



US011382727B1

(12) **United States Patent**  
**Marghalani**

(10) **Patent No.:** **US 11,382,727 B1**  
(45) **Date of Patent:** **Jul. 12, 2022**

(54) **THREE-DIMENSIONAL ORAL IMAGING SYSTEM AND METHOD**

(71) Applicant: **Thamer Marghalani**, Jeddah (SA)

(72) Inventor: **Thamer Marghalani**, Jeddah (SA)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/324,980**

(22) Filed: **May 19, 2021**

(51) **Int. Cl.**

**A61C 9/00** (2006.01)

**A61C 1/00** (2006.01)

**A61B 1/24** (2006.01)

(52) **U.S. Cl.**

CPC ..... **A61C 9/0053** (2013.01); **A61C 1/0015** (2013.01); **A61C 9/0006** (2013.01); **A61B 1/24** (2013.01)

(58) **Field of Classification Search**

CPC ... **A61C 9/0053**; **A61C 1/0015**; **A61C 9/0006**; **A61B 1/24**

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,003,132 A \* 1/1977 Beck ..... A61C 9/0006 433/42  
4,173,219 A \* 11/1979 Lentine ..... A61C 19/063 128/861  
4,428,373 A \* 1/1984 Seid ..... A61C 19/063 433/80  
4,902,227 A \* 2/1990 Smith ..... A61C 19/063 433/215  
5,316,473 A \* 5/1994 Hare ..... A61C 19/004 433/215

5,487,662 A 1/1996 Kipke et al.  
5,702,250 A 12/1997 Kipke  
5,895,218 A \* 4/1999 Quinn ..... A61C 19/063 433/80  
6,077,073 A \* 6/2000 Jacob ..... A61C 19/066 433/29  
6,099,314 A 8/2000 Kopelman et al.  
6,386,867 B1 5/2002 Durbin et al.  
6,402,707 B1 6/2002 Ernst  
6,439,888 B1 8/2002 Boutoussov et al.  
6,948,936 B2 9/2005 Miller et al.  
6,956,601 B2 10/2005 Squilla et al.  
6,976,841 B1 \* 12/2005 Osterwalder ..... A61C 19/063 433/29  
7,013,191 B2 3/2006 Rubbert et al.  
7,106,958 B2 9/2006 Kershbaumer et al.  
7,244,122 B2 7/2007 Jung et al.

(Continued)

Primary Examiner — Nicholas D Lucchesi

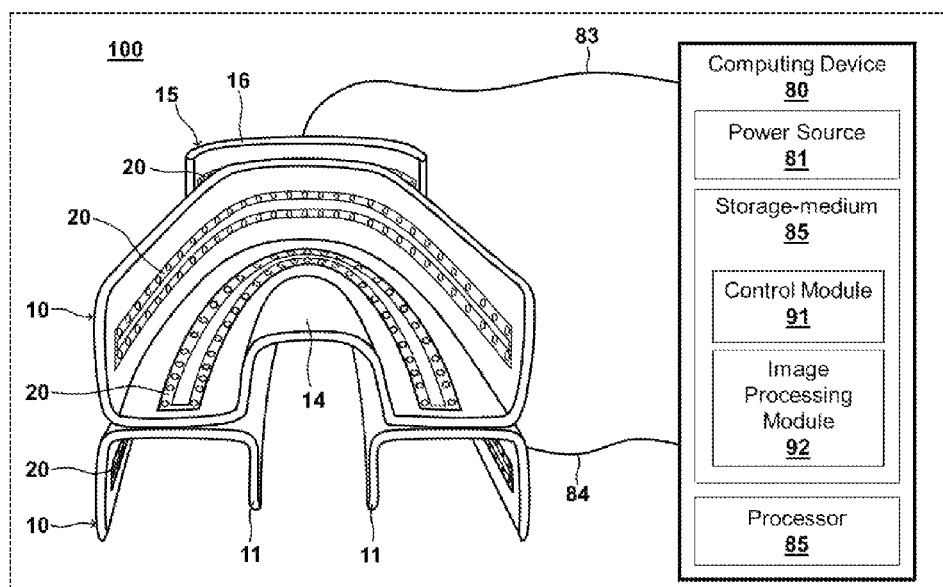
(74) Attorney, Agent, or Firm — John A. Arsenault; Galen Peterson

(57)

**ABSTRACT**

An oral imaging system and method for acquiring dental impression scans is provided by having one or more imaging strips with illumination elements and imaging sensors that are positioned along the contour of the various surfaces of a dental tray and acquire images of the lips, teeth, and gum regions of a mouth. Fluid channels interconnecting a vacuum source or pressurized air source to openings near the imaging sensors on the dental tray are provided to reduce condensation on the imaging sensors. An extraoral extension may also be provided to acquire images of the exterior region of the lips. Furthermore, two dental trays of the present invention may be stacked together so that the entire mouth may be scanned at one time. A ramp is provided on the lower dental tray in the stacked configuration for acquiring relative jaw positions.

**18 Claims, 9 Drawing Sheets**



(56)	<b>References Cited</b>		2011/0076636 A1 *	3/2011	Wolff .....	A61C 19/066 433/27
	U.S. PATENT DOCUMENTS		2011/0207074 A1	8/2011	Hall-Holt et al.	
			2011/0217667 A1	9/2011	Groscurth et al.	
	7,312,924 B2	12/2007 Trissel	2012/0064477 A1	3/2012	Schmitt	
	7,361,020 B2	4/2008 Abolfathi et al.	2013/0027516 A1	1/2013	Hart et al.	
	7,545,372 B2	6/2009 Kopelman et al.	2014/0132747 A1	5/2014	Andrews	
	7,572,124 B2	8/2009 Cipolla	2014/0248576 A1	9/2014	Tchouprakov et al.	
	8,029,278 B1 *	10/2011 Levine .....	2014/0277665 A1 *	9/2014	Fisker .....	G06F 30/00 700/98
						433/29
	8,184,147 B2	5/2012 Cruces et al.	2014/0345626 A1 *	11/2014	Brett .....	A63B 71/085 128/861
	8,366,442 B2	2/2013 Schmitt				
	8,591,227 B2	11/2013 Levine	2015/0056575 A1	2/2015	Groscurth et al.	
	8,831,528 B2	9/2014 Shi	2015/0079534 A1 *	3/2015	Tsuji .....	A61C 9/006 433/29
	8,971,999 B2	3/2015 Kim				
	8,989,567 B1 *	3/2015 Pulido .....	2015/0118638 A1	4/2015	Cowburn	
			2015/0164618 A1 *	6/2015	Heacock .....	A61C 7/08 433/6
	9,131,909 B1 *	9/2015 Ganz .....				
	9,226,801 B2	1/2016 Groscurth et al.	2016/0014396 A1	1/2016	Glinec et al.	
	9,763,760 B2 *	9/2017 Senn .....	2016/0242692 A1 *	8/2016	McAuliffe .....	G06F 30/00
	10,206,757 B2	2/2019 Pettersson	2016/0262856 A1 *	9/2016	Atiya .....	A61B 1/015
	10,213,275 B2	2/2019 Groscurth et al.	2017/0049607 A1 *	2/2017	Thornton .....	A61F 5/566
	11,064,957 B2 *	7/2021 Martin .....	2017/0215997 A1 *	8/2017	Martin .....	A61B 5/6844
	2002/0055082 A1 *	5/2002 Durbin .....	2017/0231733 A1	8/2017	Schmid et al.	
			2018/0000563 A1 *	1/2018	Shanjani .....	A61B 5/682
	2003/0143512 A1	7/2003 Hirsch et al.	2018/0140394 A1	5/2018	Atiya et al.	
	2005/0084816 A1 *	4/2005 Mehdizadeh .....	2019/0365237 A1 *	12/2019	Lee .....	A61B 1/00045
			2020/0230432 A1 *	7/2020	Jablow .....	A61C 17/22
	2005/0202363 A1	9/2005 Osterwalder	2020/0360118 A1 *	11/2020	Olivier .....	A61B 1/24
	2008/0032252 A1	2/2008 Hayman et al.	2021/0059534 A1 *	3/2021	Okuyama .....	A61B 1/00135
	2010/0067756 A1	3/2010 Hart et al.	2021/0127979 A1 *	5/2021	Binkowski .....	A61B 5/0088
	2010/0260405 A1	10/2010 Cinader, Jr.				

