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(54) **DIAGNOSTIC METHOD AND APPARATUS FOR PREDICTING POTENTIAL PRESERVED VISUAL ACUITY**

DIAGNOSEVERFAHREN UND VORRICHTUNG ZUR VORHERSAGE VON MÖGLICHER ERHALTENER SEHSCHÄRFE

PROCÉDÉ DE DIAGNOSTIC ET APPAREIL POUR PRÉDIRE UNE ACUITÉ VISUELLE CONSERVÉE POTENTIELLE

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Description

Field of the Invention

[0001] This invention relates to the field of ophthalmology, and in particular to a method and apparatus for predicting potential preserved visual acuity in patients with impaired vision.

Background of the Invention

[0002] There are many reasons for patients to incur visual impairment, and in such cases it is important for the ophthalmologist to be able to determine the visual function and predict the visual outcome after treatment. For example, it would be futile for a patient to undergo surgical intervention if the condition of the retina is such that no possibility of improvement exists.

[0003] One common cause of visual impairment is macular oedema. Macular oedema results from abnormal accumulation of fluid in the central retina and indicates compromised function in one or both of the blood retinal barriers. It is a common sequel of many ocular conditions and the main cause of visual loss in diabetic retinopathy.

[0004] Any abnormal pooling of extracellular fluid may result in displacement of the spatial relationships between retinal neuronal components. Small amounts of fluid may lead to an increase in overall retinal thickness, whilst larger amounts may give rise to cell free spaces as seen in cystoid macular oedema.

[0005] It is known to predict visual acuity by measuring macular thickness. Such an example is non-patent literature document: "Patterns of Macular Edema in Patients with Uveitis "by N. Markomichelakis et al., Ophtalmology, J.B. Lippincott co., Philadelphia, DA, US, vol. 111, NO.5, 1 May 2004, pp. 946 - 953. However, qualitative analysis of data describing the relationship between central macular thickness (CMT) and visual acuity shows that the correlation between CMT and visual acuity is only moderate that CMT is only able to predict 16.6% of visual acuity.

SUMMARY OF THE INVENTION

[0006] It is an object of the invention to provide a method of predicting potential visual acuity with improved performance as well as the corresponding apparatus and computer program product as defined by the claims.

[0007] According to the present invention there is provided a method of determining a potential preserved visual acuity in a retina of a patient, the method comprising imaging the retina of the patient to create a dataset corresponding to an amount of tissue connecting inner and outer plexiform layers at different distances from the fovea, and computing the potential preserved visual acuity from said dataset.

[0008] The inventors have shown that there is a good correlation between the amount of remaining tissue connecting the inner and outer plexiform layers and potential visual acuity. The reason for this correlation is believed to be that the retinal tissue within these layers provides axonal connections within the retina between the photoreceptors and ganglion cells, and the measure of preserved axonal connections is a good indicator of preserved visual acuity.

[0009] In one embodiment, a series of coronal images are taken at different distances from the fovea. These provide a series of concentric rings (which may or may not be circular) of different radii surrounding the fovea. The amount of tissue remaining between the plexiform layers computed from an analysis of the image dataset. The inventors have found that connecting tissue in the region between about 1000-2000 microns from the fovea is the most effective predictor of preserved visual acuity.

[0010] The plane in which the amount of tissue is determined may be the minimum detectable plane between the inner and outer plexiform layers. In this context, it will be understood that the term plane is used to define a layer having a finite thickness following a planar contour.

[0011] Additionally, the level of visual acuity can be determined from an analysis of the sizes, for example the minimum sizes, of Muller fibers and/or bipolar cells connecting the inner and outer plexiform layers.

[0012] The measurements are preferably taken with a suitable imaging and processing system such as Optical Coherence Tomography (OCT), ultrasound, or confocal. A preferred system uses a combined OCT/confocal system that allows the OCT and confocal images to be displayed with a pixel for pixel correspondence on a computer screen.

[0013] In another aspect the invention provides a diagnostic apparatus configured to determine the potential preserved visual acuity in a retina of a patient, comprising an imaging system configured to obtain images of the retinal tissue between the inner and outer plexiform layers; and a processor configured to process said images to obtain the potential preserved visual acuity based on an amount of said retinal tissue between said inner and outer plexiform layers as observed by said imaging system.

[0014] The processor may select the layer and position to measure the amount of connecting tissue automatically, and may make an indirect measurement of the amount of tissue connecting the inner and outer plexiform layers.

[0015] In another aspect the invention provides a computer program product comprising a storage medium having

stored therein instructions for processing a dataset derived from a 3D ophthalmic imaging system to derive therefrom the amount of tissue connecting the inner and outer plexiform layers in the retina, and to compute from said dataset the potential preserved visual acuity based on the amount of said retinal tissue remaining between said inner and outer plexiform layers as observed by said imaging system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:-

FIG. 1 shows light microscopy and optical coherence tomography images of a human retina affected by cystoid macular oedema (CMO).
FIG. 2 is a scanning electron microscopy image of cystoid macular oedema.
FIG. 3A is a macular thickness map of a patient with macular oedema representing subfield mean thicknesses as from ETDRS study;
Figure 3B is a grayscale coronal OCT scan with superimposed grid dividing the macula in 5 areas of increasing eccentricity (radii:500μ, 1000μ, 1500μ, 2000μ, 2500μ).
Figure 4 shows scatter plots of the relationship between a) Central macular thickness versus LogMAR VA (rs=0.407*); b) Tissue integrity within circle 1 versus LogMAR VA (rs=-0.832*); c) Tissue integrity within circle 2 versus LogMAR VA (rs=-0.841*); d) Tissue integrity within circle 3 versus LogMAR VA (rs=-0.624*); e) Tissue integrity within circle 4 versus LogMAR VA (rs=-0.277*); and f) Tissue integrity within circle 5 versus LogMAR VA (rs=-0.134*).
Figure 5 shows the variation in R2 values representing the association between visual acuity and retinal spared tissue at increasing eccentricity as well as visual acuity and central macular thickness (CMT);
Figure 6 is a scatter plot, with line of equality, for measured versus predicted LogMAR visual acuity using the linear regression model;
Figure 7 is a Bland-Altman mean-difference plot demonstrating agreement between measured and predicted Log-MAR visual acuity;
Figure 8 is a Bland-Altman mean-difference plot showing bias (solid line) and upper and lower limits of agreement (dashed line); and
Figure 9 is a block diagram showing an apparatus in accordance with one embodiment of the invention.

Detailed Description of the Invention

[0017] Observations from histology and optical coherence tomography (OCT), as shown in Figure 1, give a false impression of multiple cysts delineated by tissue structures in the Z-plane of the retina. However, scanning electron microscopy, as shown in Figure 2, shows that more commonly a single cystic space is present within which a number of structures extend from the inner to the outer retina. Such structures consist of columns of Muller's fibers together with the axonal elements of bipolar cells passing between the two plexiform layers. Empirical studies have demonstrated that the two plexiform layers together with the outer limiting membrane form a physical resistance barrier to fluid movements. Thus, extracellular fluid may be contained within layers defined by these resistance barriers. In diabetic retinopathy, cystic spaces may occur either between the inner and the outer plexiform layers or between the outer limiting membrane and the outer plexiform layer. In the former location, there is a potential to displace bipolar cells leading to cell loss or compromised function, while in the latter, only photoreceptor cells are at risk.

[0018] Given the fundamental role of bipolar cells as the sole communication pathway between photoreceptors and ganglion cells, any loss of connectivity between these cells will compromise visual function. It therefore follows that the more the retinal thickness increases, the more such axons will be stretched. As a consequence some will break. This phenomenon is believed to explain the mechanism underlying the apparent relationship between increasing retinal thickness and decreasing visual acuity.

[0019] By contrast, those bipolar cells whose axons are closely adjacent to Muller's fibers will have a greater chance of surviving displacement because of the greater physical strength and support provided by the adjacent Muller's fibers.

[0020] The inventors have shown that a useful indicator of the visual acuity and potential visual outcome in eyes with macular oedema is to analyze the residual volume of tissue passing between the two plexiform layers, as only such areas would allow passage of bipolar axons between photoreceptors and ganglion cells. The impact of photoreceptor-ganglion cell connectivity on visual acuity further depends upon the location of surviving axons within the central visual field. An optimal measurement of potential function would be an evaluation of the number of vertical elements passing between the plexiform layers, their diameter and eccentricity from the fovea.

Experimental results

[0021] Patients with macular oedema were prospectively recruited from both diabetic and uveitic outpatient clinics over a period of nine months. The study involved a baseline assessment of visual function, ophthalmoscopy and OCT imaging at a single timepoint. Patient information was anonymized at the time of patient recruitment to allow independent data analysis.

[0022] Inclusion criteria for the study were a clinical diagnosis of cystoid macular oedema (CMO), confirmed either by OCT alone or by OCT and fundus fluorescein angiography (FFA) at the time of enrolment. For each patient either one or both eyes were included in the study.

[0023] Patients with coexisting ocular pathologies were excluded. Exclusion criteria included the presence of media opacity affecting the quality of the OCT scan and angiographic or clinical evidence of ischaemic maculopathy.

