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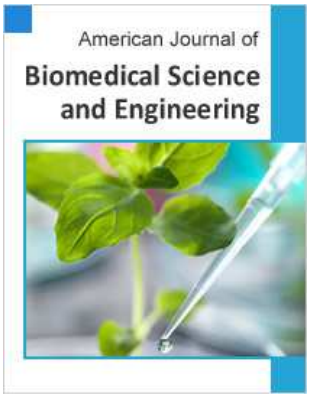

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Individual Optometry Devices

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Abstract
This article is a short overview of new branch of optometry – the Individual Optometry. It is optometry where anyone can check up his eyes himself, or with a minimal assistance. It is like a "thermometer" for eyes and people know when to ask optometrist's assistance. Some devices for individual optometry and its principles were discussed and different models were compared. Preliminary classification of these devices was done. Also, perspectives for individual optometry are discussing.

1. Introduction

Today more than 2 billions from more than 7 billions of the Earth population have problems with a sight. For economically advanced countries this problem is more serious, because essential part (more than 25%) of qualified workers have problems with there sight. According to official statistics 1995 in USA the nearsightedness people are 24 %, and in Japan - 70 % etc. [1]. It is well known, that any disaster is easier to overcome in its beginning. It is true for eyes too. So, monitoring and self control of own eyes has good perspectives.

Today we understand basic process in our eyes [2] and we know many methods and devices for measuring vision parameters, but all they are expensive and need special knowledge and education before using them. There were no methods and devices for self controlling eye's parameters.

The main idea of the Individual Optometry is maximal simplification of the measuring process for eye's refraction and to create very simple devices for that. It must be easy to control eye's parameters like nearsightedness, farsightedness or astigmatism by not qualified persons or by patient itself. But it is easier to say than to do.

For example, it is possible to use principles of automatic refractometer, when mark moves along optical axis from "far point" to "near point", and where refraction and accommodation was measured by correspondence to distance at "far point" and "near point". But for displacement of mark we use our hands, and like a "computer" we use our brain. These ideas were realizes in some models of eye testers.

2. Problems

One of the main characteristics of the eye is visual acuity, it is an ability to see fine details of objects and it is the main sight's parameter. Visual acuity depends on the structure of retina, the contrast and the background of an observed object, a diameter of a pupil, defects of the vision, an illumination, etc. A unit of visual acuity defined as ability of an eye to see an object of 1 angular minute in dimension. The deviation from normal refraction (nearsightedness, farsightedness) allows seeing fine objects, but only at certain distances. Another deviation from the normal vision is color blindness that is an inability

to distinguish color hues of certain spectral ranges. Color blindness, as a rule, does not affect on visual acuity, if it does not cause for this person coincidence of the background color with the object's color. An impossibility of precise seeing of objects (images duplication), resulting from aspherical surface of the cornea, is called an astigmatism. Reduced eye accommodation, as the result of the crystalline lens muscles degeneration, or other abnormal conditions, causes difficulties in recognition of near and/or far objects. The best to know all these parameters, but it is impossible do in one simple device. So, we try to measure the basic - refraction, visual acuity and astigmatism.

Modern optometry well equipped today and for refraction measurements some devices graduated with accuracy 0.1 D. The first what we are interesting in: Is a scale correct? Or by other words – what is a limit for accuracy in refraction measurements? Is it possible to measure refraction of human eye, for example, with accuracy 0.01D?

The physical principles and computer simulations in optometry let us find answers for these and other questions. Today we know [3] that accuracy for refraction of human eye depends on its parameters and cannot be better than 0.25 D. So, our devices must measure it.

But more essential problem is the calibration of such simplified devices. Nobody can be sure that he has an excellent sight. When I asked for official certification accuracy of eye testers, expert says – OK, we agree, but how to do it?

Today we can overcome this problem by computer simulations of the scale and by attaching the scale of real devices to some point (as a rule zero of a scale to objects at infinity).

Also these devices need a reasonable price not more than $100 - $250 to be available for home users and it restricts us in use of complicated optical schemes, because extra optical elements ever are more expensive.

3. Equipment for Individual Optometry

We cannot say that individual optometry ideas are very fresh. The first patents on similar devices we can find in 1882 year [4] and later the author modified his invention in 1902 [5]. Fig. 1 shows the scheme of last proposed device.

Its main idea is in changing a distance between some test and a lens and to measure a range where an eye can see this test (main idea for individual optometry and automatic refractometer). It was based on a fact, that normal eye cannot see focusing rays (farsightedness eye can), as nearsightedness eye cannot see parallel rays (normal eye can). So, there exists a correspondence between points on the scale and eye's refraction.