\* cited by examiner

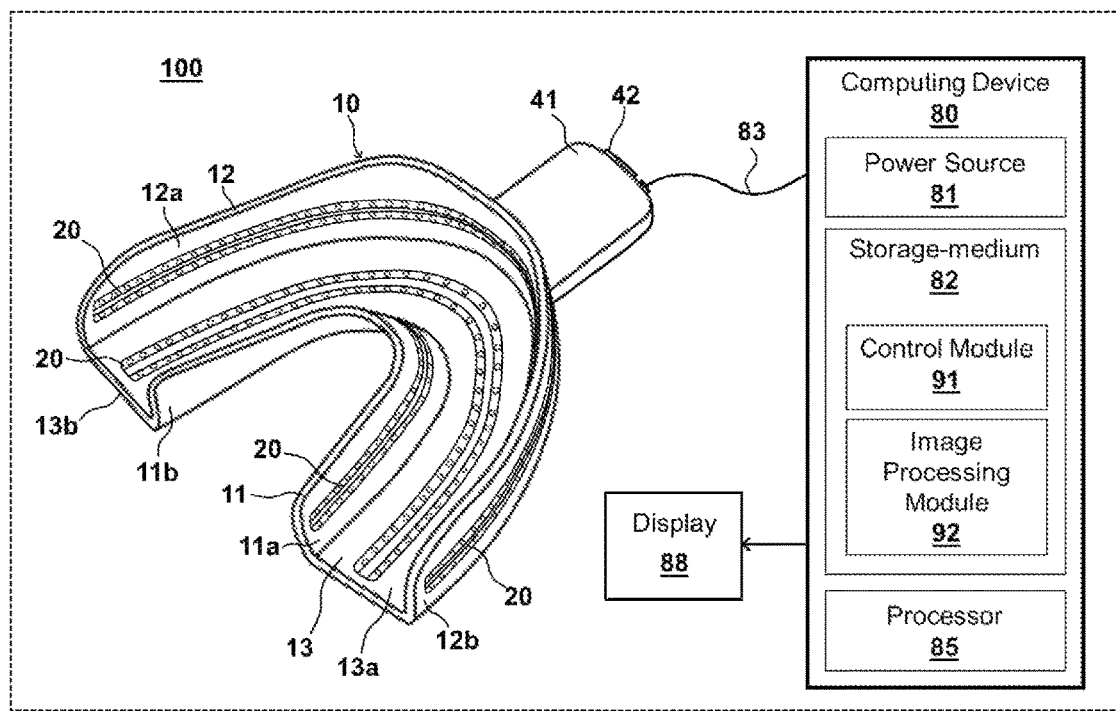


FIG. 1A

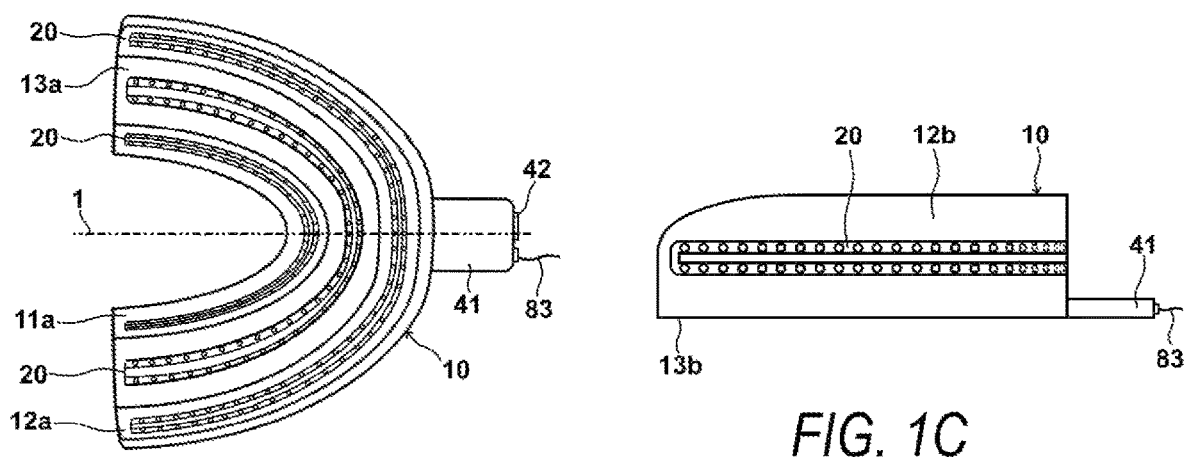


FIG. 1B

FIG. 1C

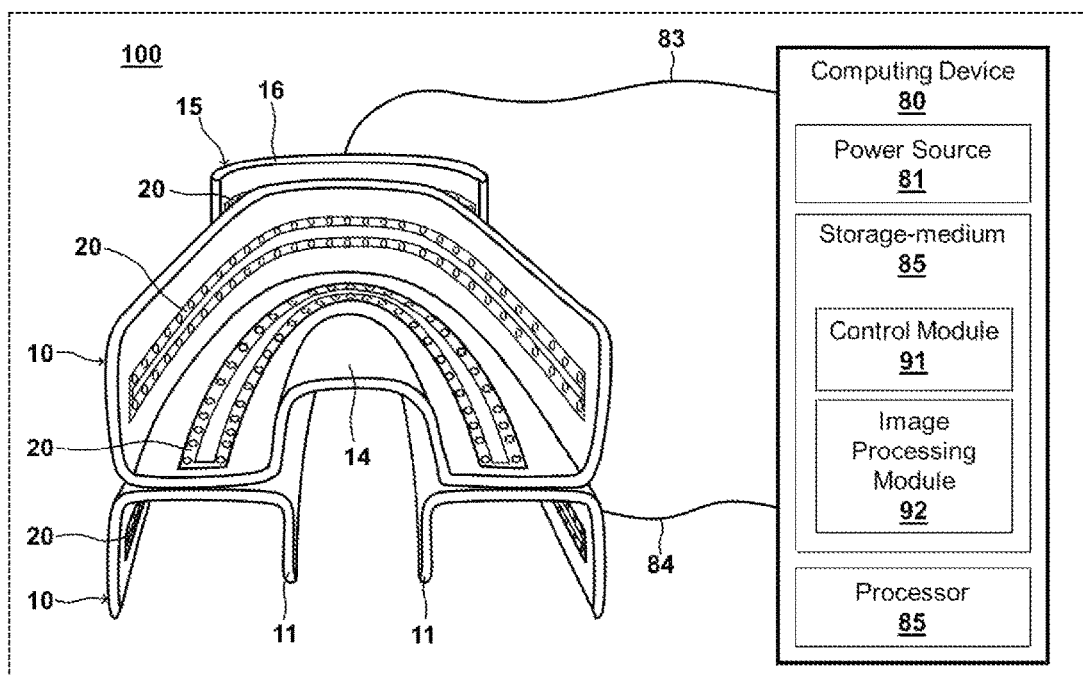


FIG. 2A

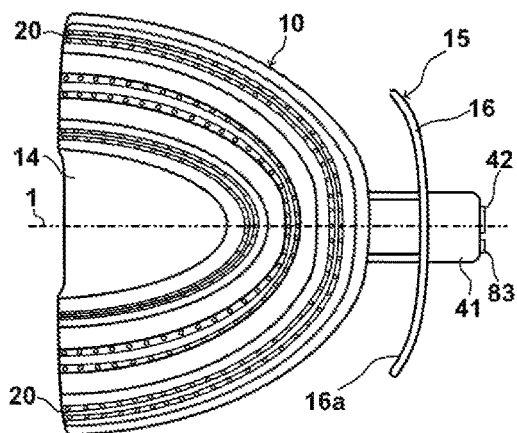


FIG. 2B

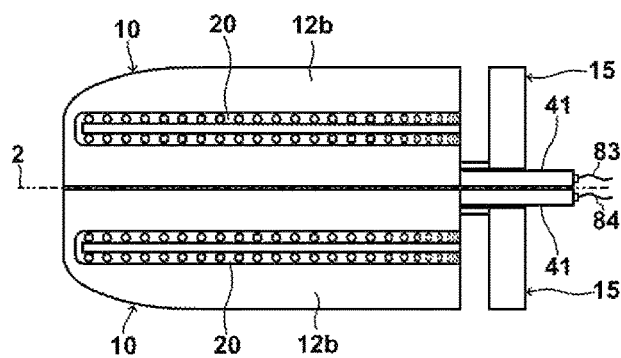