[0024] Each patient underwent a complete anterior segment examination by slit-lamp biomicroscopy and best corrected visual acuity assessment using a LogMAR chart at 3 meters distance. All patients were then dilated using Phenylephrine 2.5% and Tropicamide 1% and examined by indirect fundoscopy with a 78D lens. In the diabetic patients, fluorescein angiography was required as one of the inclusion criteria of the study in order to assess retinal circulation and to allow exclusion of patients with subclinical foveal ischaemia.

[0025] Optical coherence tomography was carried out using a Spectrum-OTI spectral domain OCT/SLO system (Spectral OCTSLO model E, Spectrum-Ophthalmic Technologies Inc., Toronto, Canada). This device is an optical imaging system, combining a Confocal Scanning Ophthalmoscope and Optical Coherence Tomography. Both the confocal fundus SLO image and the OCT image are generated through the same optics and displayed simultaneously on the computer screen with pixel to pixel correspondence. The system uses light generated from an infrared broadband super luminescent diode (SLD) with a wavelength between 790nm and 950nm. Cross-sectional images of the retina along the x-y plane (B-Scan), such as single line, radial and raster scans, could be obtained as well as coronal images within the z plane (C-scan). The setup is shown in Figure 9, where the OCT/SLO unit 10 was used to image the eye of patient 12. The results were processed in computer 14 and displayed on screen 16.

[0026] A state of the art Fourier domain OCT device, such as described above, and designed for ophthalmic use can typically capture axial data over 2mm in depth (measured in air) at 20,000 lines per second. The scan pattern across the retina can be arranged in a grid of 200 by 200 points with a spacing between lines and rows of around 25 microns. This scan pattern is centered on the fovea with a capture time of 2 seconds. The imaging depth is defined by several parameters, but the useful depth for use in this analysis is at least 1.5mm measured in air.

[0027] Automated methods to adjust for patient movement during acquisition can be employed on the dataset prior to analysis. This can make use of the fast acquisition and small spacing between lines and rows, but can take the form of other simultaneous acquisition streams.

[0028] Analysis of the 3D dataset is achieved by segmenting the dataset through the retina in the coronal plane to view tissue present at a level between the inner and outer plexiform layers of the retina. In this embodiment the segmentation thickness would be around 10 microns (the resolution of the system in the axial direction).

[0029] From this segmented view (image), the image is processed to a 2 bit image so that each pixel is either turned into a one or zero (where a one would be tissue and a zero, none or oedema). The amount of remaining tissue within a 1 mm radius of the anatomical fovea is measured and this used as a predictor of the visual acuity that could be potentially achieved after treatment and resolution of the oedema.

[0030] In preliminary studies, scans were obtained using three different modes of operation. First, a series of 24 radial scans over 360 degrees were automatically initiated intersecting at the centre of the patient's fixation. Secondly, a single scan mode was selected whose orientation and location within the fundus was determined by the operator. Thirdly, the system was used to generate a raster scan of the macula from the superior to the inferior arcade with 64 scans, again centred by the patient's fixation.

[0031] Three dimensional views of the macula were obtained by selecting the topography mode where images were viewed as surface maps and these were extracted manually by slicing the 3-D picture using the device based image analysis software. The topography scan also allowed the operator to extract information about retinal thickness in different areas of the posterior pole by using the ETDRS macular grid. Coronal scans (C-scans) were fundamental to the present study and obtained by selecting the mid point between the ganglion cell layer and the innermost aspect of the outer plexiform layer, in most cases to mid depth of the cysts. In practice this was obtained by adjusting the section plane to an appropriate level parallel with the retinal surface in the B scan displayed on the x-axis of the coronal image (Figure 3A).

[0032] The image analysis system extracted three datasets, namely 1) the number of columns of tissue present 2) their cross-sectional area at their narrowest point 3) and their eccentricity from the foveal centre. Data were collected from a series of concentric rings of 500 μm, 1000 μm, 1500 μm, 2000 μm, 2500 μm radii respectively (Figure 3B). Within each ring, the area of surviving tissue as opposed to cystic space was extracted by first processing the data to compress the grayscale such that tissue became white and the oedema black.

[0033] Next, the data were processed to count the number of white pixels present within each ring, thus giving a

measure proportionate to the potential number of connections passing between the two plexiform layers. The number of pixels of spared tissue within each annulus was converted to an area in mm^2 by scaling the ratio of the number of pixels of spared tissue to the total number of pixels in the annulus by the area in mm^2 of the annulus.

[0034] This study had three primary outcomes: 1) Best corrected Log MAR visual acuity; 2) retinal tissue integrity evaluated as number of pixels corresponding to the tissue component between cystic spaces and observable at increasing eccentricities from the fovea in segmented images of OCT/SLO coronal scans; and 3) central macular thickness measurement obtained from the OCT/SLO retinal thickness map.

[0035] A linear regression model was developed to assess if the amount of glia could be used to predict visual acuity. A data set of 129 eyes were randomized and split into two data sets, one of 100 eyes and the other of 29 eyes.

[0036] The first group of 100 eyes was used to determine the linear regression model. The remaining 29 eyes were used to test the validity of the model in predicting visual acuity. All outcome variables were entered into a stepwise linear regression model with logMAR visual acuity as the outcome variable. LogMAR is a commonly used scale for measuring visual acuity.

[0037] The criterion for entry into the model was P=0.05 and P=0.10 for removal. Stepwise linear regression is an extension of simple linear regression where the dependent variable is predicted by a linear equation involving one outcome or independent variable and a constant. In stepwise linear regression, multiple variables can be linearly combined in the model. They are entered automatically by the statistics software provided they make a statistically significant improvement in the model.

[0038] The remaining 29 eyes were used to test the model by assessing the agreement between the predicted and measured visual acuity using the Bland-Altman method. A total of 81 participants enrolled, 36 males and 45 females. The average age was 63 years (range 26-87 years).

[0039] Most patients (73%, 59 subjects) underwent fluorescein angiography, whereas in the remaining group an angiographic study could not be performed (27%, 22 subjects) due to previously documented adverse reaction to the dye (9 subjects), refusal to the investigation (8 subjects) or technical difficulty to obtain a satisfactory venous access (7 subjects). Typical patient contact time was 40 minutes of which only 5 minutes were required for OCT imaging.

[0040] The distribution of spared retinal tissue values in the concentric annuli varied with eccentricity. Tissue integrity date in ring 1, 2 and 3 were not normally distributed (p=0.001; 0.001; and 0.02 respectively), whereas data related to tissue integrity within rings 4 and 5 displayed a normal distribution (p=0.093 and p=0.2, respectively). Values for central macular thickness showed a normal distribution (p=0.059), whereas LogMAR visual acuity values were not normally distributed. The relationship between tissue integrity at increasing eccentricity and LogMAR visual acuity was significant at the 0.01 level (2 tailed) in circles 1 (r=0.832), 2 (r=0.841), 3 (R=0.624), 4 (R=0.277). The correlation was significant at 0.05 level (2 tailed) in ring 5 (r=0.152).

[0041] Qualitative analysis of the data shows a clear linear relationship between the amount of spared tissue within rings 1 and 2 and Log MAR visual acuity. The relationship between spared tissue in ring 3 and visual acuity was less clear and became even less apparent in rings 4 and 5 (Figure 4).

[0042] The linear regression model demonstrated that measures of tissue integrity derived from rings 1 and 2 predicted up to 74% and 75% of visual acuity respectively. The r^2 values for rings 3, 4 and 5 were significantly lower as shown in the following table.

Table

Variable	R	P (2 tailed)	R2%	R2
CMT	0.047	<0.001	16.6%	0.14
Tissue spared in ring 1 (500μ)	-0.832	<0.001	69.2%	0.74
Tissue spared in ring 2 (1000μ)	-0.841	<0.001	70.7%	0.75
Tissue spared in ring 3 (1500μ)	-0.624	<0.001	38.9%	0.43
Tissue spared in ring 4 (2000μ)	-0.277	0.001	7.7%	0.09
Tissue spared in ring 5 (2500μ)	-0.133	0.132	1.8%	0.092

Comparative example

[0043] The scatter plots shown in Figure 5 represent the relationship between central macular thickness and visual acuity (a) and between spared retinal tissue at increasing eccentricities and visual acuity (b - f) for all 129 eyes.

[0044] Qualitative analysis of data describing the relationship between central macular thickness (CMT) and visual acuity showed a very weak link as shown in Figure 5. The correlation between CMT and LogMAR visual acuity was

moderate (r=0.407). The regression analysis of CMT versus visual acuity demonstrates that CMT predicts only 16% of visual acuity.

[0045] The linear regression model was given by

$$\log MAR = 1.089 + 0.252 \times CMT - 2.140 \times T1 - 0.854 \times T2 \quad (1)$$

where CMT is the central macular thickness in mm and T1 and T2 are the areas of tissue sparing in mm^2 in rings 1 and 2 respectively. This model has an R^2 value of 80.7% indicating that equation (1) explained over 80.7% of the variation in LogMAR visual acuity. It was noteworthy that the most predictive variable was T2 and this alone could predict 74.4% of the variation in LogMAR visual acuity.

