, the pendant unit 500 collects, processes, stores, and displays data related to milk expression. Preferably, the pendant unit 500 can transmit the data to a second device, such as a mobile phone 510.

FIG. 11 illustrates data transmission 515 between pendant unit 500 and a mobile phone 510. Suitable methods for communication and data transmission between devices are known to those of skill in the art, such as Bluetooth or near field communication.

In exemplary embodiments, the pendant unit 500 communicates with a mobile phone 510 to transmit milk expression data, such as expression volume, duration, and date. The mobile phone 510 includes a mobile application to collect and aggregate the expression data and display it in an interactive format. Preferably, the mobile application includes additional features that allow the user to overlay information such as lifestyle choices, diet, and strategies for increasing milk production, in order to facilitate the comparison of such information with milk production statistics. Additionally, the pendant unit 500 can send information about the times of pump usage to the mobile phone 510 so that the mobile application can identify when pumping has occurred and set reminders at desired pumping times. Such reminders can help avoid missed pumping sessions, and thus reduce the incidence of associated complications such as mastitis.

One of skill in the art will appreciate that components and features of any of the exemplary embodiments of the milk collection and quantification system can be combined or substituted with components and features of any of the embodiments of the present invention as described herein.

Mechanical Pumping Device

FIG. 12 illustrates an alternative embodiment of a breast interface 600 in which a mechanical deformable member 605 can be used in place of a flexible membrane. The mechanical deformable member 605 can be constructed from similar techniques as those used for the flexible membrane as described herein. The mechanical deformable member 605 is coupled to a tensile element 610. In some instances, tensile element 610 is disposed within an axial load absorbing member 615. The axial load absorbing member 615 is disposed within tube 620. Preferably, tensile element 610 is concentrically disposed within axial load...
absorbing member 615 and axial load absorbing member 615 is concentrically disposed within tube 620. Alternative arrangements of tensile element 610, axial load absorbing member 615, and tube 620 can also be used.

[0078] FIG. 13 illustrates the tensile element 610 coupled to driving element 625 of an actuatable assembly 630 within an assembly housing 635. Driving element 625 is operatively coupled to a driving mechanism, such as a driving mechanism housed within a pendant unit, through shaft 640. Axial load absorbing member 615 within tube 620 is fixedly coupled to the assembly housing 635. Displacement of the driving element 625 transmits tensile force through tensile element 610 to the mechanical deforming member 605 to create vacuum pressure against the breast.

[0079] The tensile element 610 can be any suitable device, such as a wire, coil, or rope, and can be made from any suitable material, such as metals, polymers, or elastomers. Axial load absorbing member 615 can be made from any suitable axially stiff materials, such as metals or polymers, and can be configured into any suitable axially stiff geometry, such as a tube or coil.

[0080] One of skill in the art will appreciate that components and features of any of the exemplary embodiments of the mechanical pumping device can be combined or substituted with components and features of any of the embodiments of the present invention as described herein.

[0081] Experimental Data

[0082] FIGS. 14 and 15 illustrate experimental pumping data obtained from a commercial breast pump device and an exemplary embodiment of the present invention. The exemplary embodiment utilized an incompressible fluid for pumping and had a maximum hydraulic fluid volume of 4 cc, while the commercial device utilized air for pumping and had a maximum volume of 114 cc.

[0083] FIG. 14 illustrates a graph of the pump performance as quantified by vacuum pressure generated per run. For the exemplary embodiment, pressure measurements were taken for 1 cc, 2 cc, 3 cc, and 4 cc of fluid volume displaced by the pump, with the run number corresponding to the volume in cc. For the commercial device, measurements were taken with the pump set to one of seven equally incremented positions along the vacuum adjustment gauge representing 46 cc, 57 cc, 68 cc, 80 cc, 91 cc, 103 cc, and 114 cc of fluid volume displaced by the pump, respectively, with the run number corresponding to the position number. Curve 700 corresponds to the exemplary embodiment and curve 705 corresponds to the commercial device. The exemplary embodiment generated a higher level of vacuum pressure per displacement volume compared to the commercial device, with maximum vacuum pressures of ~240.5 mmHg and ~177.9 mmHg, respectively.

[0084] FIG. 15 illustrates a graph of the pump efficiency as measured by the maximum vacuum pressure per maximum volume of fluid displaced, with bar 710 corresponding to the exemplary embodiment and bar 715 corresponding to the commercial device. The exemplary embodiment demonstrated a 42-fold increase in pumping efficiency compared to the commercial device, with efficiencies of ~71.1 mmHg/cc and ~1.7 mmHg/cc, respectively.