FIG. 2C

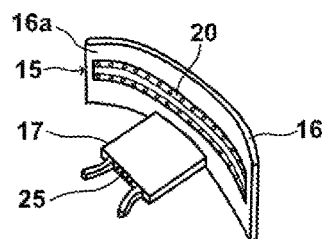


FIG. 2D

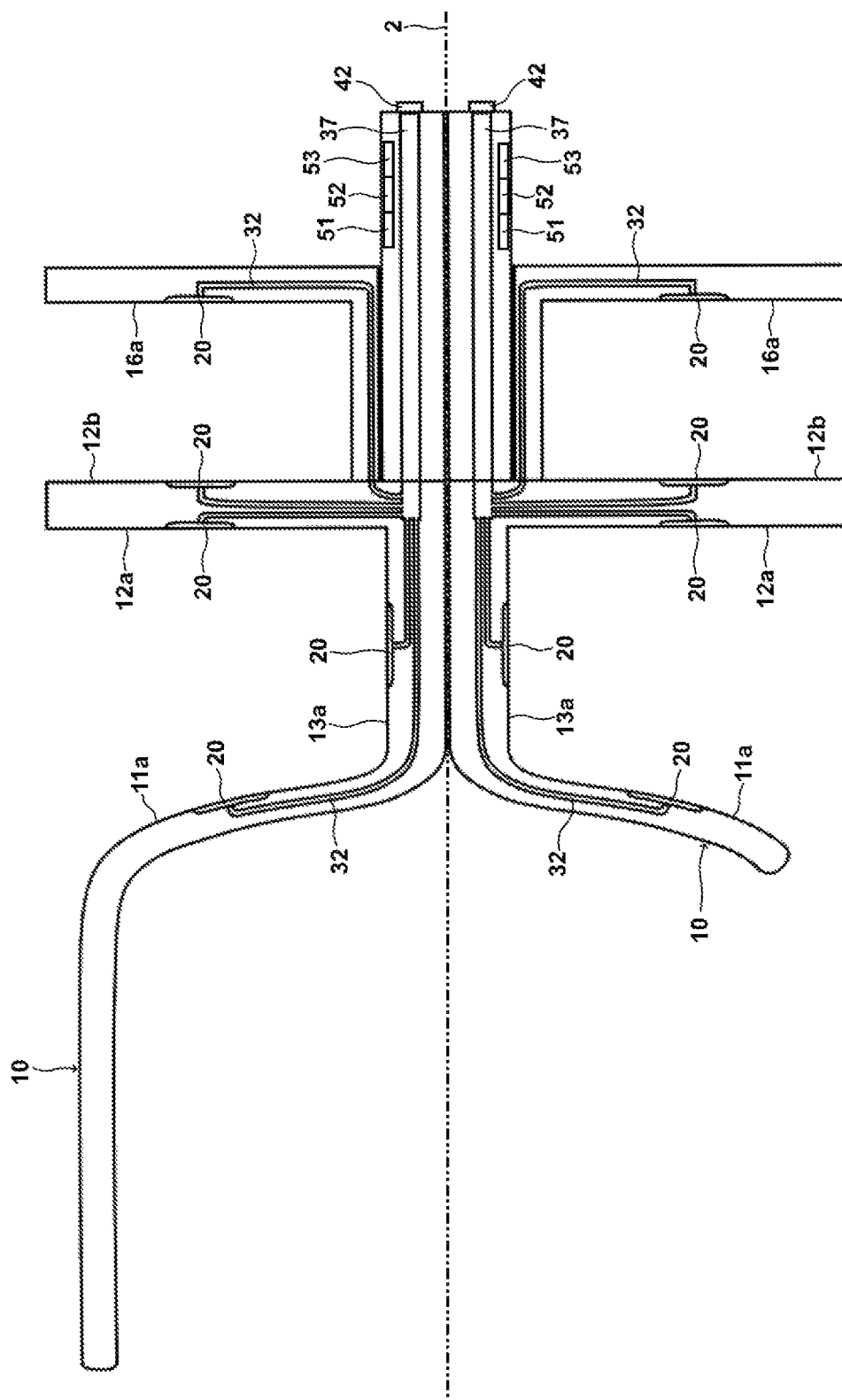


FIG. 2E

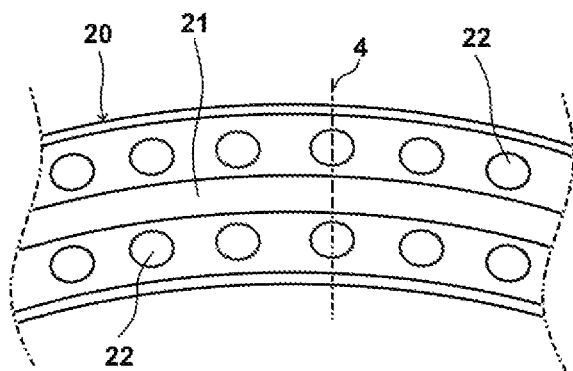


FIG. 3A

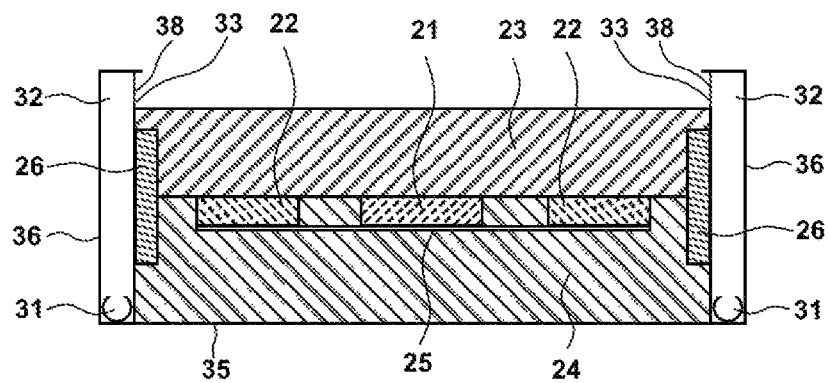


FIG. 3B

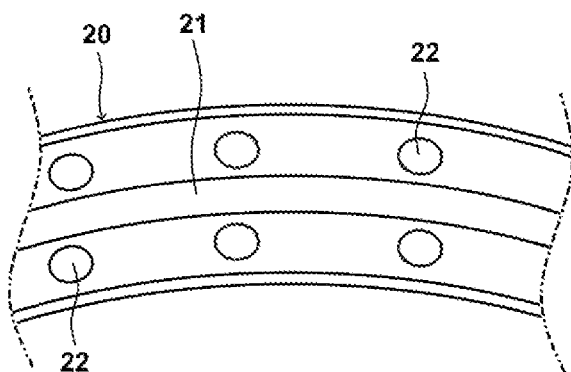


FIG. 4A