[0046] Figure 6 shows a scatter plot of the measured Log MAR visual acuity plotted against the estimated LogMAR visual acuity. A line of equality is shown along which all data points would be expected to lie in presence of perfect agreement. This was not the case, as would be expected from most clinical measures.

[0047] Figure 7 shows the Bland-Altman mean-difference plot for the data. It shows that there is a relationship between the mean LogMAR visual acuity and the differences (r=-0.44; P=0.016). This means that the bias changes with visual acuity and that the limits of agreement will be underestimated for good visual acuity (small values of LogMAR visual acuity) and overestimated for poor visual acuity (high values of LogMAR visual acuity).

[0048] Figure 8 shows the change in bias and limits of agreement with mean LogMAR acuity. A more accurate value for the limits of agreement is $\pm$ 0.17 log units at a LogMAR visual acuity of 0.5 although this changes slightly with the mean measured value.

[0049] The above results also demonstrate that there is a strong correlation between visual acuity in patients with cystoid macular oedema and the volume of tissue passing between the two plexiform layers in the central retina as determined by OCT. It is the first time that a predictive measure of visual performance has been derived from imaging of macular oedema.

[0050] The results demonstrate that good visual acuity only occurred in those patients with an adequate volume of tissue running between the inner and the outer plexiform layers in the central 1000-2000μ of retina (Figure 4 and 5). Given that foveal cones have inner connecting fibers that may be up to 500μm in length, foveolal cones may connect to bipolar cells displaced 500μm radially from the inner and outer segments. Thus this lateral displacement of connections between foveal cones and ganglion cells explains the dependency of visual acuity on the tissue integrity in both rings 1 and 2.

[0051] While there was still reasonable correlation within ring 3, which is believed to be due to signals derived from photoreceptors at the extreme edges of the fovea, correlation was lost within rings 4 and 5. In these locations, although large amounts of tissue volume may be spared, the connectivity is predominantly with extrafoveal photoreceptors.

[0052] From the linear regression model, it appears that a minimum of 50% of preserved retinal tissue within ring 1 is necessary in order to maintain a visual acuity of 0.4 LogMAR or better (Figure 4, scatter plot b), whereas at least 70% of the retinal tissue within ring 2 is necessary for a level of visual acuity of 0.4 LogMAR or better (Figure 4, scatter plot c).

[0053] Even though the total number of bipolar axons traversing the space between the plexiform layers may be significantly reduced, both horizontal and amacrine cells will contribute to image processing and VA by integrating signals over a number of photoreceptor cells and ganglion cells respectively.

[0054] The apparent correlation between the increase in retinal thickness and the decrease in visual acuity in accordance with prior art methods may be explained by the present results whereby increase in thickness will be associated with increase in loss in viable axons. The more direct approach to assessing neuronal survival in the present invention would also explain why the correlation values are so much better.

[0055] The above results establish retinal tissue integrity as a measure of preserved axonal connections and indicator of visual function. The strength of the relationship between preserved tissue and visual function, as expected, decreases at increasing eccentricities from the centre of the fovea.

[0056] The ability to determine the potential visual outcome for patients prior to the commencement of any treatment trial is highly beneficial in that it will allow exclusion of those individuals who could not in anyway benefit from intervention.

[0057] It will be appreciated that the invention could be implemented in software, and as such the invention also extends to a computer program product comprising a storage medium having stored thereon instructions which when executed on a general purpose computer process a dataset obtained from a 3D ophthalmic imaging system, such as an OCT/confocal system, to derive therefrom the amount of tissue connecting the inner and outer plexiform layers remaining in the retina.

Claims

1. A method of determining a potential preserved visual acuity in a retina of a patient, the method comprising imaging the retina of the patient to create a dataset corresponding to an amount of tissue connecting inner and outer plexiform layers at different distances from the fovea, and computing the potential preserved visual acuity from said dataset.

2. A method as claimed in claim 1 wherein said dataset includes the amount of tissue between the outer plexiform layers and the external limiting membrane.

3. A method as claimed in claim 1, wherein said dataset comprises the amount of tissue in a series of concentric rings of different radii surrounding the fovea.

4. A method as claimed in any one of claims 1 to 3, wherein the amount of said tissue is determined in a region lying between 1000 and 2000 microns from the fovea.

5. A method as claimed in claim 1, wherein a plane in which the amount of tissue is determined is the minimum detectable between the inner and outer plexiform layers.

6. A method as claimed in claim 5, wherein the plane in which the measurements are taken is shaped to follow the contour of a predefined surface, said predefined surface being the retinal surface or retinal pigment epithelium layer, and preferably wherein the level of visual acuity is determined from an analysis of the sizes of Muller fibers and/or bipolar cells connecting the inner and outer plexiform layers, and more preferably wherein the amount of said remaining tissue is determined with the aid of an imaging system such as a three-dimensional imaging system, in particular a combined OCT/confocal imaging system.

7. A diagnostic apparatus configured to determine a potential preserved visual acuity in a retina of a patient, comprising:

   an imaging system configured to obtain images of the retinal tissue between the inner and outer plexiform layers; and a processor configured to process said images to obtain the potential preserved visual acuity based on an amount of said retinal tissue between said inner and outer plexiform layers as observed by said imaging system , wherein said processor is programmed to create a dataset corresponding to the amount of said tissue observed by said imaging system at different distances from the fovea, and said potential preserved visual acuity is predicted from an analysis of said dataset.

8. A diagnostic apparatus as claimed in claim 7, wherein said dataset includes the amount of tissue between the outer plexiform layers and the external limiting membrane, and preferably wherein said dataset comprises the amount of tissue in a series of concentric rings of different radii surrounding the fovea, and the processor is preferably configured to determine the amount of said tissue in a region lying between 1000 and 2000 microns from the fovea.

9. A diagnostic apparatus as claimed in any one of claims 7 to 8, wherein said imaging system is configured to determine the amount of tissue in the plane which is the minimum detectable between the inner and outer plexiform layers.

10. A diagnostic apparatus as claimed in claim 7, wherein the plane is shaped to follow the contour of a predefined surface, and wherein said predefined surface is preferably the retinal surface or retinal pigment epithelium layer.

11. A diagnostic apparatus as claimed in claim 7, wherein said processor is programmed to determine the level of visual acuity from an analysis of the sizes of Muller fibers and/or bipolar cells connecting the inner and outer plexiform layers, and said imaging system is preferably a three-dimensional imaging system such as a combined OCT/confocal imaging system.

12. A computer program product comprising a storage medium having stored therein instructions for processing a dataset derived from imaging the retina of a patient with a 3D ophthalmic imagine system at different distances from the fovea to derive therefrom the amount of tissue connecting the inner and outer plexiform layers in the retina, and to compute from said dataset the potential preserved visual acuity based on the amount of said retinal tissue remaining between said inner and outer plexiform layers as observed by said imaging system.

13. A computer program product as claimed in claim 12, wherein said instructions cause said computer to derive obtain measurements made in a series of concentric rings of different radii surrounding the fovea from said dataset.

14. A computer program product as claimed in claim 13, wherein said instructions cause said computer to determine the amount of said tissue in a region lying between 1000 and 2000 microns from the fovea, and preferably cause the computer to obtain measurements from said dataset in a plane shaped to follow the contour of a predefined surface, and wherein said predefined surface is preferably the retinal surface or retinal pigment epithelium layer.

Patentansprüche

1. Verfahren zum Bestimmen einer möglichen erhaltenen Sehschärfe in einer Netzhaut eines Patienten, wobei das Verfahren das Abbilden der Netzhaut des Patienten, um einen Datensatz zu erzeugen, der einer Menge an Gewebe entspricht, das innere und äußere plexiforme Schichten bei unterschiedlichen Abständen von der Sehgrube verbindet, und das Berechnen der möglichen erhaltenen Sehschärfe aus dem Datensatz umfasst.

2. Verfahren nach Anspruch 1, wobei der Datensatz die Menge an Gewebe zwischen den äußeren plexiformen Schichten und der Membrana limitans externa einschließt.

3. Verfahren nach Anspruch 1, wobei der Datensatz die Menge an Gewebe in einer Reihe von konzentrischen Ringen mit unterschiedlichen Radien, welche die Sehgrube umgeben, einschließt.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei die Menge des Gewebes in einem Bereich bestimmt wird, der zwischen 1000 und 2000 Mikrometer von der Sehgrube liegt.

5. Verfahren nach Anspruch 1, wobei eine Ebene, in der die Menge an Gewebe bestimmt wird, die minimal erkennbare zwischen den inneren und äußeren plexiformen Schichten ist.