[0085] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

What is claimed is:

1. A device for expression and collection of breast milk, said device comprising:
   a breast interface configured to engage a breast and fluidly seal thereagainst, the breast interface comprising a movable member disposed within at least a portion thereof; and
   a tensile element operatively coupling the actuatable assembly to the movable member, wherein the tensile element is disposed within an axial load absorbing member,
   wherein actuation of the actuatable assembly applies a tensile force to the tensile element, and wherein the tensile element transmits the tensile force to the movable member to move the movable member away from the breast, thereby applying negative pressure to the breast to express milk therefrom.

2. The device of claim 1, wherein the tensile element extends continuously between the movable member and the actuatable assembly.

3. The device of claim 1, wherein the tensile element comprises a cable, wire, or rope.

4. The device of claim 1, wherein the axial load absorbing member comprises a tube or coil having an axially stiff geometry to absorb the reactive forces of the tensile element.

5. The device of claim 1, wherein the device further comprises a tube extending between the breast interface and the actuatable assembly, and wherein the tensile element and the axial load absorbing member are disposed within the tube.

6. The device of claim 5, wherein the tensile element is concentrically disposed within the axial load absorbing member, and wherein the axial load absorbing member is concentrically disposed within the tube.

7. The device of claim 1, wherein the breast interface further comprises an interface housing having the movable member disposed therein, and the actuatable assembly further comprises a driving element and an assembly housing having the driving element disposed therein, wherein the tensile element comprises a first end coupled to the movable member and a second end opposite the first end and coupled to the driving element, and wherein the axial load absorbing member comprises a first end coupled to the interface housing and a second end opposite the first end and coupled to the assembly housing.

8. The device of claim 1, further comprising a driving mechanism releasably coupled with the actuatable assembly, wherein the actuatable assembly comprises a driving element, and wherein actuation of the driving mechanism displaces the driving element from a rest position to move the movable member away from the breast or replaces the driving element to the rest position to move the movable member toward the breast.
9. The device of claim 1, wherein the movable member comprises a deformable member configured to fluidly seal against the breast.

10. The device of claim 9, wherein the movable member comprises a flexible membrane.

11. The device of claim 10, wherein the flexible membrane comprises a corrugated region configured to expand and collapse.

12. A device for expression and collection of breast milk, said device comprising:
   a breast interface configured to engage a breast and fluidly seal thereto, the breast interface comprising a movable member disposed within at least a portion thereof; and
   a tensile element operatively coupling the actutable assembly to the movable member, the tensile element extending continuously between the movable member and the actutable assembly,
   wherein actuation of the actutable assembly applies a tensile force to the tensile element, and wherein the tensile element transmits the tensile force to the movable member to move the movable member away from the breast, thereby applying negative pressure to the breast to express milk therefrom.

13. The device of claim 12, wherein the tensile element comprises a cable, wire, or rope.

14. The device of claim 12, wherein the device further comprises an axial load absorbing member, and wherein the tensile element is disposed within the axial load absorbing member that is axially stiff to absorb reactive forces of the tensile element during application of the tensile force to the tensile element.

15. The device of claim 14, wherein the axial load absorbing member comprises a tube or coil having an axially stiff geometry to absorb the reactive forces of the tensile element.

16. The device of claim 14, wherein the device further comprises a tube extending between the breast interface and the actutable assembly, and wherein the tensile element and the axial load absorbing member are disposed within the tube.

17. The device of claim 16, wherein the tensile element is concentrically disposed within the axial load absorbing member, and wherein the axial load absorbing member is concentrically disposed within the tube.

18. The device of claim 14, wherein the breast interface further comprises an interface housing having the movable member disposed therein, and the actutable assembly further comprises a driving element and an assembly housing having the driving element disposed therein, wherein the tensile element comprises a first end coupled to the movable member and a second end opposite the first end and coupled to the driving element, and wherein the axial load absorbing member comprises a first end coupled to the interface housing and a second end opposite the first end and coupled to the assembly housing.

19. The device of claim 12, further comprising a driving mechanism releasably coupled with the actutable assembly, wherein the actutable assembly comprises a driving element, and wherein actuation of the driving mechanism displaces the driving element from a rest position to move the movable member away from the breast or replaces the driving element to the rest position to move the movable member toward the breast.

20. The device of claim 12, wherein the movable member comprises a deformable member.

21. The device of claim 20, wherein the movable member comprises a flexible membrane.

22. The device of claim 21, wherein the flexible membrane comprises a corrugated region configured to expand and collapse.

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