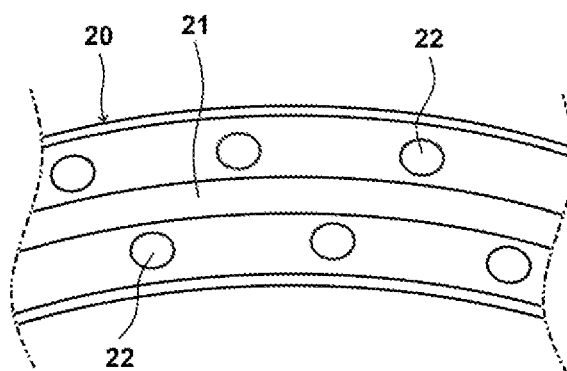


FIG. 4B

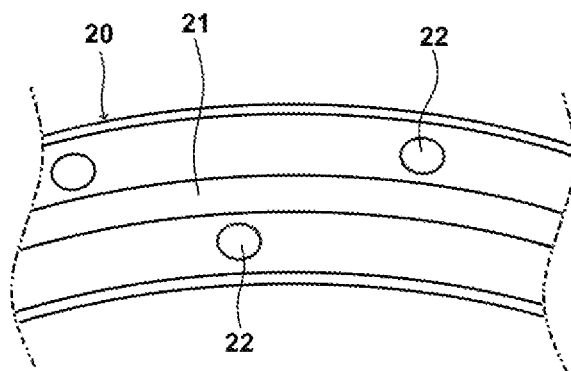


FIG. 4C

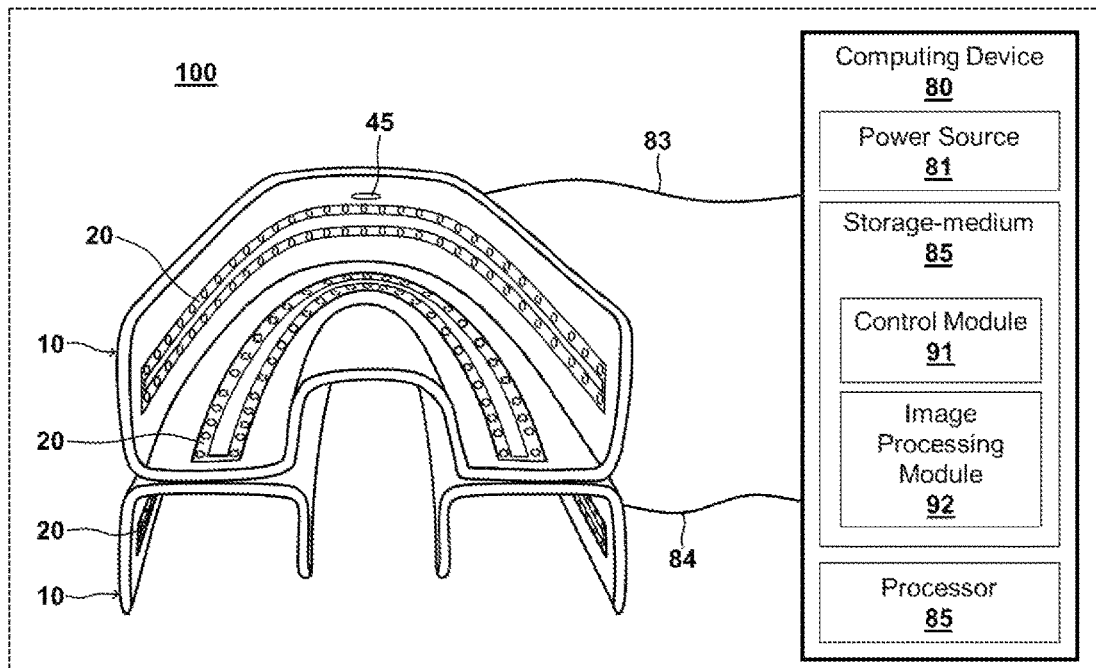


FIG. 5A

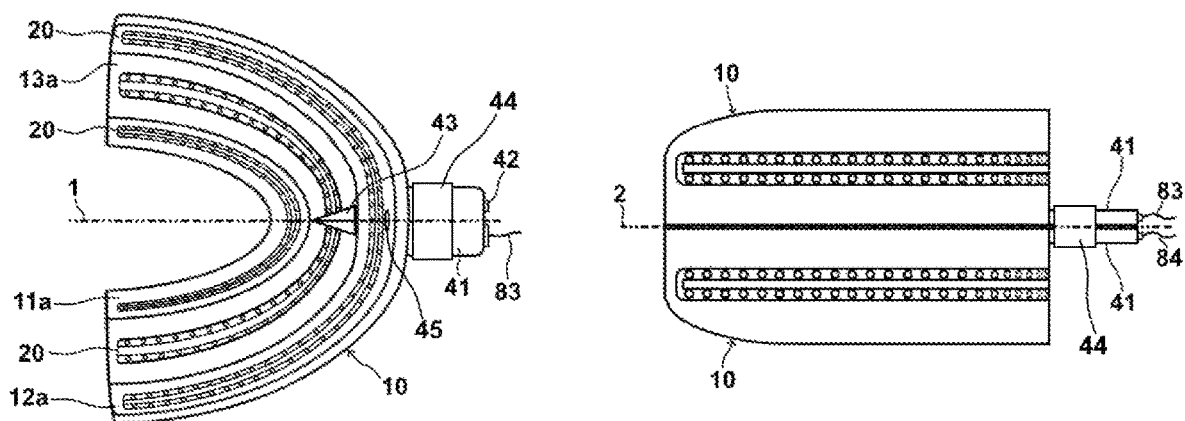


FIG. 5B

FIG. 5C



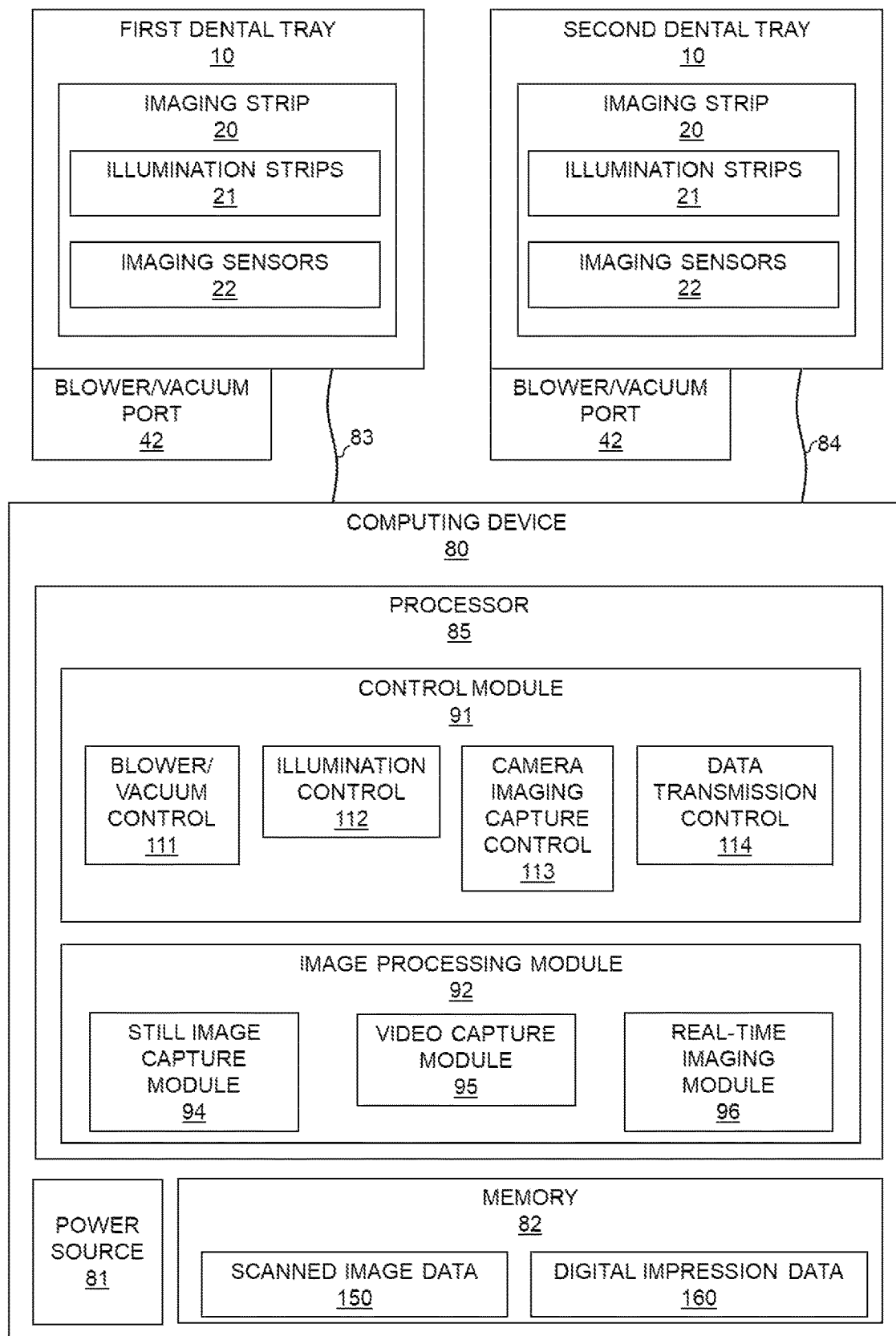
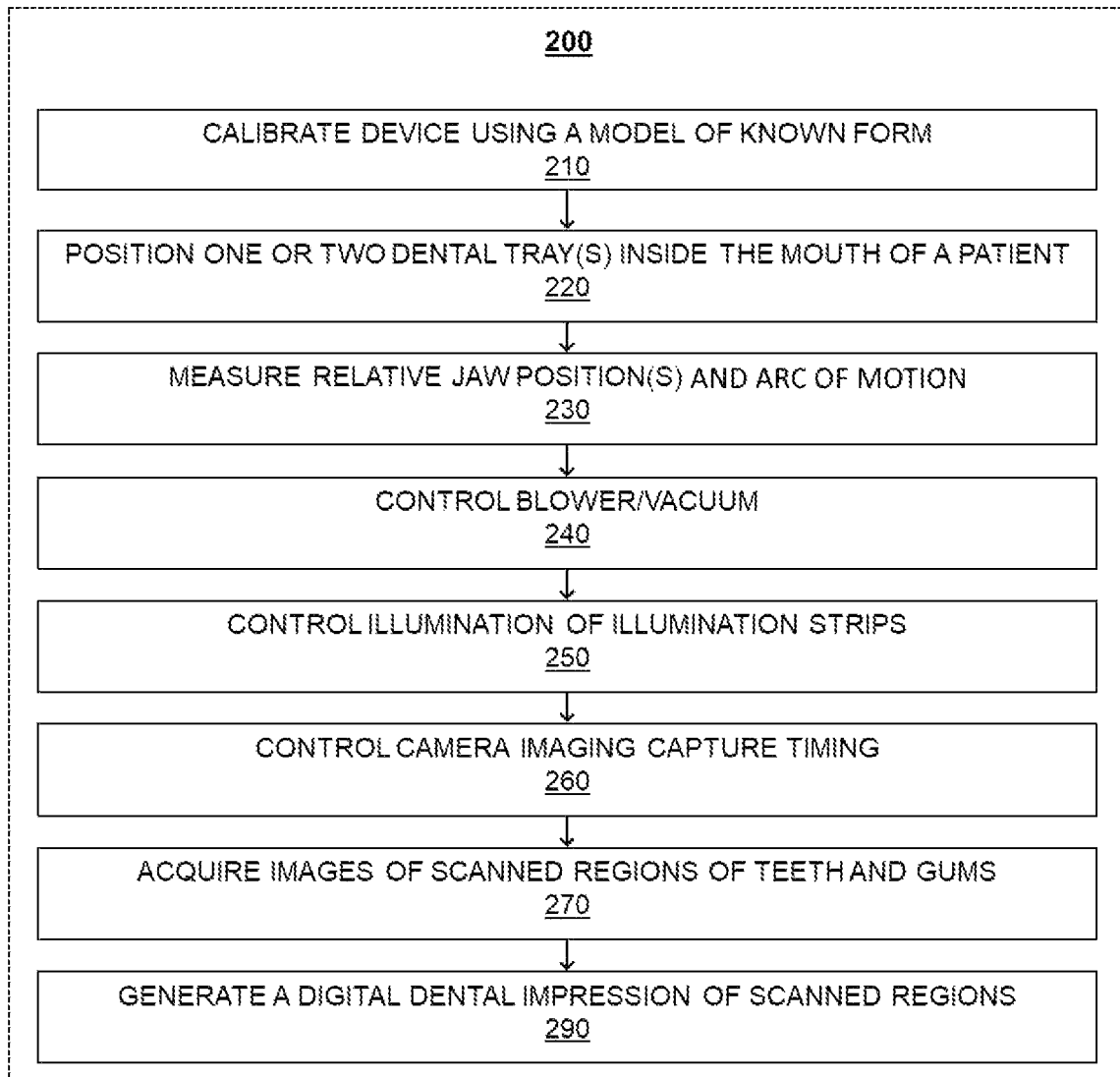