6. Verfahren nach Anspruch 5, wobei die Ebene, in der die Messungen vorgenommen werden, so geformt ist, dass sie dem Umriss einer vordefinierten Oberfläche folgt, wobei die vordefinierte Oberfläche die Netzhaut-Oberfläche oder die Netzhaut-Pigmentepithelschicht ist, und wobei vorzugsweise das Niveau der Sehschärfe aus einer Analyse der Größen von Müller-Fasern und/oder bipolaren Zellen, welche die inneren und äußeren plexiformen Schichten verbinden, bestimmt wird und wobei insbesondere die Menge des verbleibenden Gewebes mit der Hilfe eines bildgebenden Systems, wie beispielsweise eines dreidimensionalen bildgebenden Systems, insbesondere eines kombinierten OCT-/konfokalen bildgebenden Systems, bestimmt wird.

7. Diagnosevorrichtung, die dafür konfiguriert ist, eine mögliche erhaltene Sehschärfe in einer Netzhaut eines Patienten zu bestimmen, wobei die Vorrichtung Folgendes umfasst:

   ein bildgebendes System, das dafür konfiguriert ist, Bilder des Netzhautgewebes zwischen den inneren und äußeren plexiformen Schichten zu erhalten,
   und einen Prozessor, der dafür konfiguriert ist, die Bilder zu verarbeiten, um auf der Grundlage einer Menge des Netzhautgewebes zwischen den inneren und äußeren plexiformen Schichten, wie durch das bildgebende System beobachtet, die mögliche erhaltene Sehschärfe zu erhalten,
   wobei der Prozessor dafür programmiert ist, einen Datensatz zu erzeugen, welcher der Menge des Gewebes entspricht, das durch das bildgebende System bei unterschiedlichen Abständen von der Sehgrube beobachtet wird, und die mögliche erhaltene Sehschärfe aus einer Analyse des Datensatzes vorhergesagt wird.

8. Diagnosevorrichtung nach Anspruch 7, wobei der Datensatz die Menge an Gewebe zwischen den äußeren plexiformen Schichten und der Membrana limitans externa einschließt und wobei vorzugsweise der Datensatz die Menge an Gewebe in einer Reihe von konzentrischen Ringen mit unterschiedlichen Radien, welche die Sehgrube umgeben, einschließt und der Prozessor vorzugsweise dafür konfiguriert ist, die Menge des Gewebes in einem Bereich zu bestimmen, der zwischen 1000 und 2000 Mikrometer von der Sehgrube liegt.

9. Diagnosevorrichtung nach einem der Ansprüche 7 bis 8, wobei das bildgebende System dafür konfiguriert ist, die Menge an Gewebe in der Ebene zu bestimmen, welche die minimal erkennbare zwischen den inneren und äußeren plexiformen Schichten ist.

10. Diagnosevorrichtung nach Anspruch 7, wobei die Ebene so geformt ist, dass sie dem Umriss einer vordefinierten Oberfläche folgt, und wobei die vordefinierte Oberfläche vorzugsweise die Netzhaut-Oberfläche oder die Netzhaut-Pigmentepithelschicht ist.

11. Diagnosevorrichtung nach Anspruch 7, wobei der Prozessor dafür programmiert ist, das Niveau der Sehschärfe aus einer Analyse der Größen von Müller-Fasern und/oder bipolaren Zellen, welche die inneren und äußeren plexiformen Schichten verbinden, zu bestimmen, und wobei das bildgebende System vorzugsweise ein dreidimensionales bildgebendes System, wie beispielsweise ein kombiniertes OCT-/konfokales bildgebendes System, ist.

12. Rechnerprogrammerzeugnis, das ein Speichermedium umfasst, das in demselben Anweisungen zum Verarbeiten eines vom Abbilden der Netzhaut eines Patienten mit einem 3D-Augenbildgebungssystem bei unterschiedlichen Abständen von der Sehgrube abgeleiteten Datensatzes gespeichert hat, um aus demselben die Menge an Gewebe abzuleiten, das die inneren und äußeren plexiformen Schichten in der Netzhaut verbindet, und aus dem Datensatz auf der Grundlage des Netzhautgewebes, das zwischen den inneren und äußeren plexiformen Schichten verbleibt, wie durch das bildgebende System beobachtet, die mögliche erhaltene Sehschärfe zu berechnen.

13. Rechnerprogrammerzeugnis nach Anspruch 12, wobei die Anweisungen veranlassen, dass der Rechner erhaltene Messungen aus dem Datensatz ableitet, die in einer Reihe von konzentrischen Ringen mit unterschiedlichen Radien, welche die Sehgrube umgeben, vorgenommen werden.

14. Rechnerprogrammerzeugnis nach Anspruch 13, wobei die Anweisungen veranlassen, dass der Rechner die Menge des Gewebes in einem Bereich bestimmt, der zwischen 1000 und 2000 Mikrometer von der Sehgrube liegt, und vorzugsweise veranlassen, dass der Rechner Messungen aus dem Datensatz in einer Ebene erhält, die so geformt ist, dass sie dem Umriss einer vordefinierten Oberfläche folgt, und wobei die vordefinierte Oberfläche vorzugsweise die Netzhaut-Oberfläche oder die Netzhaut-Pigmentepithelschicht ist.

Revendications

1. Procédé de détermination d'une acuité visuelle conservée potentielle d'une rétine d'un patient, le procédé comprenant les étapes consistant à réaliser une imagerie de la rétine du patient afin de créer un ensemble de données correspondant à une quantité de tissu raccordant des couches plexiformes internes et externes à différentes distances de la fovéa, et calculer l'acuité visuelle conservée potentielle à partir dudit ensemble de données.

2. Procédé selon la revendication 1, dans lequel ledit ensemble de données comprend la quantité de tissu présente entre les couches plexiformes externes et la membrane de délimitation externe.

3. Procédé selon la revendication 1, dans lequel ledit ensemble de données comprend la quantité de tissu d'une série d'anneaux concentriques de différents rayons entourant la fovéa.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel la quantité dudit tissu est déterminée dans une région située à une distance comprise entre 1 000 et 2 000 microns de la fovéa.

5. Procédé selon la revendication 1, dans lequel un plan dans lequel la quantité de tissu est déterminée constitue le minimum détectable entre les couches plexiformes internes et externes.

6. Procédé selon la revendication 5, dans lequel le plan dans lequel sont effectuées les mesures est mis en forme de manière à suivre le contour d'une surface prédéfinie, ladite surface prédéfinie étant la surface rétinienne ou la couche d'épithélium pigmentaire rétinien, et de manière préférée dans lequel le niveau d'acuité visuelle est déterminé à partir d'une analyse des tailles des fibres de Muller et/ou des cellules bipolaires raccordant les couches plexiformes internes et externes, et de manière plus préférée dans lequel la quantité dudit tissu restant est déterminée à l'aide d'un système d'imagerie tel qu'un système d'imagerie tridimensionnelle, en particulier un système d'imagerie TCO/confocal combiné.

7. Appareil de diagnostic configuré pour déterminer une acuité visuelle conservée potentielle d'une rétine d'un patient, comprenant :

   un système d'imagerie configuré pour obtenir des images du tissu rétinien entre les couches plexiformes internes et externes ;
   et un processeur configuré pour traiter lesdites images afin d'obtenir l'acuité visuelle conservée potentielle en se basant sur une quantité dudit tissu rétinien présent entre lesdites couches plexiformes internes et externes telle qu'elle est observé grâce audit système d'imagerie,

dans lequel ledit processeur est programmé pour créer un ensemble de données correspondant à la quantité dudit tissu observée grâce audit système d'imagerie à différentes distances de la fovéa, et ladite acuité visuelle conservée potentielle est prédite à partir d'une analyse dudit ensemble de données.

8. Appareil de diagnostic selon la revendication 7, dans lequel ledit ensemble de données comprend la quantité de tissu présente entre les couches plexiformes externes et la membrane de délimitation externe, et de manière préférée dans lequel ledit ensemble de données comprend la quantité de tissu présente dans une série d'anneaux concentriques de différents rayons entourant la fovéa, et le processeur est de manière préférée configuré pour déterminer la quantité dudit tissu dans une région située à une distance comprise entre 1 000 et 2 000 microns de la fovéa.

9. Appareil de diagnostic selon la revendication 7 à 8, dans lequel ledit système d'imagerie est configuré pour déterminer la quantité de tissu dans le plan qui constitue le minimum détectable entre les couches plexiformes internes et externes.

10. Appareil de diagnostic selon la revendication 7, dans lequel le plan est mis en forme de manière à suivre le contour d'une surface prédéfinie, et dans lequel ladite surface prédéfinie est de manière préférée la surface rétinienne ou la couche d'épithélium pigmentaire rétinien.

11. Appareil de diagnostic selon la revendication 7, dans lequel ledit processeur est programmé pour déterminer le niveau d'acuité visuelle à partir d'une analyse des tailles des fibres de Muller et/ou des cellules bipolaires raccordant les couches plexiformes internes et externes, et ledit système d'imagerie est de manière préférée un système d'imagerie tridimensionnelle tel qu'un système d'imagerie TCO/confocal combiné.

