METHOD AND DEVICE FOR DETERMINING THE INTRAOCULAR PRESSURE, BY MEASURING THE CHANGING OF THE FREQUENCY CHARACTERISTICS
VERFAHREN UND GERÄT ZUR BESTIMMUNG DES AUGENDRUCKES DURCH MESSUNG DER ÄNDEMUNG DES FREQUENZVERHALTENS
PROCEDE ET DISPOSITIF DE DETERMINATION DE LA PRESSION INTRA-OCULAIRE EN MESURANT LE CHANGEMENT DES COURBES DE RESONANCE

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Description

[0001] The present invention relates to a method and device for determining the internal pressure in an eye, the so-called intraocular pressure (IOP).

[0002] As long-term increased pressure in the human eye can lead to blindness, the pressure is routinely measured at all eye clinics. An application method is normally used at the clinic, e.g. the so-called Goldman applanation tonometer, which means that a probe is brought to press against the eye until a predetermined deformation is reached and the force required is read.

[0003] The basis of the pressure determination is then the known relation between pressure, force and area:

\[ P = \frac{F}{A} \]

where \( P \) = pressure, \( F \) = force and \( A \) = area

[0004] The internal pressure of the eye can thus be calculated from the contact force against the eye and the area of deformation of the eye.

[0005] To establish that a specified deformation (area) has been reached, a fluorescent chemical is introduced to the eye and the eye is illuminated so that changes in light reflection at deformation can be read.

[0006] Another method is used when the demand on accuracy is not so high. It is a method where a jet of pressurised air is used to deform the eye with a specified force, whereby the deformation is read by detecting light reflections. This method has no physical contact between a fixed object and the eye.

[0007] Both methods are based on a force deforming the eye, which the patient can experience as being uncomfortable or painful, even though local anaesthetic is used with, for example, the Goldman method.

[0008] In addition, the former method has shown to be sensitive to astigmatism, as light refraction is always employed during measurement of the deformation of the eye. The latter method has documented shortcomings in precision and is thus not used when the nominal pressure is to be determined, but is often used instead by opticians, etc., for an initial measurement of the magnitude of the pressure.

[0009] There is always a risk of damaging the eye, especially the cornea, when the eye is pressed. This is one reason why it is desirable to minimise the contact force against the eye. The lowest force possible is determined according to the equation above by the area or deformation that is needed for this area to be correctly detected. The light reflection method that is used to detect or read the area of deformation requires a relatively large area for a correct reading and thus an equivalent relatively large force.

[0010] It is the aim of the present invention to alleviate or overcome the disadvantages stated above for known methods and devices for measuring the internal pressure in an eye.

[0011] This aim is achieved with a method and device that is first mentioned above and that has the characteristics that are defined in the following independent claims.

[0012] These and further characteristics and advantages of the invention will become evident from the following detailed description of preferred embodiments of the invention, which constitute an example and as such are not limiting for the scope of protection of the invention.

To simplify understanding, the text includes references to an enclosed drawing. Fig. 1 shows schematically parts in a device according to one embodiment of the invention.

[0013] According to the present invention, a vibrating or oscillating contact body is pressed against the eye to determine the deformation of the eye.

[0014] We have found that changes in the frequency characteristic, between on the one hand a system oscillating in resonance and on the other hand the system partly brought into contact with an eye to form a new system oscillating in resonance, are dependent on the surface area of the contact.

[0015] One method for determining the pressure \( p \) in an eye, the so-called intraocular pressure, includes a contact body with known geometry being pressed against the eye with a progressively increasing force \( F \) and that when the deformation area \( A \) of the eye has been determined, the pressure is obtained from the relation \( P = \frac{F}{A} \). New for the invention is to read the frequency characteristic \( f_{char} \) of a, to the contact body associated, sensor system oscillating in resonance, to thereafter press the contact body against the eye to form a new system oscillating in resonance, to read the contact force and the frequency characteristic for the new system, and to calculate the change in the frequency characteristic, whereby the pressure of the eye can be determined since the sought deformation area \( A \) is a function of the change \( f_{char} \), calibrated for the actual sensor system. Calibration of the measurement instrument and measurement devices constitutes known moments and will therefore not be described in greater detail here.

[0016] The force with which the contact body is pressed against the eye can thus be adapted depending on the pressure of the eye so that a lower pressure is determined with a lower contact force against the eye and a higher pressure is determined with a higher contact force, whereby a high precision of measurement is obtained with minimum contact force over large intervals of pressure.

[0017] In an alternative embodiment, the frequency characteristic can be read continuously and the contact force \( F \) against the eye can be increased until a desired change in the frequency characteristic \( \Delta f_{char} \) has been reached, whereby the contact force \( F \) can be read and the pressure calculated as a function of the contact force \( F \) at a specific change in the frequency characteristic \( f_{char} \).