FIG. 6

*FIG. 7*

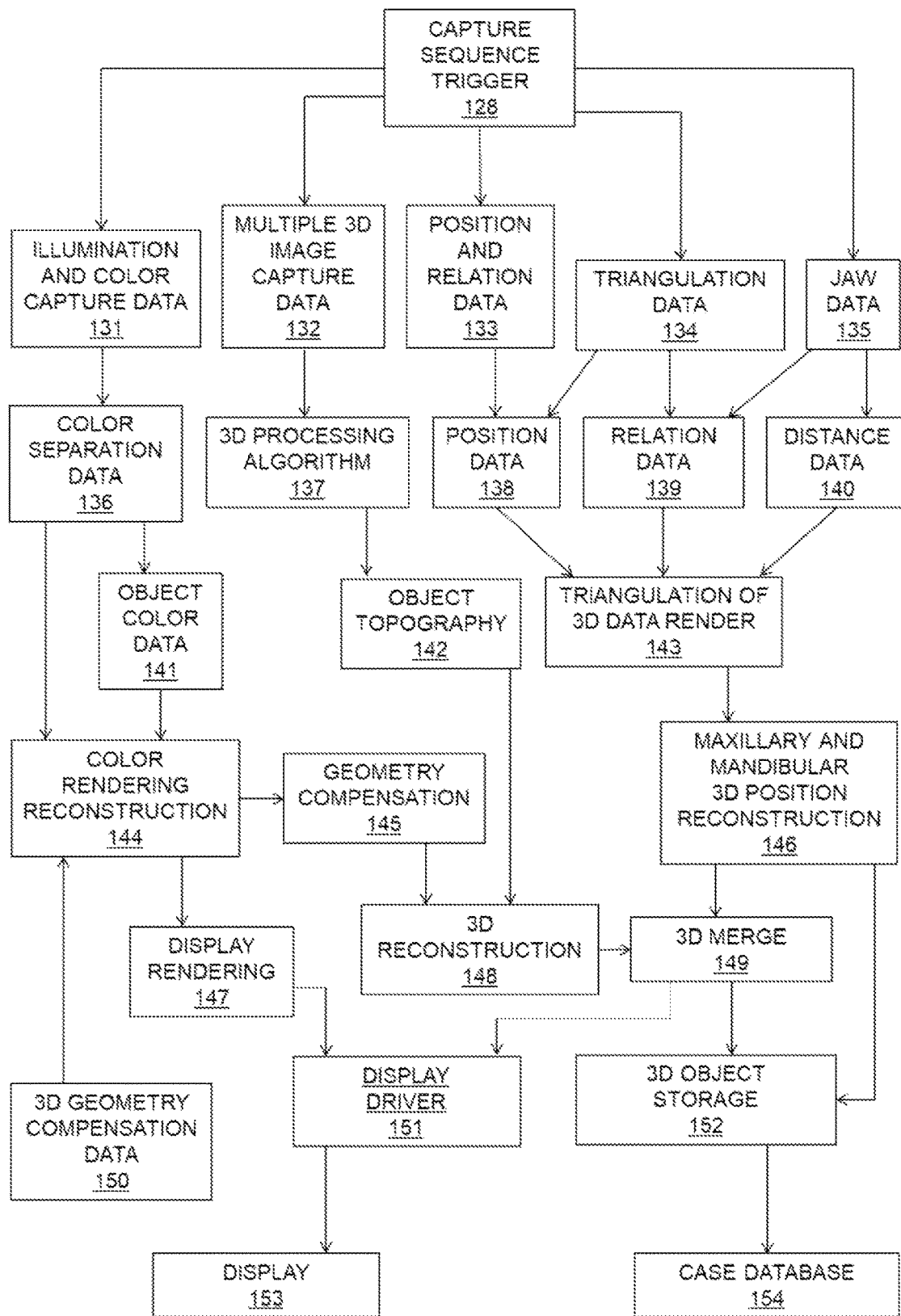


FIG. 8

1

**THREE-DIMENSIONAL ORAL IMAGING  
SYSTEM AND METHOD****STATEMENT REGARDING FEDERALLY  
SPONSORED RESEARCH AND  
DEVELOPMENT**

Not Applicable.

**FIELD OF INVENTION**

Embodiments of the present invention relate to the field of oral scanning, and relate more specifically to a system and method for using a dental tray device for intraoral and extraoral scanning.

**BACKGROUND OF DISCLOSURE**

Numerous processes for acquiring dental impressions have been implemented for the purpose of creating comfortably-fitting, functional, and cosmetically appealing dental restorations. Information acquired by such processes are typically used for careful planning of dental surgeries as well as for gaining a better understanding of orthodontic movements. Analog techniques typically involve taking an impression using an elastic material; however, these techniques bear the disadvantages of increased discomfort to the user and increased procedure time. Digital intraoral scanning (IOS) techniques offer many benefits over traditional, analog techniques, including the ability to acquire three-dimensional (3D) digital impressions with a higher degree of accuracy, greater strength and comfort to the user. The 3D digital impressions can then be manufactured through reverse engineering procedures by means of computer-aided design (CAD) and computer assisted manufacturing (CAM) systems.

Two common types of digital IOS devices that have been implemented are scanner wands and benchtop scanners. Scanner wands offer a compact and light-weight method for acquiring 3D images but with many inherent disadvantages, such as errors in the resulting 3D images due to movement between the source and target, or discomfort to the person being scanned. Benchtop scanners are a bulky alternative to scanner wands and typically consist of two cameras or sensors attached to a rotating mechanism where the objects being scanned are rotated on several axes so that the scanner can accurately capture details from several perspectives. Several alternative intraoral devices have been described that attempt to overcome the issues presented by scanner wands and benchtop scanners. These devices, however, frequently exhibit other notable problems, such as difficulty in detecting deep margin lines in prepared teeth or in the case of bleeding, problems arising from condensation of water on the lenses. There exists a need for a lightweight, compact digital IOS device and method capable of acquiring high resolution 3D images of the teeth, lips, and gums in a timely manner and with minimal discomfort.

**SUMMARY OF THE DISCLOSURE**

The present invention provides an oral imaging system and method for scanning the interior and exterior regions of a mouth. In a preferred embodiment, the oral imaging system comprises a dental tray having one or more imaging strips positioned on the various surfaces of the dental tray. Each imaging strip has an illumination strip extending along the length of the imaging strip for providing light to the

2

region of the mouth being scanned. Each imaging strip is also equipped with one or more imaging sensors for acquiring images of the region of the mouth being scanned, each imaging sensor being positioned in proximity to and along the illumination strip in a configuration that may be either expanded or condensed and may be either matched or alternating. In matched configurations, the imaging sensors are positioned on both sides of a respective illumination strip and directly across from one another. In alternating configurations, the imaging sensors are positioned on both sides of a respective illumination strip diagonally across from one another.

It is a feature of the present invention that suction channels or blow channels positioned in proximity to the imaging sensors along the edge of the imaging strip significantly reduce the amount of water that condenses on or stays condensed on the imaging sensors while the dental tray is inside a mouth.

It is a feature of the present invention to integrate technology such as time of flight cameras, one or more polarizing lenses for imaging sensors used herein, or similar functionality to reduce the need for powders that reduce the reflectivity of teeth when taking a dental impression.

It is a feature of the present invention that an extraoral extension be reversibly attachable to the handle of the dental tray so that the exterior regions of the lips may also be scanned at the same time as the interior regions of the mouth.

It is a feature of the present invention that two embodied dental trays may be used in a stacked configuration to scan the entire oral region of a user at one time. It is a further feature of the present invention that for embodiments having two dental trays in a stacked configuration, a detachable triangular ramp placed in the fitting surface of the lower, or mandibular tray compartment allows for the efficient and effective placement, positioning, and directing of the lower jaw and associated condyles toward the Centric Relation (CR), a repeatable and reliable position used in recording the jaw relations. Furthermore, it is a feature of the present invention that excursive movement data may be acquired by placing accelerometers or other relational data sensors on the dental trays and any teeth, gums, or dental structures, moving the lower jaw in opening and closing and to left and right relative to the initial jaw position, capturing multiple images, and comparing relational data.

It is a feature of the present invention that, during operation of the oral imaging system, the position and orientation of the imaging sensors and illumination strips are substantially stationary with respect to the oral features being imaged through lens based optical imaging stabilization, thus allowing for improved image capture over wand and other non-stationary type devices.

It is a feature of the present invention that the imaging strips contemplated herein are manufactured using flexible printed circuit boards to allow the imaging strips to curve along and conform to the U-shape of a mouth. The inventor contemplates manufacturing the flexible printed circuit boards of an imaging strip to comprise a thin insulating polymer film having conductive circuit patterns affixed thereto and supplied with a thin polymer coating to protect the conductor circuits, in addition to the power source connection to the tray itself to provide energy to the sensors and lenses along the strip needed to take a digital impression.

It is a feature of the present invention to acquire digital dental impression data with high accuracy and reduced scanning time while also reducing patient discomfort. The present invention is capable of utilizing a variety of image

processing techniques, is energy efficient, and exhibits a high degree of reusability, all of which can contribute to an overall reduced cost for manufacturing a physical model of the dental impression.

It is a feature of the present invention to utilize the images and digital dental impression data and transform them into a visual representation on a display and provide a sufficient set of data to provide a three-dimensional representation of the patient's upper or lower teeth as well as information about a patient's jaw.