A graduation of the scale in dioptres can be simply carried out, for example, by calculation using a formula for thin lens:

$$1/x+1/b = 1/f \quad (1),$$

Or modified for devices as:

$$x = f/(1-fN) \quad (2),$$

where f is a focal length of a focusing optical element, x is a distance between the focusing optical element and the test-object, b is a distance from the focusing optical element to the test-object's image and N is a positive or negative value of dioptres on a scale [6].

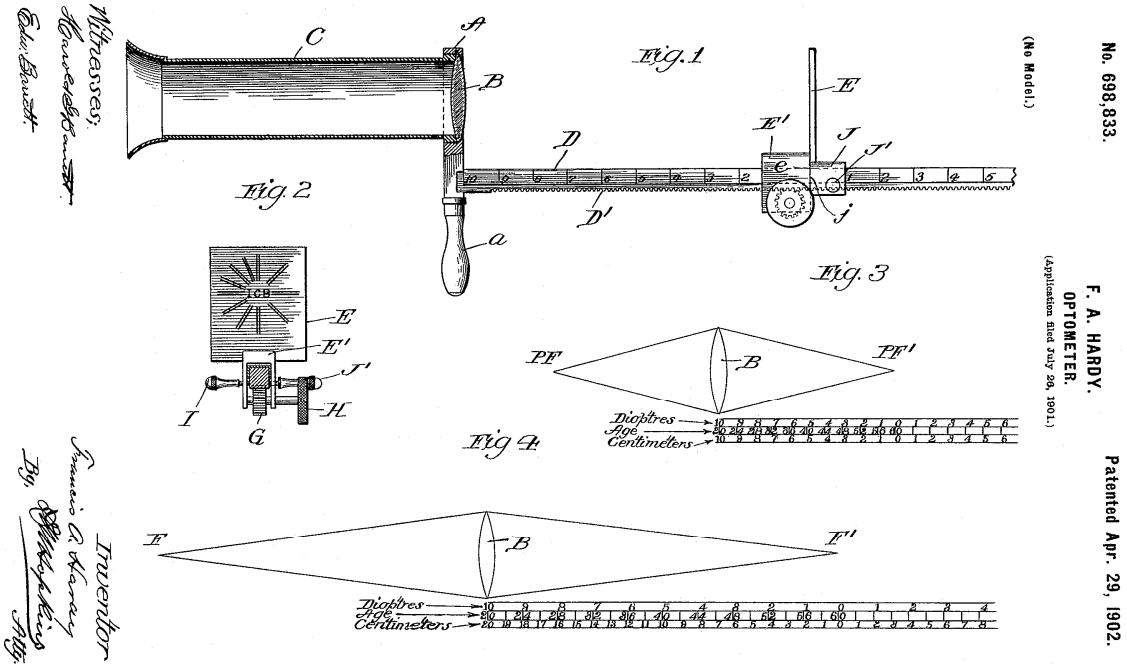

Fig. 1. *From US patent F.A. Hardy # 698833, Apr. 29, 1902.*

But why after a century from F.A. Hardy we don't see similar devices on a market? It seems that he and many other inventors don't overcome the problem of calibration these devices.

Fig. 2. *Focometer*

Today on a market there are only few devisees for self monitoring of eye's refraction and only in USA and in Russia. But there are no simple devices for monitoring astigmatism or visual acuity yet.

In USA you can test eye refraction yourself by a Focometer (see Fig. 2) and you can buy it (its price is about $500). It used for non astigmatic eye only. The real accuracy of measurement for Focometer is unknown.

Its scheme based on US patent #5455645 from1995 [7]. Focometer has a weight more than 1 kg and is very expensive because it has a complicated optical scheme (with Pechan inverting prisms etc.). It is a heavy and expensive device and it is its main disadvantages. Also it can measure refraction only in the range from -4D to +5D and it is good only for farsightedness. Focometer was tested in India and demonstrated good results [8].

Fig. 3. *Eye tester.*

In Russia we know some models (Fig. 3) of Eye Testers (as original invention it has a gold medal from Paris in 2000 year). It used for non astigmatic eye too, but some modifications can control a visual acuity and astigmatism. All Eye Testers based on Russian patents: RU #2137414 [6] (from 1999) and RU #2202937 [9] (from 2003). All Eye Testers were fully optimized; they have a weight 20 - 50 gram and a price about $50 – $100. Its accuracy was certificated (near 0.25 D) and corresponds to professional equipment. Basic model has refraction range from -10D to +4D, but also exist modification for farsightedness with the range from -7D to +7D.