[0018] In a further embodiment, repeated readings can be made of the contact force \( F \) and the frequency characteristic while keeping the contact body pressed against the eye, whereby a series of measured values
are obtained. A series of measured values increases the possibility of identifying and discarding measured values that fall outside the range of reliable measurements, for example, because the contact force was too low or because the force was so large that the deformation formed became larger than the area of contact.

[0019] During measurement and calculation of the frequency characteristic, components such as resonance frequency or phase can, for example, be used.

[0020] The enclosed figure shows schematically a device according to one embodiment of the present invention. The device shows a sensor 1 arranged in position to measure the intraocular pressure in an eye 2. The sensor 1 is supported by an arrangement 3 for regulating the pressing of the sensor 1 against the eye. Arrangement 3 can control the force with which the sensor is pressed against the eye.

[0021] The sensor includes a contact body 4 having a contact area 5 that abuts the eye.

[0022] The contact body is supported in the sensor by, or it forms an integrated part of, an oscillating unit. In the embodiment shown, the oscillating unit 7 is a piezo-electric element. The piezo-electric element is appropriately suspended in a casing 10 that allows the piezo-electric element to swing as freely as possible. Attached to the piezo-electric element 7 is a smaller piezo-electric element 6, a so-called pick-up, firmly fixed, which is used to capture the oscillations in the piezo-electric element.

[0023] A means of driving is connected to the oscillating unit 7 to achieve its oscillating movement. In the present embodiment, a feedback circuit 8 is connected to the piezo-electric element 7 to feed back the oscillations registered by the pick-up 6 and to achieve a resonance oscillation in the system.

[0024] In the embodiment shown schematically in the figure, the piezo-electric element 7 is connected to earth and to a band-pass filter BP. The pick-up 6 is glued firmly to the piezo-electric element 7 and connected to an amplifier Am, which in turn is connected to the band-pass filter BP for feed-back. Am and BP are tuned for optimal oscillation conditions, i.e. resonance frequency.

[0025] In addition, a means 9 for reading the frequency characteristic is connected to the system. This means 9 can be an ordinary frequency counter or another instrument suitable for signal processing.

[0026] Furthermore, it is advantageous if a calculator unit 11 is connected to the frequency counter for calculating the frequency difference.

[0027] In this embodiment, the contact surface is flat. The surface can, for example, be provided with a structure or pattern to displace the tear fluid. The contact surface can also be made concave with a radius of curvature that exceeds that of the surface of the eye against which it is intended to be pressed.

[0028] In a further embodiment, the contact surface can also be made convex. This is preferable when, for example, measuring the pressure of an eye that has a flat cornea. Flat corneas can, for example, be the result for someone who has undergone correction of their sight by smoothing the cornea by treatment with a laser, for example.

[0029] The contact body should be made of an electrically insulating material that prevents galvanic connections between the piezo-electric element and the eye. The contact body can advantageously be made of a polymer material. In addition, the contact body should have acoustic properties that allow frequencies to be transmitted to the eye. The piezo-electric element should be encased to avoid galvanic connections between the piezo-electric element and body of the patient or the treating person.

[0030] When the system is brought to oscillate in resonance and the frequency characteristic of the system has been read, the system is ready for measurement. Contact surface 5 is brought oscillating against an eye whose pressure is to be determined. The contact force and the frequency characteristic for the system then oscillating in resonance are then read. One or more readings can be taken for each occasion of measurement.

[0031] With the help of the previously made calibrations of the sensor system, the contact area can be interpreted from changes in frequency characteristic \( f_{\text{char}} \) and the pressure of the eye can be established.

[0032] To obtain reliable values, the area of the contact surface (5) must exceed that area that is formed when pressing against the eye.

[0033] The advantage of the method described here is obvious as it does not require a predetermined area of deformation and thus no lower limit of contact force for determining the pressure. Furthermore, the use of fluorescent chemicals in the eye is avoided.

[0034] As the device can be used for continuous measuring and gathering of information, it is also possible to study the pulsation in the intraocular pressure during a period of measurement. This pulsation can be affected by different underlying illnesses.

Claims

1. Method for measuring the pressure \( p \) in an eye, the so-called intraocular pressure, that includes a contact body with a known geometry, being pressed against the eye with a gradually increasing force \( F \) and that when the area of deformation of the eye \( A \) can be determined, the pressure can be obtained from the correlation, \( P = F/A \) characterised in that the frequency characteristic of a contact body associated with a sensor system oscillating in resonance is read, that the contact body is pressed against the eye to form a new system oscillating in resonance, that the contact force and frequency characteristic for the new system is read, and that the change in frequency characteristic is calculated, whereby the pressure of the eye can then be deter-
minded since the deformation area $A$ sought is a function of the change $A(f_{\text{char}})$.