Embodiments include one, more, or any combination of all of the features listed above. Other features and advantages of the present invention will become apparent from the following more detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

#### DESCRIPTION OF THE DRAWINGS

FIG. 1A is an upper perspective view of an oral imaging system, in accordance with an exemplary embodiment of the present invention;

FIG. 1B illustrates a top view of the dental tray shown in FIG. 1A, in accordance with an exemplary embodiment of the present invention;

FIG. 1C illustrates a side view of the dental tray shown in FIG. 1A, in accordance with an exemplary embodiment of the present invention;

FIG. 2A is an upper perspective view of an alternative oral imaging system, wherein the system is in a stacked configuration and each dental tray incorporates an extraoral extension, in accordance with an exemplary embodiment of the present invention;

FIG. 2B illustrates a top view of the dental trays shown in FIG. 2A, in accordance with an exemplary embodiment of the present invention;

FIG. 2C illustrates a side view of the dental trays shown in FIG. 2A, in accordance with an exemplary embodiment of the present invention;

FIG. 2D illustrates a perspective view of an extraoral attachment, in accordance with an exemplary embodiment of the present invention;

FIG. 2E illustrates a side cross-sectional view at the first longitudinal center plane of the dental trays shown in FIGS. 2A-2C, in accordance with an exemplary embodiment of the present invention;

FIG. 3A illustrates a close-up top view of a section of an imaging strip in a condensed matched configuration, in accordance with an exemplary embodiment of the present invention;

FIG. 3B illustrates a cross-sectional view of a section of the imaging strip shown in FIG. 3A, in accordance with an exemplary embodiment of the present invention;

FIG. 4A illustrates a top view of an embodiment of an imaging strip for generating oral images using an expanded matched configuration, in accordance with an exemplary embodiment of the present invention;

FIG. 4B illustrates a top view of an embodiment of an imaging strip for generating oral images using a condensed alternating configuration, in accordance with an exemplary embodiment of the present invention;

FIG. 4C illustrates a top view of an embodiment of an imaging strip for generating oral images using an expanded alternating configuration, in accordance with an exemplary embodiment of the present invention;

FIG. 5A is an upper perspective view of an alternative oral imaging system, wherein the system is in a stacked configuration,

and the lower dental tray incorporates a ramp, in accordance with an exemplary embodiment of the present invention;

FIG. 5B illustrates a bottom view of the lower dental tray of FIG. 5A, in accordance with an exemplary embodiment of the present invention;

FIG. 5C illustrates a side view of the dental trays shown in FIG. 5A, in accordance with an exemplary embodiment of the present invention;

FIG. 6 illustrates a flow chart of one embodiment of the oral imaging system consistent with embodiments of the present disclosure;

FIG. 7 illustrates a flow chart of one embodiment of the image acquisition method consistent with embodiments of the present disclosure; and

FIG. 8 illustrates a flow chart of one embodiment of the image processing module consistent with embodiments of the present disclosure.

#### DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENT

Illustrative embodiments of the invention are described below in the accompanying Figures. The following detailed description provides detailed schematics for a thorough understanding of and an enabling description for these embodiments. One having ordinary skill in the art will understand that the invention may be practiced without certain details. In other instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments. In the description, terms such as "upper", "lower", "top", "bottom", "inner", and "outer" should be construed to refer to orientation as then described or as shown in the drawings under discussion. The terms are for convenience of description and do not require that the system or component of the system be operated in a particular orientation.

FIG. 1A is an upper perspective view of an oral imaging system **100**, in accordance with an exemplary embodiment of the present invention. FIG. 1B illustrates a top view of the dental tray **10** shown in FIG. 1A, in accordance with an exemplary embodiment of the present invention. FIG. 1C illustrates a side view of the dental tray **10** shown in FIG. 1A, in accordance with an exemplary embodiment of the present invention. The oral imaging system **100** may comprise a dental tray **10** equipped with one or more imaging strips **20**, a handle **41** extending therefrom the dental tray **10**, and a first communication link **83** between the dental tray **10** and a computing device **80**. The dental trays **10** for the lower dental region and the upper dental region are each defined by a generally U-shaped channel formed to at least partially surround the teeth and gums of a patient, whereby the U-shaped channel may comprise an inner wall **11** having inner internal surface **11a** and inner external surface **11b**, an outer wall **12** having outer internal surface **12a** and outer external surface **12b**, and a base **13** interconnecting the inner wall **11** and the outer wall **12** and having a base internal surface **13a** and a base external surface **13b**.

The imaging strips **20** may be adhered directly to or incorporated within any one or more of internal surfaces **11a**, **12a**, or **13a**, or outer external surface **12b**, and each imaging strip **20** is generally length-wise oriented parallel with the curvature of a corresponding internal surface **11a**, **12a**, **13a**, or **12b**. The computing device **80** may comprise a power source **81**, a computer-readable storage medium **82**, and a processor **85**, wherein the storage medium **82** may

5

include a control module **91** and an image processing module **92**. Printed circuit boards **25** housed within the imaging strips **20** or within the body of the dental tray **10** transmit or receive electrical or imaging signals between the imaging strips **20** and the computing device **80** via first communication link **83**, which may be a transmission cable or wireless transmitter and receiver. Images and other information acquired or generated by the imaging system **100** may be communicated to a visual display **88** for viewing. The power source **81** provides power to components of the dental tray and/or the computing device **80**.

FIG. 2A is an upper perspective view of an alternative oral imaging system **100**, wherein the system **100** is in a stacked configuration and each dental tray **10** incorporates an extraoral extension **15**, in accordance with an exemplary embodiment of the present invention. FIG. 2B illustrates a top view of the dental trays **10** shown in FIG. 2A, in accordance with an exemplary embodiment of the present invention. FIG. 2C illustrates a side view of the dental trays **10** shown in FIG. 2A, in accordance with an exemplary embodiment of the present invention. FIG. 2D illustrates a perspective view of an extraoral attachment **15**, in accordance with an exemplary embodiment of the present invention. FIG. 2E illustrates a side cross-sectional view at the first longitudinal center plane **1** of the dental trays **10** shown in FIGS. 2A-2C, in accordance with an exemplary embodiment of the present invention.

In this example embodiment, two dental trays **10** are in a stacked configuration with the base external surface **13b** of the upper dental tray **10** positioned adjacent to a base external surface **13b** of the lower dental tray **10** about a second longitudinal center plane **2**, each dental tray **10** having an extraoral extension **15** so that both the upper, lower, internal and external sections of a mouth may be scanned and imaged simultaneously. The extraoral extensions **15** reversibly fasten to the dental trays **10** proximate to the handles **41** if scanning of the mouth exterior is desired by the user. An extraoral extension **15** may comprise an extraoral elongation **16**, a clipping member **17**, and one or more imaging strips **20**. The clipping member **17** inserts into a receiving member positioned within the volume of each dental tray **10** proximate to the respective handle **41**. The extraoral elongation **16** has an extension internal surface **16a** and is designed to be positioned closely against the lips or the extraoral region of a user by curving towards a respective dental tray **10** with increasing distance from the first longitudinal center plane **1**. The dental tray **10** for the upper dental region may further comprise a central inner platform **14** connecting the two opposing sides of the inner wall **11**.

In this example embodiment, additional imaging strips **20** may be adhered directly to or incorporated within any one or more of surfaces **12b** or **16a**, and each imaging strip **20** is generally length-wise oriented parallel with the curvature of a corresponding surface of either **12b** or **16a** or within the palatal section of the dental tray **10**. Each type of imaging strip **20** is manufactured to substantially match the contour of a corresponding surface **11a**, **12a**, **12b**, **13a** or **16a**. An imaging strip **20** may be securely fastened to the inner internal surface **11a** for generating oral images of the inner gums and inner side of the teeth or inner oral structures. An imaging strip **20** may be securely fastened to the outer internal surface **12a** for generating oral images of the outer side of teeth and outer gums or outer oral structures. An imaging strip **20** may be securely fastened to the base internal surface **13a** for generating oral images of the teeth crowns and lower gums or lower oral structures. An imaging strip **20** may be securely fastened to the outer external

6

surface **12b** for generating oral images of the inner side of the lips. An imaging strip **20** may be securely fastened to the extension internal surface **16a** for generating oral images of the outer side of the lips.

Furthermore, the oral imaging system **100** may further comprise a second communication link **84** between the computing device **80** and the second dental tray **10** for transmitting or receiving electrical or imaging signals between the imaging strips **20** on the second dental tray **10** and the computing device **80**.

In some embodiments, any of the dental trays **10** may further comprise an internal power source **51**, an internal memory **52**, or an internal processor **53**. It is contemplated that internal power source **51** may include a button cell battery located on or within the handle **41** of a dental tray **10**, a rechargeable battery powered by an induction coil located on the outside surface of the handle **41** or within the handle **41** of a dental tray **10** that may be placed into sufficient physical contact with another induction coil on a flat surface of a charging base station, a rechargeable the dental tray **10** that are placed into sufficient physical contact with charging connection pins on a charging base station wherein the dental tray may be securely stored during the charging process, or a rechargeable battery that may be connected to an external power source via a cable to recharge. A millimeter wave wireless receiver placed in the handle **41** of the dental tray **10** may be wirelessly powered via a base station broadcasting a compatible signal to send wireless power to a receiver in the handle **41**. Use of induction based wireless charging herein is contemplated because there would be a smaller area wherein moisture could accumulate within the interior portions of the tray **10**. In addition to a charging station, a contemplated base station may also include a means to sterilize a dental tray **10** via one or more ultraviolet lights placed above and around the dental tray **10** or through activating a haptic chip at or near the surface of the charging station wherein cavitation and implosion is achieved via ultrasonic agitation of a fluid or solvent within a charging station. Internal memory **52** may be a solid state drive or other computer-readable storage medium capable of storing information from the illumination strips **20** prior to transmitting signals to the computing device **80**. Internal processor **53** may be configured to process various forms of data between the computing device **80** and the internal memory **52**.