12. Produit-programme informatique comprenant un support de stockage au sein duquel sont stockées des instructions permettant de traiter un ensemble de données dérivées d'une imagerie de la rétine d'un patient réalisée avec un système d'imagerie ophtalmologique 3D à différentes distances de la fovéa afin d'en dériver la quantité de tissu raccordant les couches plexiformes internes et externes de la rétine, et de calculer à partir dudit ensemble de données l'acuité visuelle conservée potentielle en se basant sur la quantité dudit tissu rétinien restant entre lesdites couches plexiformes internes et externes telle qu'elle est observée grâce audit système d'imagerie.

13. Produit-programme informatique selon la revendication 12, dans lequel lesdites instructions amènent ledit ordinateur à dériver des mesures obtenues réalisées dans une série d'anneaux concentriques de différents rayons entourant la fovéa à partir dudit ensemble de données.

14. Produit-programme informatique selon la revendication 13, dans lequel lesdites instructions amènent ledit ordinateur à déterminer la quantité dudit tissu dans une région située à une distance comprise entre 1 000 et 2 000 microns de la fovéa, et amènent de manière préférée ledit ordinateur à obtenir des mesures à partir dudit ensemble de données dans un plan mis en forme de manière à suivre le contour d'une surface prédéfinie, et dans lequel ladite surface prédéfinie est de manière préférée la surface rétinienne ou la couche d'épithélium pigmentaire rétinien.

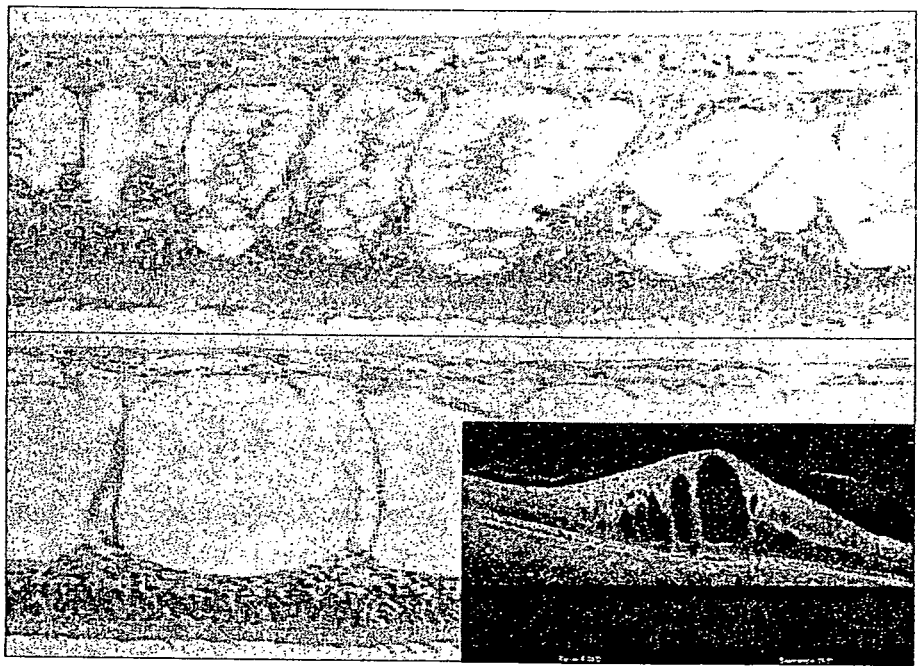


Fig. 1

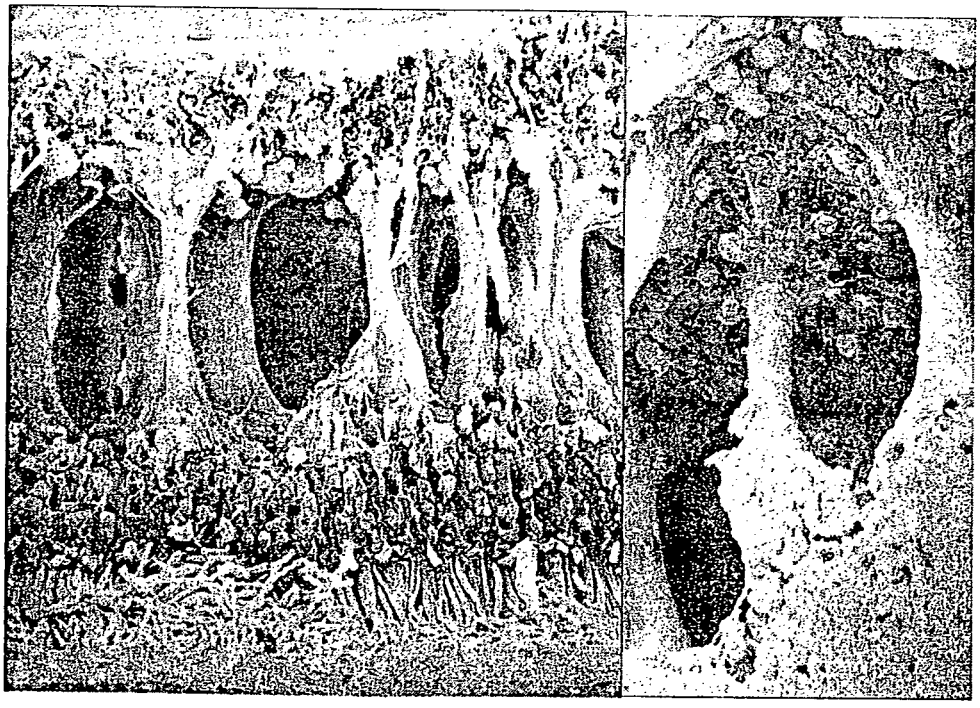
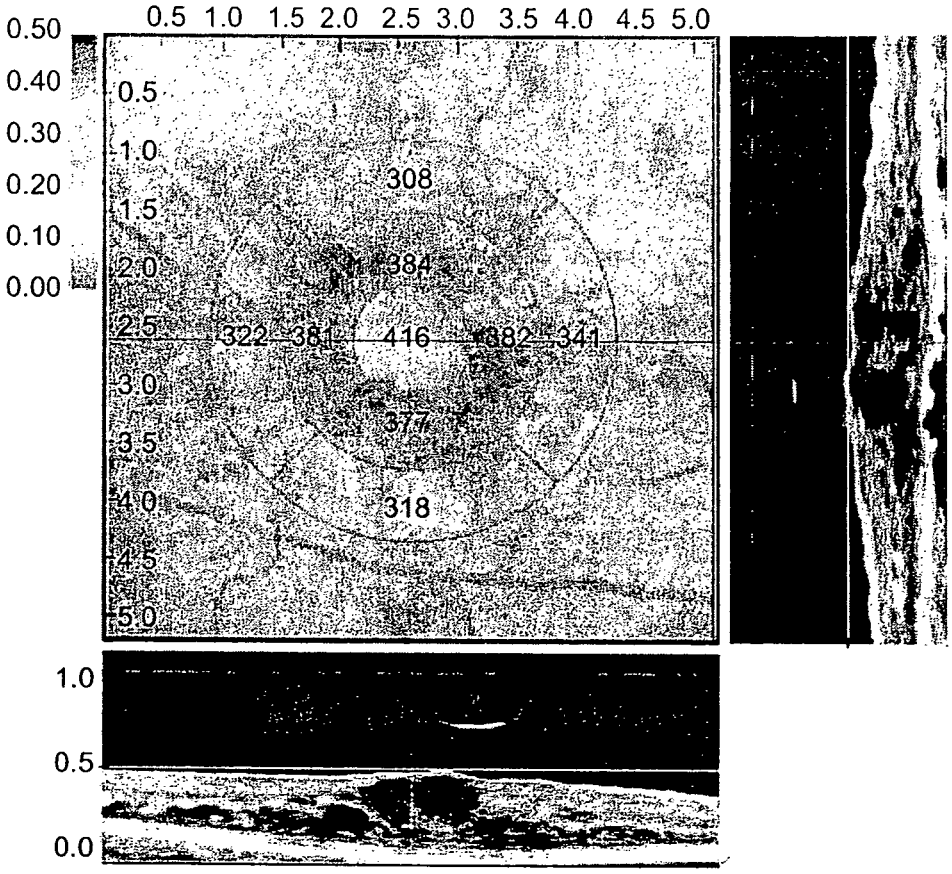


Fig. 2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0.50
0.40
0.30
0.20
0.10
0.00
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
308
384
322 381 416 382 341
377
318
1.0
0.5
0.0

Fig. 3A

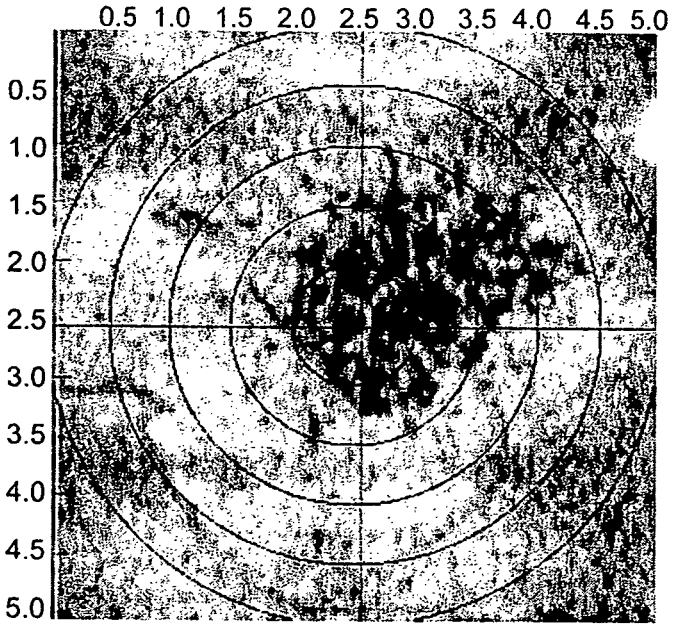
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