In some models of modified eye tester (see Fig. 3) the scale (see Fig. 4) done by laser inside a glass and only patient can see it.

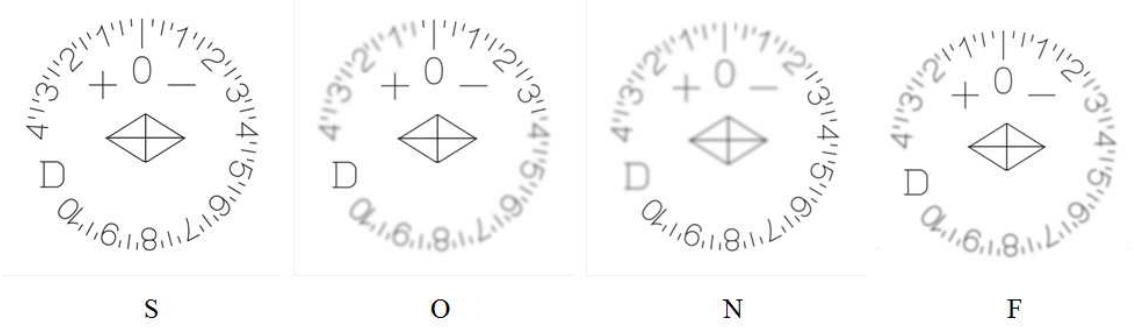

Fig. 4. *View of scale inside eye tester. S –real scale, O – for about normal eye (+0.25D – in the range of accuracy), F – for farsightedness (+ 1.5D) and N - for nearsightedness (-2.5D) eyes.*

For checking farsightedness or nearsightedness you simply look inside eye tester and depends on your eye refraction you'll see different pictures (Fig. 4 O, N or F). Refraction - is sharp left ends of scales on corresponding pictures. The sharp

right ends of the scale depend on accommodation volume and you can measure it.

Using the tester you can improve your eyesight! It is like a fitness room for eyes.

For a troubled eye spend daily 5-7 minutes and trying to see clearly the minimum or maximum numbers on the tester scale. In nearsightedness, a maxim umclearly visible number is at the top of the scale's minus sign values. (* For example, taking into account the sign of the scale, minus 2 is greater than minus 4, and so on.) Try to see maximum of the scale and continue the exercises every day, approaching zero of the scale.

After having seen clearly a number (or streak, dot) at the border during 5-15 seconds, move your eyesight to any other point in the middle of a clearly visible scale range for the same 5-15 seconds. Repeat this refocusing for 5-7 minutes for troubled eyes.

For farsightedness practice in the same way 5-7 minutes daily, but try to see clearly the minimum value (with the sign), and refocus, for example, at zero.

But the problem is in relaxation eye's parameters to previous situation, as you'll stopping trying.

So, this model is for self testing only, but with additional function of training accommodation. There are no movements inside device and patient measure eye's refraction and volume of accommodation simultaneously by looking a test.

All another devices like Eyenetra Fig. 5 (startup of MIT students) or any other are on a stage of ideas or startups today.

Fig. 5. *Eyenetra with iphone.*

The Eyenetra based on patent [10] has some original ideas, but need iphone with super resolution of its display. Patent announce that it can measure: eye refraction, astigmatism and visual acuity. Let us wait results...

So, we can separate all individual optometry devices in several classes:

1. With the scale outside device (patient don't know result in process of measurement).
2. With the scale inside device (only patient knows his results).
3. With additional options (training of accommodation, astigmatism measuring etc.).

4. Conclusion

So, all these devices can measure refraction of the eye (in a very simple way), but with a different accuracy. Today, only eye testers have certificated accuracy 0.25-0.5D. And eye tester has some another preference (the price $50, small weight 20-50 gram, option of correction eye's refraction etc) in comparison Focometer (weight 1 kg) and Eyenetra (no exists any standard phone for this method). And there are no individual devices monitoring together all basic parameters: refraction, visual acuity and astigmatism.

Of cause, it is very large market for this kind of optometric equipments estimated by MIT group as $75,000,000,000 and 2.4 billions people. Our estimations are not so optimistic, but we sure in possibility to sale 1-2 millions devices per month.

Let us summarize. All these devices are like "thermometer" for eyes and must to say when you need to ask optometrist's assistance. But they are absolutely unknown for peoples today and it is main problem for the market.

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