FIG. 3A illustrates a close-up top view of a section of an imaging strip **20** in a condensed matched configuration, in accordance with an exemplary embodiment of the present invention. FIG. 3B illustrates a cross-sectional view of a section **4** of the imaging strip **20** shown in FIG. 3A, in accordance with an exemplary embodiment of the present invention. Each imaging strip **20** may comprise one or more illumination strips **21** and a plurality of imaging sensors **22** along the imaging strip **20** as an array. The illumination strips **21** may comprise a plurality of adjacently positioned individual light sources or may be a single continuous illuminating extension. The illumination strips **21** are configured to provide illumination to the region of the mouth being imaged and are generally either light emitting diodes (LED), structured striped light, lasers, infrared sources, other coherent light sources, or combinations thereof. The imaging sensors **22** are configured to acquire images of the teeth and gum regions of the mouth and transmit the acquired images to the computing device **80** via printed circuit boards **25** and communication links **83** and **84**. A variety of imaging sensors **22** may be used including, but not limited to, optical imaging sensors, time of flight sensors,

laser sensors, blue CAM sensors, back-illuminated CMOS, three-dimensional cameras, optical coherence tomography (OCT), other various types of optical camera sensors, or combinations thereof. The imaging sensors 22 may also include lens-based optical imaging stabilization for more accurate imaging via an internal floating lens element within the sensor, wherein the floating lens is electronically controlled and shifts the lens opposite to the direction a lens is moved. The inventor contemplates using one or more wide-angle imaging sensors along the imaging strip in order to capture a plurality of close-up images which may then be transformed for sharpness and then consolidated into a single three-dimensional impression image via imaging software that may then be output to a display. Furthermore, it is contemplated that the imaging system 100 could be improved by including a hydrophobic coating onto the outer surface of the imaging sensors 22 for preventing fog or condensation on the surface of the sensors 22.

The illumination strips 21 and imaging sensors 22 may be directly attached between a first cover layer 23 and a second cover layer 24. The first cover layer 23 and second cover layer 24 protect the illumination strips 21 and imaging sensors 22 from damage caused by abrasion and bodily fluids and are manufactured from a polymer exhibiting a substantially high transparency and at least partial flexibility. The inventor contemplates using polyimide, polyester, or a similar polymer as a base material for a flexible printed circuit board 25 used for the imaging strip 20 and connecting the imaging strip 20 to a power source 51 or 81, illumination strips 21, imaging sensors 22, or other electronic components. The first cover layer 23 provides a minimal imaging distance between the imaging sensors 22 and the target to be imaged and exhibits a substantially high transmissivity of light. The second cover layer 24 houses the illumination strips 21, the imaging sensors 22, and printed circuit boards 25. In various embodiments, one or more of the imaging strips 20 may each comprise one or more fluid collection channels 31 extending along the back portion 35 of at least one transverse end portion 36 of the imaging strip 20 and each being designed to communicate fluid from one or more blow channels 32 to a vacuum. The fluid collection channels 31 may have either a semi-elliptical cross section or may have holes along the length of each fluid collection channel 31 and generally converge into a main fluid channel 37 located near and within the handle 41 of the dental tray 10 before terminating at a blower/vacuum line 42, or channel, that attaches to a pressurized air supply or vacuum. The blow channels 32 generally extend adjacently along the transverse end portions 36 and communicate fluid from the blow channel openings 33 to the fluid collection channels 31. In various embodiments, any imaging strip 20 with blow channels 32 may further comprise a mesh 38 for filtering particles from entering the blow channels 32, the mesh 38 generally being positioned at the blow channel openings 33. In various embodiments, the imaging strips 20 may further comprise one or more heating elements 26 for applying heat to the air and surfaces of the blow channels 32 or to the first cover layer 23 or second cover layer 24. The heating elements 26 are generally positioned adjacent to and along the blow channels 32.

FIG. 4A illustrates a top view of an embodiment of an imaging strip 20 for generating oral images using an expanded matched configuration, in accordance with an exemplary embodiment of the present invention. FIG. 4B illustrates a top view of an embodiment of an imaging strip 20 for generating oral images using a condensed alternating configuration, in accordance with an exemplary embodiment

of the present invention. FIG. 4C illustrates a top view of an embodiment of an imaging strip 20 for generating oral images using an expanded alternating configuration, in accordance with an exemplary embodiment of the present invention. A user may find it advantageous to use any one of the expanded matched, expanded alternating, condensed matched, or condensed alternating configurations depending on numerous factors such as, but not limiting to, mouth size or extent of thermal dissipation from the illumination strips 21.

FIG. 5A is an upper perspective view of an alternative oral imaging system 100, wherein the system 100 is in a stacked configuration and the lower dental tray 10 incorporates a ramp, in accordance with an exemplary embodiment of the present invention. FIG. 5B illustrates a bottom view of the lower dental tray 10 of FIG. 5A, in accordance with an exemplary embodiment of the present invention. FIG. 5C illustrates a side view of the dental trays shown in FIG. 5A, in accordance with an exemplary embodiment of the present invention. In embodiments where two dental trays 10 are in a stacked configuration, the oral imaging system 100 may further comprise a ramp 43 for acquiring the jaw position of a user. The ramp 43 may take the form of a triangular pyramid or a right triangular pyramid and may be positioned on the base internal surface 13a of the lower dental tray 10. The ramp 43 may be detachable and may be sloping or inclining toward the outer internal surface 12a near the cross-section 1. The ramp 43 is designed to align the mandible and maxilla of a user towards the CR position when the lower front teeth contacts and presses against the lower dental tray 10. The three-dimensional digital scanning of the jaws and recording of this position is useful in relating and positioning of the 3D scanned models of the jaws into the correct CR position. This recorded CR position is an essential record for the proper construction of simple and complex dental prostheses and mouth rehabilitation of the patients. A clip 44 may be attached to the handles 41 of stacked dental trays 10 to firmly press the dental trays 10 together and maintain the relative positions and alignment of the dental trays 10. Other suitable methods of maintaining the relative positions and alignment of dental trays 10 in a stacked configuration include, but are not limited to, rails and respective rail inserts positioned on the base external surface 13b of each dental tray 10, adhesive materials applied to the base external surface 13b of one or more dental trays 10, or manufacturing the dental trays 10 together as a single piece. In various embodiments, one or more dental trays 10 may further comprise one or more accelerometers 45 on one of the surfaces 11a, 12a, or 13a, or directly on the imaging strip 20, as well as on any teeth, gums, or dental structures.

FIG. 6 illustrates a flow chart of one embodiment of the oral imaging system 100 consistent with embodiments of the present disclosure. The processor 85 may be configured to perform operations, tasks or actions related to obtaining images using the imaging strips 20 on the dental tray 10 or to further process the images obtained by scanning the teeth and gum regions into digital dental impressions. The computer-readable storage medium 82 may comprise modules, software and algorithms that the processor 85 implements during the steps of the image acquisition method 200. In the embodiments described herein, representative data may refer to tabulated data, graphical data, visual data or functional relationships.

The control module 91 may comprise a blower/vacuum control 111 for controlling and adjusting the humidity and degree of either reduced or elevated pressure in the fluid

collection channels **31**, an illumination control **112** for controlling and adjusting the degree of illumination for the illumination strips **21**, a camera imaging capture control **113** for controlling and adjusting the capture timing or rate of the imaging sensors **22**, and a data transmission control **114** for controlling and adjusting the transmission of images and representative data from the dental tray(s) **10** to the computing device **80**.

The image processing module **92** may comprise instructions, tasks or executable commands related to the processing of scanned images or representative data into digital dental impressions. Images or representative data from the scanning step may be further processed using a variety of techniques which include, but are not limited to, color separation and rendering techniques, multiple 3D image capture techniques, position and relation techniques, techniques using artificial intelligence, gaussian smoothing techniques, image sharpening techniques, optical coherence tomography, light detection and ranging (LiDAR), and triangulation techniques. Furthermore, the image processing module **92** may comprise instructions, tasks or executable commands related to adjusting the relative positions and orientations of the maxilla dental tray and mandible dental tray when two dental trays **10** are used simultaneously.

The image processing module **92** may comprise a still image capture module **94**, a video capture module **95**, or a real-time imaging module **96**. The still image capture module **94** uses triangulation techniques to acquire images generally by emitting light beams that intersect to identify a particular point in 3D space. For passive triangulation techniques, Equation 1 may be used to calculate the distance ( $d$ ) of a target perpendicular from the plane intersecting mediums **23** and **24** from the distance ( $x$ ) between the illumination strip **21** and a respective imaging sensor **22** along the plane intersecting mediums **23** and **24**, the angle ( $\alpha$ ) between the target at distance ( $d$ ) and the plane intersecting mediums **23** and **24** relative to the illumination strip **21**, and the angle ( $\beta$ ) between the target at distance ( $d$ ) and the plane intersecting mediums **23** and **24** relative to the respective imaging sensor **22**.

$$d = \frac{x}{\frac{1}{\tan(\alpha)} + \frac{1}{\tan(\beta)}} \quad (\text{Equation 1})$$

Furthermore, for embodiments wherein the imaging sensors **22** are fixed focus cameras, the blur  $\psi$  or defocus of generated images may be quantified by Equation 2, where  $\lambda$  is the wavelength of light coming from the illumination strips **21**,  $r$  is a measure of the aperture of the imaging sensor **22**, and  $z_o^f$  and  $z_o^f$  are the in-focus and actual object distances from the imaging sensor **22**.

$$\psi = \frac{2\pi}{\lambda} \left( \frac{1}{z_o^f} - \frac{1}{z_o^f} \right) r^2 \quad (\text{Equation 2})$$

The video capture module **95** uses active wavefront sampling techniques to acquire images by emitting blue wavelength light directed at the teeth, gums or dental structures that is detected by each individual imaging sensor **22** at different angles. The captured video images may then be then assembled or stitched together into a 3D rendering using a variety of well established techniques. The real-time

imaging module **96** uses ultrafast optical sectioning techniques that generate 3D images based on real-time geometric representative data.