Fig. 3B

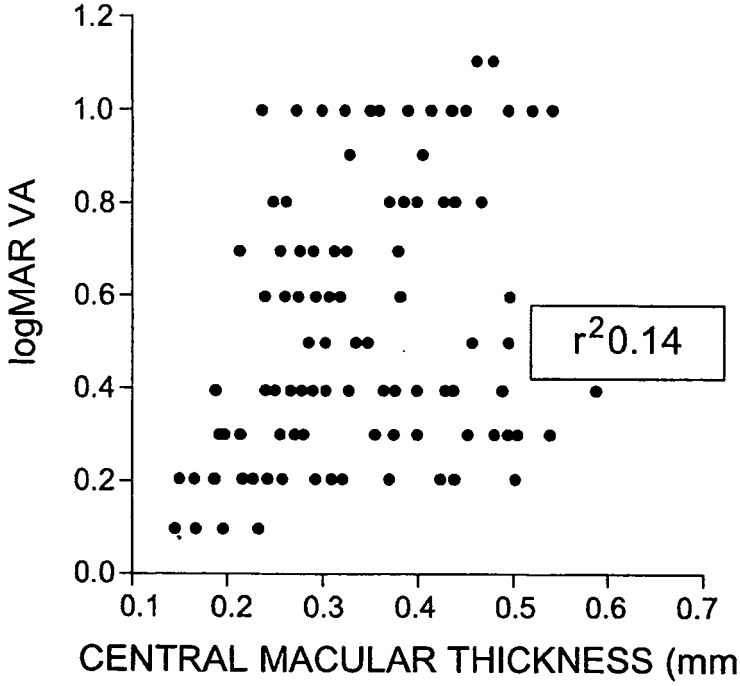
1.2
1.0
0.8
0.6
0.4
0.2
0.0
logMAR VA
r²0.14
0.1
0.2
0.3
0.4
0.5
0.6
0.7
CENTRAL MACULAR THICKNESS (mm)

FIG. 4a

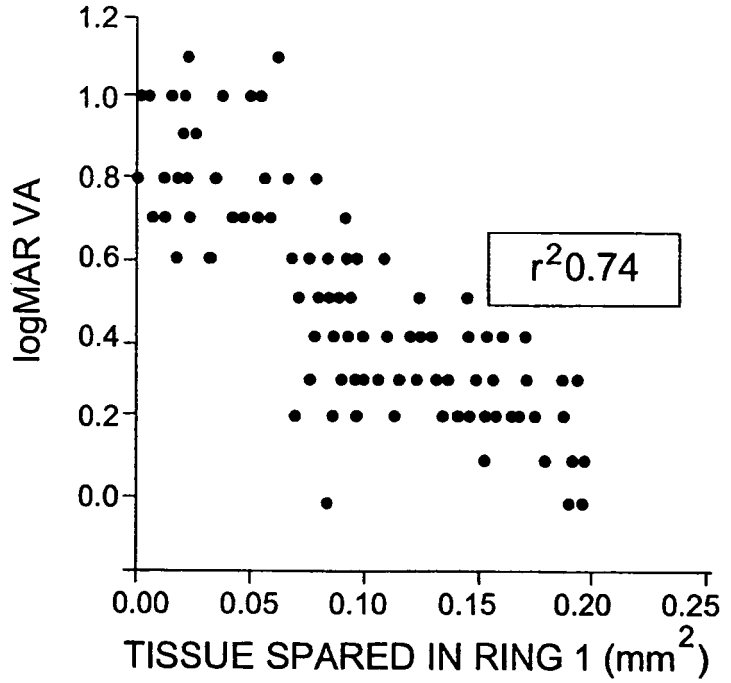
1.2
1.0
0.8
0.6
0.4
0.2
0.0
logMAR VA
r²0.74
0.00
0.05
0.10
0.15
0.20
0.25
TISSUE SPARED IN RING 1 (mm²)

FIG. 4b

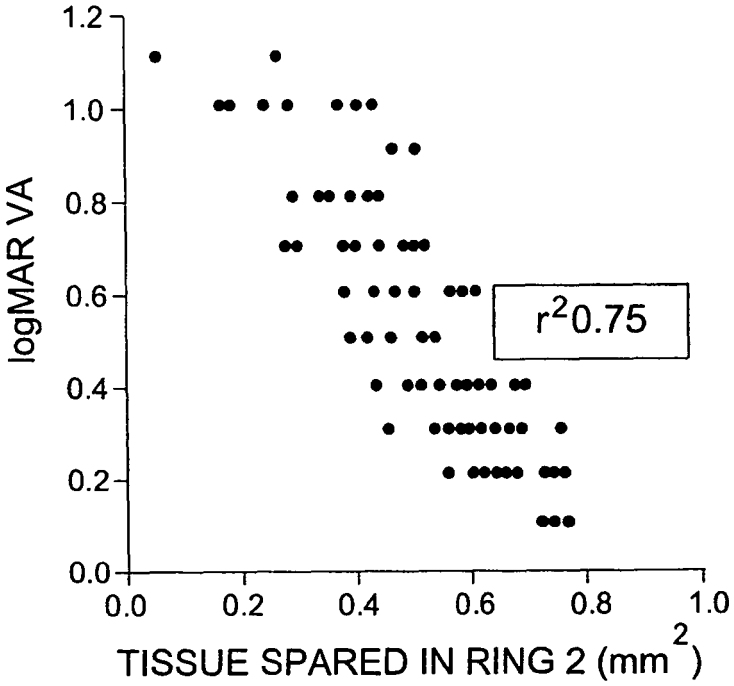
1.2
1.0
0.8
0.6
0.4
0.2
0.0
logMAR VA
r²0.75
0.0
0.2
0.4
0.6
0.8
1.0
TISSUE SPARED IN RING 2 (mm²)

FIG. 4c

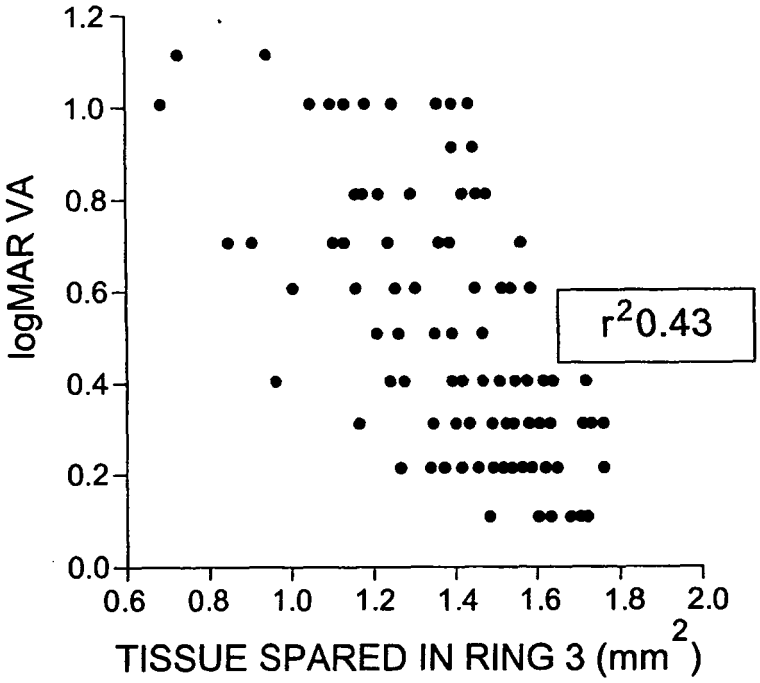
1.2
1.0
0.8
0.6
0.4
0.2
0.0
logMAR VA
r²0.43
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TISSUE SPARED IN RING 3 (mm²)