2. Method according to claim 1 characterised in that the force with which the contact body is pressed against the eye is chosen depending on the pressure of the eye, so that a lower pressure is determined with a lower contact force against the eye and a higher pressure is determined with a higher contact force, whereby a high degree of measurement accuracy is obtained with a minimal contact force over a large pressure interval.

3. Method according to claim 1 characterised in that the frequency characteristic is read continuously, that the contact force $F$ is increased until a desired change in the frequency characteristic $f_{\text{char}}$ has been reached, that the contact force $F$ is read and that the pressure is determined as a function of the contact force $F$ at a specified change of frequency characteristic $f_{\text{char}}$.

4. Method according to claim 1 or 3 characterised in that repeated readings of the contact force $F$ and frequency characteristic are made while the contact body is pressed against the eye, whereby a series of measurement values are obtained.

5. Method according to any of claims 1-4 characterised in that the frequency characteristic is described by one of either the change in resonance frequency $f$ or the change in phase $\varphi$.

6. Device for measuring the internal pressure in an eye, the so-called intraocular pressure, having a contact body (4) for pressing against the eye (1) and a means (3) of determining the force with which the contact body is pressed against the eye, characterised in that the contact body (4) is part of a system oscillating in resonance, and that the resonance system is connected to a means (9) for reading the frequency characteristic of the system.

7. Device according to claim 6 characterised in that the system oscillating in resonance includes a piezo-electric element.

8. Device according to claim 6 or 7 characterised in that the contact body (4) has a flat surface of contact (5) and that the contact surface preferably has a structure or a pattern.

9. Device according to any of claims 6 to 8 characterised in that a means is arranged for calculating the change in frequency characteristic.

10. Device according to any of claims 6 or 7 characterised in that the contact surface (5) is concave, preferably with a radius of curvature that exceeds the radius of curvature of the surface of the eye against which it is intended to be pressed.

11. Use of the device according to claim 6 for measuring pulsation in the intraocular pressure.

Patentansprüche

1. Verfahren zur Messung des Drucks $p$ im Auge, d.h. des sogenannten intraokularen Drucks, mit einem Kontaktkörper mit bekannter Geometrie, der mit einer schrittweise zunehmenden Kraft $F$ gegen das Auge gedrückt wird, wobei sich der Druck aus der Beziehung $P=F/A$ ergibt, wenn die Verformungsfläche $A$ des Auges bestimbar ist, dadurch gekennzeichnet, dass der Frequenzgang eines Kontaktkörpers gelesen wird, der mit einem in Resonanz schwingenden Sensorsystem verbunden ist, dass der Kontaktkörper gegen das Auge gedrückt wird, um ein neues in Resonanz schwingendes System zu bilden, dass die Kontaktkraft und der Frequenzgang des neuen Systems gelesen werden und die Änderung des Frequenzgangs berechnet wird, wodurch der Augendruck bestimmt werden kann, da die gesuchte Verformungsfläche $A$ eine Funktion der Änderung $A(f_{\text{char}})$ ist.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass die Kraft, mit welcher der Kontaktkörper gegen das Auge gedrückt wird, in Abhängigkeit vom Augendruck gewählt wird, so dass ein niedrigerer Druck mit einer niedrigeren Kontaktkraft gegenüber dem Auge und ein höherer Druck mit einer höheren Kontaktkraft bestimmt wird, wodurch mit einer minimalen Kontaktkraft in einem grossen Druckbereich eine hohe Messgenauigkeit erzielt wird.

3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass der Frequenzgang laufend gelesen wird, dass die Kontaktkraft $F$ erhöht wird, bis eine gewünschte Veränderung des Frequenzgangs $f_{\text{char}}$ eintritt, dass die Kontaktkraft $F$ gelesen wird und der Druck als Funktion der Kontaktkraft $F$ bei einer bestimmten Änderung des Frequenzgangs $f_{\text{char}}$ bestimmt wird.

4. Verfahren nach Anspruch 1 oder 3, dadurch gekennzeichnet, dass die Kontaktkraft $F$ und der Frequenzgang wiederholt gemessen werden, während der Kontaktkörper ans Auge angedrückt wird, wodurch eine Reihe von Messwerten gewonnen wird.

5. Verfahren nach einem der Ansprüche 1-4, dadurch gekennzeichnet, dass der Frequenzgang entwe-
der durch die Änderung der Resonanzfrequenz $f$ oder durch die Phasenänderung $\varphi$ beschrieben wird.

6. Vorrichtung zur Messung des Innendrucks in einem Auge, d.h. des sogenannten intraokularen Drucks, mit einem Kontaktkörper (4), zum Andrücken ans Auge (1) und einem Mittel (3) zur Bestimmung der Andruckkraft des Kontaktkörpers gegenüber dem Auge, dadurch gekennzeichnet, dass der Kontaktkörper (4) Teil eines in Resonanz schwingenden Systems ist und dass das Resonanzerstreckung mit einem Mittel (9) zum Anzeigen des Frequenzgangs des Systems verbunden ist.

7. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, dass das in Resonanz schwingende System ein piezoelektrisches Element enthält.

8. Vorrichtung nach Anspruch 6 oder 7, dadurch gekennzeichnet, dass der Kontaktkörper (4) eine flache Kontaktfläche (5) aufweist, und dass die Kontaktfläche vorzugsweise strukturiert oder mit einem Muster versehen ist.

9. Vorrichtung nach einem der Ansprüche 6 - 8, dadurch gekennzeichnet, dass ein Mittel zur Berechnung der Änderung des Frequenzgangs vorgesehen ist.

10. Vorrichtung nach einem der Ansprüche 6 oder 7, dadurch gekennzeichnet, dass die Kontaktfläche (5) konkav ist, vorzugsweise mit einem größeren Krümmungsradius als dem Krümmungsradius der Augenoberfläche, an welche sie angedrückt werden soll.

11. Anwendung der Vorrichtung nach Anspruch 6 zur Messung der Pulsation des intraokularen Drucks.

**Revendications**

1. Procédé de mesure de la pression $p$ d’un œil, c’est-à-dire de la pression dite intraoculaire, comprenant un corps de contact de géométrie connue, lequel est pressé contre l’œil avec une force $F$ graduellment croissante, la pression pouvant être obtenue sur la base de la relation $P = F/A$ lorsque la superficie $A$ de déformation de l’œil peut être déterminée, **caractérisé en ce que** la courbe de résonance d’un corps de contact associé à un système capteur oscillant en résonance est relevé, que le corps de contact est pressé contre l’œil afin de former un nouveau système oscillant en résonance, que la force de contact et la courbe de résonance du nouveau système sont lues, et que la variation de la courbe de résonance est calculée, ce qui permet de déterminer la pression de l’œil puisque la superficie de déformation $A$ recherchée est une fonction de la variation $A(f_{\text{char}})$.  

2. Procédé selon la revendication 1, **caractérisé en ce que** la force avec laquelle le corps de contact est pressé contre l’œil est choisie en fonction de la pression de l’œil, afin qu’une pression plus basse soit déterminée en appliquant une force de contact plus basse contre l’œil et qu’une pression plus grande soit déterminée en appliquant une force de contact plus basse, ce qui permet d’obtenir une haute précision de mesure dans un grand intervalle de pression avec une force de contact minimale.

3. Procédé selon la revendication 1, **caractérisé en ce que** la courbe de résonance est relevée continuellement, que la force de contact $F$ est augmentée jusqu’à ce qu’un changement souhaité de la courbe de résonance $f_{\text{char}}$ soit obtenue, que la force de contact $F$ est relevée, et que la pression est déterminée en fonction de la force de contact $F$ lors d’un changement spécifié de la courbe de résonance $f_{\text{char}}$.

4. Procédé selon la revendication 1 ou 3, **caractérisé en ce que** des lectures répétées de la force de contact $F$ et de la courbe de résonance sont effectuées pendant que le corps de contact est pressé contre l’œil, de manière qu’une série de valeurs de mesure est obtenue.

5. Procédé selon l’une quelconque des revendications 1 à 4, **caractérisé en ce que** la courbe de résonance est décrite soit par le changement de la courbe de résonance $f$ ou par le changement de phase $\varphi$.

6. Dispositif de mesure de la pression intérieure d’un œil, c’est-à-dire de la pression dite intraoculaire, comprenant un corps de contact (4) destiné à être pressé contre l’œil (1) et un moyen (3) permettant de déterminer la force avec laquelle le corps de contact est pressé contre l’œil, **caractérisé en ce que** le corps de contact (4) fait partie d’un système oscillant en résonance, et que le système de résonance est relié à un moyen (9) permettant de relever la courbe de résonance du système.

7. Dispositif selon la revendication 6, **caractérisé en ce que** le système oscillant en résonance comporte un élément piezoelectrique.

8. Dispositif selon la revendication 6 ou 7, **caractérisé en ce que** le corps de contact (4) a une surface de contact (5) plate, et que la surface de contact présente de préférence une structure ou une forme.

9. Dispositif selon l’une quelconque des revendica-
tions 6 à 8, caractérisé en ce qu’un moyen est prévu pour calculer le changement de la courbe de résonance.

10. Dispositif selon l’une quelconque des revendications 6 ou 7, caractérisé en ce que la surface de contact (5) est concave, préférentiellement avec un rayon de courbure supérieur au rayon de courbure de la surface de l’œil contre laquelle elle est destinée à être pressée.

11. Utilisation du dispositif selon la revendication 6 pour la mesure de la pulsation de la pression intraoculaire.