FIG. 7 illustrates a flow chart of one embodiment of the image acquisition method **200** consistent with embodiments of the present disclosure. During use and operation of the oral imaging system **100**, steps from the image acquisition method **200** may be implemented to acquire digital dental impressions of a user's teeth and gums as well as extraoral features of the mouth and lips. The image acquisition method **200** may comprise one or more calibration steps **210**, wherein the calibration steps **210** may include the step of scanning a manufactured model of teeth and gums and adjusting parameters of the scanned image data **150** to be set substantially equal to the calibrated model. The image acquisition method **200** may comprise one or more device placement steps (Block **220**), which generally involves insertion of the embodied device into the mouth of a user. In embodiments wherein two dental trays **10** are in a stacked configuration, the image acquisition method **200** may further comprise the step of a measuring relative bite or jaw positions (Block **230**) and the envelope of motion, the former of which is generally performed by having the user bite the dental trays **10** together, the latter of which is generally performed by having the user move the bottom jaw up, down, left, right, and diagonal within the dental tray **10** relative to the initial jaw position and comparing with the initial jaw position data. The image acquisition method **200** may comprise the step of controlling the degree of suction or blow and affecting the humidity levels proximate to the illumination strips **21** and the imaging sensors **22** (Block **240**).

The image acquisition method **200** may comprise one or more steps of controlling the extent of and the timing of illumination of one or more illumination strips **21** (Block **250**). The image acquisition method **200** may comprise one or more steps of controlling the camera imaging capture timing of imaging sensors **22** (Block **260**).

The image acquisition method **200** may comprise one or more image acquisition steps **270** for acquiring scanned image data **150** of the targeted areas of the patient's teeth and/or gums. During the image acquisition steps **270** of the embodied device **100**, the position and orientation of the oral imaging system **100** is substantially stationary with respect to the oral features being imaged at a given time.

The image acquisition method **200** may comprise one or more steps for generating digital dental impression data **160** using the scanned image data **150** and one or more of a variety of image processing techniques (Block **290**). The 3D digital impression data **160** may then be used by suitable CAD and CAM software to generate a model for the teeth and gums of a user.

FIG. 8 illustrates a flow chart of one embodiment of the image processing module **130** consistent with embodiments of the present disclosure. The capture sequence trigger **128** may initiate the image processing module **130** at the user's desire and may generate any combination of illumination and color capture data **131**, multiple 3D image capture data **132**, position and relation data **133**, triangulation data **134**, or jaw data **135**. Color separation data **136** may be generated from illumination and color capture data **131** and may be used to generate object color data **141** or color rendering reconstruction **144**; the object color data **141** or 3D geometry compensation data **150** may also be used to generate color rendering reconstruction **144**. The color rendering reconstruction **144** may be used to generate geometry compensation **145** or display rendering **147**.



## 11

Multiple 3D image capture data **132** may be used to generate a 3D processing algorithm **137**, which may be used to generate object topography **142** that, along with geometry compensation **145**, may be used to generate a 3D reconstruction **148**. Position data **138** may be generated from position and relation data **133** or triangulation data **134** and may be used to generate a triangulation of 3D data render **143**. Relation data **139** generated from triangulation data **134** or jaw data **135** may also be used to generate a triangulation of 3D data render **143**. The triangulation of 3D data render **143** may then be used to generate a maxillary and mandibular 3D position reconstruction **146**, which may be sent to 3D object storage **152** or used in conjunction with the 3D reconstruction **148** to generate a 3D merge **149**. The 3D merge **149** may be sent to 3D object storage **152** or to a display driver **151** and eventually to a display **153**. Data in the 3D object storage **152** may be stored within a case database **154**.

While particular embodiments of the invention have been described and disclosed in the present application, it is clear that any number of permutations, modifications, or embodiments may be made without departing from the spirit and the scope of this invention. Accordingly, it is not the inventor's intention to limit this invention in this application, except as by the claims.

Particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated. In general, the terms used in the claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention.

The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise embodiment or form disclosed herein or to the particular field of usage mentioned in this disclosure. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Also, the teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

In general, the terms used in the claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

In light of the above "Detailed Description," Inventor may make changes to the invention. While the detailed

## 12

description outlines possible embodiments of the invention and discloses the best mode contemplated, no matter how detailed the above appears in text, the invention may be practiced in a myriad of ways. Thus, implementation details may vary considerably while still being encompassed by the spirit of the invention as disclosed by the inventor. As discussed herein, specific terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated.

What is claimed is:

1. An oral imaging system comprising:

a dental tray in a form of a U-shaped channel formed to at least partially surround teeth and gums;

one or more imaging strips, wherein each imaging strip further comprises a first cover layer and a second cover layer, each said imaging strip comprising an illumination strip and a plurality of imaging sensors, whereby one or more illumination strips or imaging sensors are directly adhered between the first cover layer and the second cover layer, the first and second cover layers are configured to protect the imaging strip; and a handle extending therefrom said dental tray.

2. The oral imaging system of claim 1, whereby said form of a U-shaped channel comprises:

an inner wall with an inner internal surface;

an outer wall with an outer internal surface and an outer external surface; and

a base with a base internal surface and a base external surface, wherein said base interconnects said inner wall and said outer wall.

3. The oral imaging system of claim 2, wherein at least one said imaging strips is adhered directly to or incorporated within said inner internal surface, said outer internal surface, or said base internal surface.

4. The oral imaging system of claim 1, further comprising a computing device, and one or more communication links between said computing device and one or more of said dental tray, wherein said one or more communication links are configured to transmit or receive imaging signals between said one or more imaging strips and said computing device.

5. The oral imaging system of claim 4, wherein said computing device comprises a power source, a computer-readable storage medium, and a processor, wherein said storage medium comprises a control module and an image processing module.

6. The oral imaging system of claim 5, wherein said control module comprises:

a humidity suction and blow control for controlling the humidity and degree of either reduced or elevated pressure in said one or more imaging strips;

an illumination control for controlling a degree of illumination for each illumination strips;

a camera imaging capture control for controlling a capture timing of said imaging sensors; and

a data transmission control for controlling transmission of representative data.

7. The oral imaging system of claim 5, wherein said image processing module comprises:

a still image capture module;

a video capture module; or

a real-time imaging module.

## 13

8. The oral imaging system of claim 4, wherein one or more said imaging sensors are configured to acquire images of teeth and gum regions and transmit said images to said computing device.

9. The oral imaging system of claim 1, wherein said one or more illumination strips comprises a plurality of adjacently positioned individual light sources or a single continuous illuminating extension.

10. The imaging system of claim 1, wherein the first cover layer is configured to have a thickness configured to provide a minimal distance between one or more imaging strips and a target.

11. The imaging system of claim 1, wherein at least one said one or more imaging strips comprises:

one or more fluid collection channels extending along a back portion of at least one transverse end portion of said one or more imaging strips;

one or more blow channels extending adjacently along said one or more transverse end portions and designed to communicate fluid from one or more blow channel openings to said fluid collection channels, wherein each fluid collection channels are designed to communicate fluid between one or more blow channels and a vacuum or pressurized air source.

12. The imaging system of claim 11, wherein at least one imaging strip comprises one or more mesh positioned at one or more blow channel openings.

13. The imaging system of claim 1, wherein said imaging sensors are configured into a condensed matched configuration, a condensed alternating configuration, an expanded matched configuration, or an expanded alternating configuration.

14. The oral imaging system of claim 1, further comprising an extraoral extension, said extraoral extension comprising an extraoral elongation with an extension internal surface having an extraoral imaging strip configured to provide extraoral imaging, whereby said extraoral elongation is designed to be positioned in close proximity to lips or an extraoral region of a user, and whereby said extraoral extension is reversibly fastenable to said handle or to said dental tray.

15. The oral imaging system of claim 14, further comprising one or more additional imaging strips adhered directly to or incorporated within said extension internal surface, whereby each said additional imaging strip is oriented length-wise parallel with a curvature of said extension internal surface.

## 14

16. An oral imaging system comprising:

a first dental tray and a second dental tray, wherein each of said first dental tray and said second dental tray comprises a form of a U-shaped channel formed to at least partially surround teeth and gums, whereby said form of a U-shaped channel comprises an inner wall with an inner internal surface and inner external surface, an outer wall with an outer internal surface and an outer external surface, and a base with a base internal surface and a base external surface, wherein said base interconnects said inner wall and said outer wall;

wherein said first dental tray and said second dental tray are arranged in a stacked configuration with a first base exterior wall external surface of said first dental tray adjacently positioned configured to be substantially parallel with a second base exterior wall external surface of said second dental tray;

one or more imaging strips on each of said first dental tray and said second dental tray, each said imaging strip comprising an illumination strip and a plurality of imaging sensors; and

wherein one of two said dental trays further comprises a ramp having a triangular pyramidal shape, wherein the ramp is positioned on said base internal surface of one of said first dental tray or said second dental tray.

17. The oral imaging system of claim 16, further comprising a rail, a rail insert; wherein the rail is positioned on the base external surface of the first tray and is configured to couple with the rail insert positioned on the base external surface of the second tray.

18. A method for scanning images of a mouth region, said method comprising the steps of:

placing one or two dental trays into a mouth of a patient; acquiring scanned image data of one or more targeted areas of the mouth via one or more imaging sensors and illuminations strips positioned along one or more surfaces of the one or two dental trays;

calibrating an oral imaging system;

measuring relative jaw positions;

controlling a degree of suction or blow and affecting humidity levels proximate to one or more illumination strips or one or more imaging sensors;

controlling an extent of and timing of illumination of one or more illumination strips;

controlling a camera imaging capture timing of one or more imaging sensors; and

generating digital dental impression data using said scanned image data.

\* \* \* \* \*