FIG. 4d

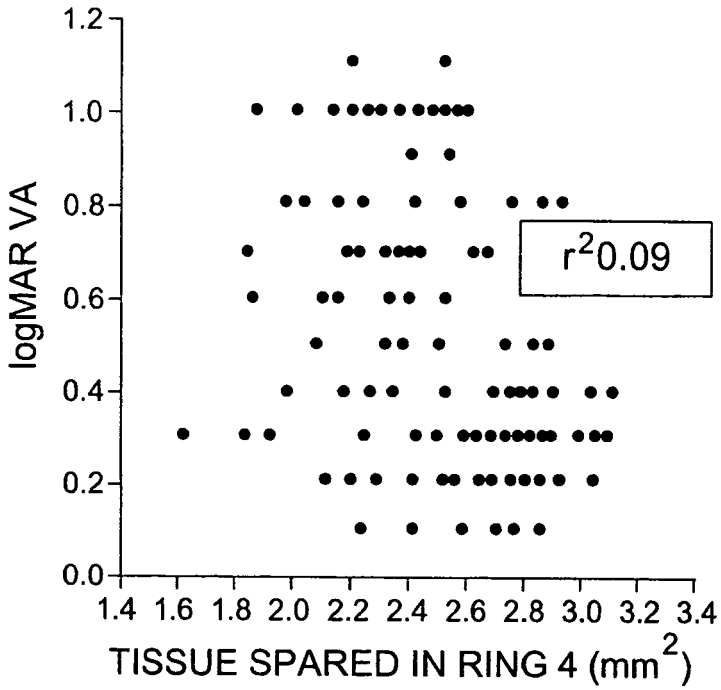
1.2
1.0
0.8
0.6
0.4
0.2
0.0
logMAR VA
r²0.09
1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4
TISSUE SPARED IN RING 4 (mm²)

FIG. 4e

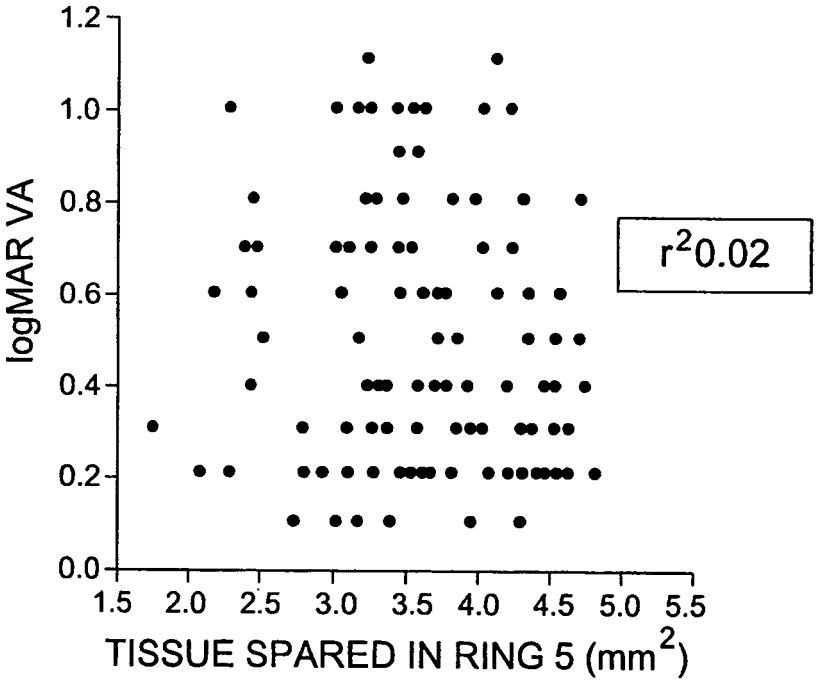
1.2
1.0
0.8
0.6
0.4
0.2
0.0
logMAR VA
r²0.02
1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
TISSUE SPARED IN RING 5 (mm²)

FIG. 4f

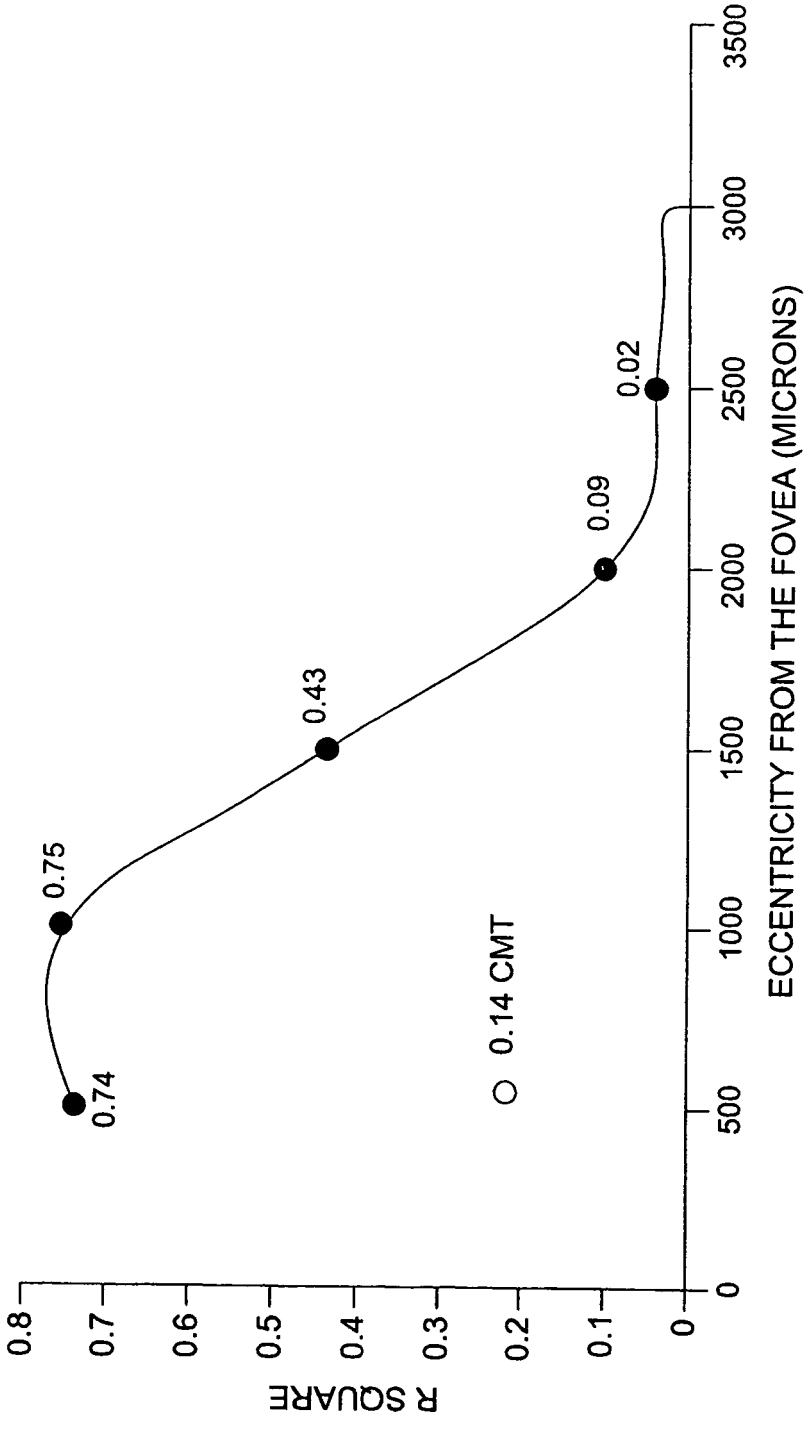
R SQUARE
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
2000
2500
3000
3500
ECCENTRICITY FROM THE FOVEA (MICRONS)
0.74
0.75
0.43
0.09
0.02
0.14 CMT

FIG. 5

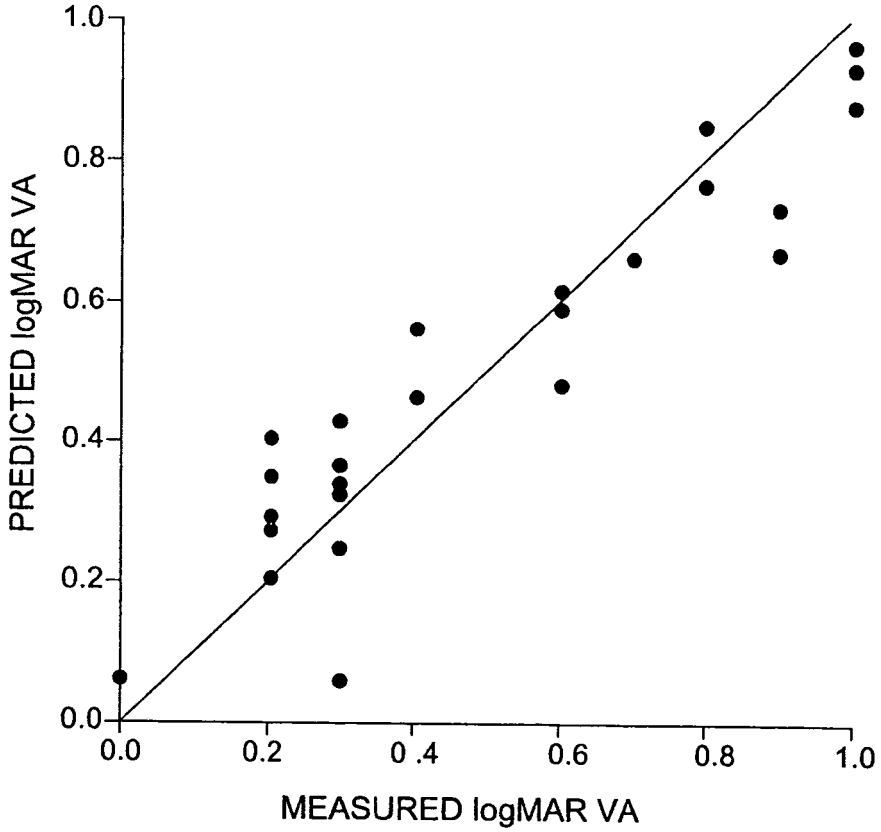
1.0
0.8
0.6
0.4
0.2
0.0
PREDICTED logMAR VA
0.0
0.2
0.4
0.6
0.8
1.0
MEASURED logMAR VA

FIG. 6

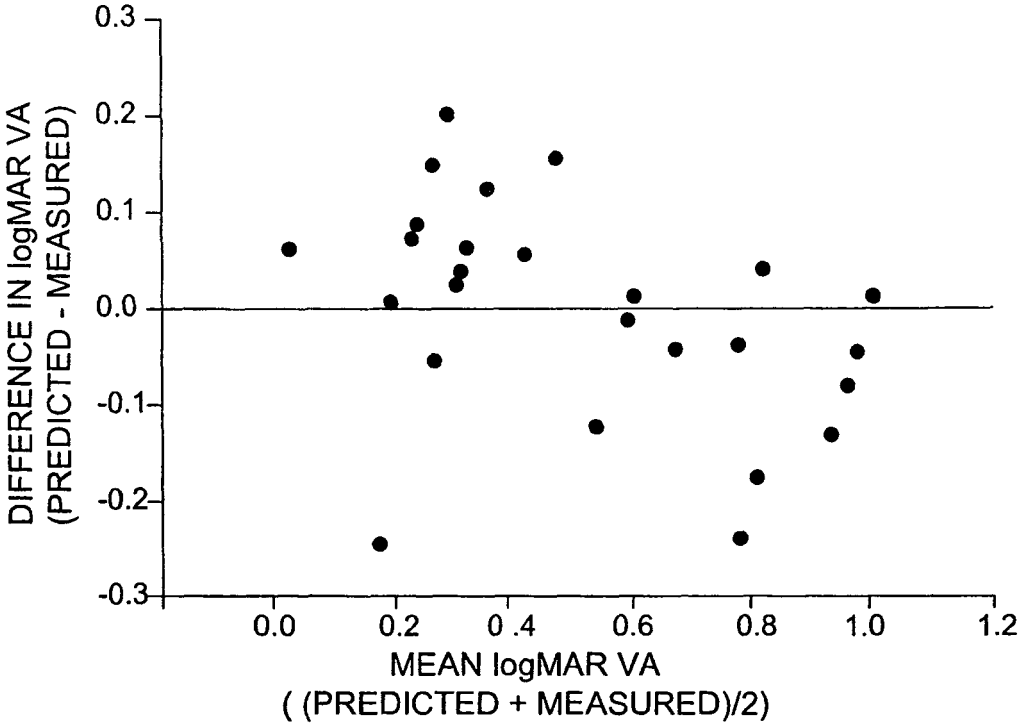
DIFFERENCE IN logMAR VA
(PREDICTED - MEASURED)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
MEAN logMAR VA
((PREDICTED + MEASURED)/2)

FIG. 7

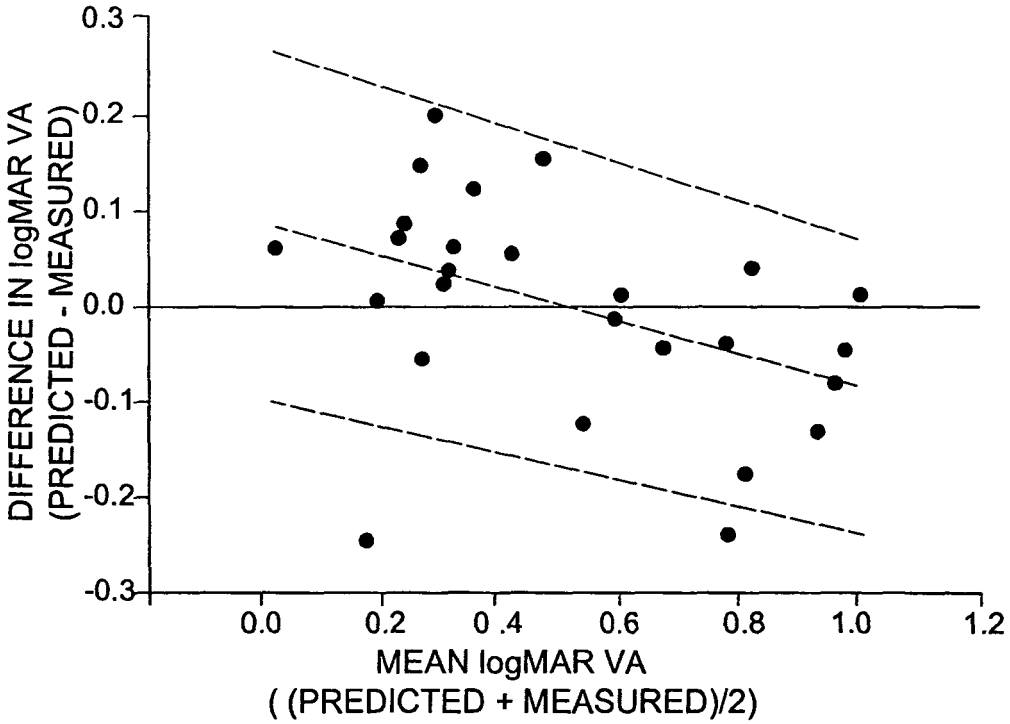
DIFFERENCE IN logMAR VA
(PREDICTED - MEASURED)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
MEAN logMAR VA
((PREDICTED + MEASURED)/2)

FIG. 8

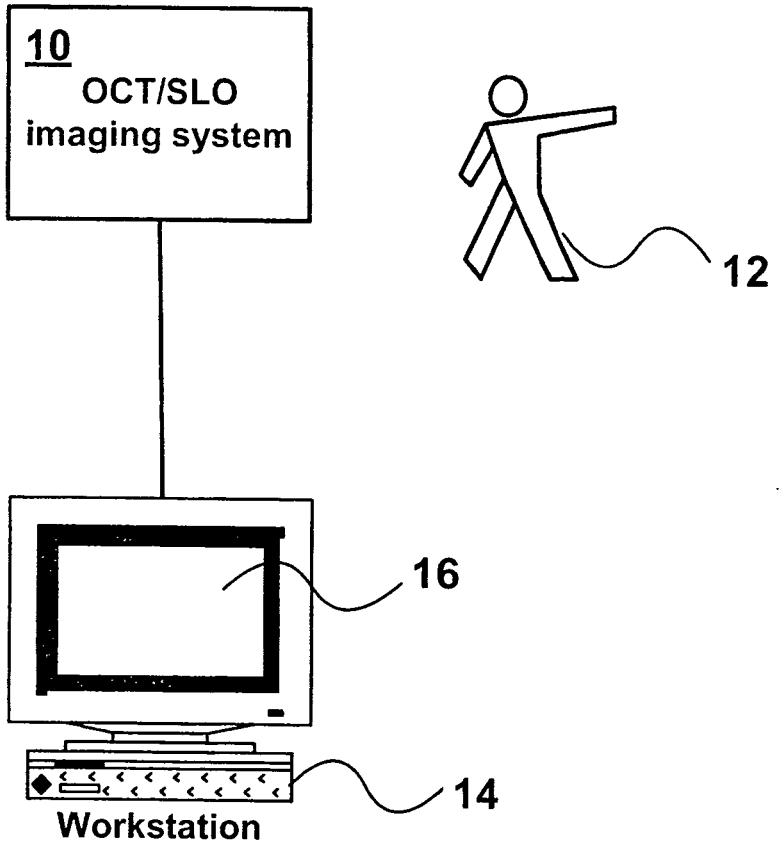

Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- Patterns of Macular Edema in Patients with Uveitis. **N. MARKOMICHELAKIS et al.** Ophtalmology. J.B. Lippincott co, 01 May 2004, vol. 111, 946-953 **[0005]**

专利名称(译)	用于预测潜在保存视力的诊断方法和装置		
公开(公告)号	EP2482711A1	公开(公告)日	2012-08-08
申请号	EP2010760353	申请日	2010-10-04
[标]申请(专利权)人(译)	奥普托斯股份有限公司		
申请(专利权)人(译)	OPTOS PLC		
当前申请(专利权)人(译)	OPTOS PLC		
[标]发明人	MARSHALL JOHN PELOSINI LUCIA		
发明人	MARSHALL, JOHN PELOSINI, LUCIA		
IPC分类号	A61B3/12 A61B5/00 A61B3/028 A61B3/00 G06T7/00		
CPC分类号	A61B5/0059 A61B5/0066 G06T7/0012 G06T2207/10101 G06T2207/30041 A61B3/0025 A61B3/1233 G16H50/50		
优先权	12/572489 2009-10-02 US		
其他公开文献	EP2482711B1		
外部链接	Espacenet		

摘要(译)

公开了一种诊断方法，其中根据连接保留在视网膜中的内网状层和外网状层的组织的量来确定患者视网膜中潜在保存的视敏度。