



Full length article

Investigation of optical characteristics of rigid protected and traditional elastic Fresnel microprisms using electronic method for measuring visual acuity



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ABSTRACT

A method for determining resolution of images through prisms using test patterns is proposed. This technique is more precise than the traditional method for measuring visual acuity, which involve ophthalmologic test charts and questioning patients. An experimental setup allowing the measurement of image resolution was developed. Comparative characteristics were obtained for “Gulden Ophthalmics” (USA) monoprisms, for “3M™Press-On™” (USA) elastic films with microrelief and for new rigid protected Fresnel microprisms developed at the Institute for Information Recording (Ukraine). The reasons for the decrease in image resolution and visual acuity are discussed for all of the investigated ophthalmic monoprisms and microprisms.

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1. Introduction

The application of Fresnel microprisms in ophthalmology always reduces the resolution of the formed optical images. Many studies have reported the deterioration of the visual acuity for patients by the application of a prism [1–4]. However, their method of investigation was traditional, involving the subjective impressions of patients who observed ophthalmic test charts with and without prisms.

At the same time, it is possible to evaluate the deterioration of the visual acuity quantitatively using known methods of spectroscopy [5]. Such methods are widely used in physics, e.g. for measuring the resolution of narrow spectral lines. Herein, we focus on the investigation of some known prisms using these physical techniques which were adjusted for ophthalmology applications [6].

Studies of microprisms with low prismatic strengths $PD < 10.0$ Δ are of particular interest. Previous researchers [1–4,7,8] reported that patients hardly noticed the influence of prisms on their visual acuity for these low-strength microprisms. However, such influences are certainly present because of the diffraction and chromaticity of the white light.

The main objective of the present research was to obtain the optical characteristics of monoprisms and microprisms made by different manufacturers by electronically registering visual image signals without patients and their impressions. It was necessary to distinguish the effect of prisms in total decrease of visual acuity and so to separate the influence of prism with the blurred visual, which is very important for diagnostics at the initial stage of eye diseases [9,10].

Comparative optical characteristics were obtained over a wide range of prismatic strengths for monoprisms manufactured by “Gulden Ophthalmics” (USA), “3M™Press-On™” elastic films with microrelief manufactured by “3M” Company (USA), and new rigid microprisms [11] developed and manufactured by the Institute for Information Recording of National Academy of Sciences of Ukraine (IIR, Ukraine). Currently, the latter are widely used in Ukraine for the diagnostics and treatment of strabismus in children.

2. Optical parameters of new rigid Fresnel microprisms

The basic view and the scheme of the new rigid microprism are shown in Fig. 1. At the first stage of its manufacturing the necessary microrelief is formed at the flat metal surface by diamond cutting method [12]. The matrix-origin made in such way is used at the next stage for formatting microprismatic relief by thermo-pressing method [12] on the surface of a billets made from the

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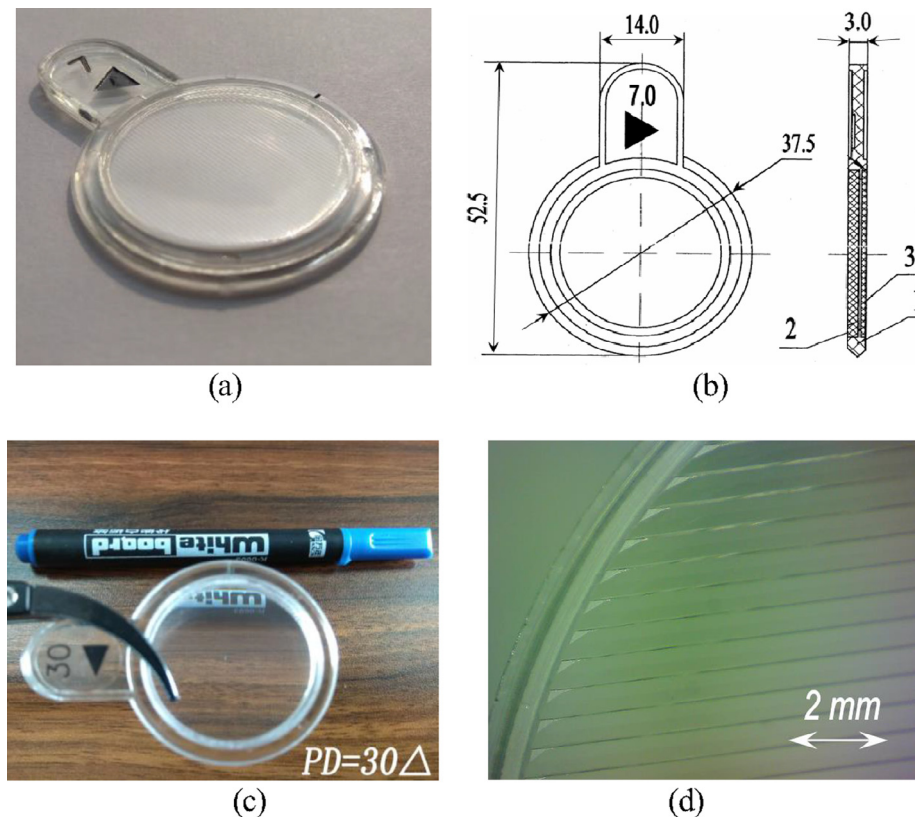


Fig. 1. IIR (Ukraine) new rigid microprism (a) General view; (b) Scheme: (1) PC holder; (2) PMMA microprism relief; (3) Protective PC plate; (c) Image-shifting effect; and (d) Magnification of microprism.

transparent rigid optical plastics. The diagnostic embodiment of such a microprism comprises a flat transparent microrelief plate 32 mm in diameter made of polymethylmethacrylate (PMMA). The microprismatic relief is sealed by a protective flat transparent plate made of polycarbonate (PC) 0.6 mm in thickness. The holder, having a diameter of 37.5 mm, is also made of PC. The prismatic strength Δ and the direction of prismatic action (triangle) are shown at the holder. All of these elements are hermetically connected by ultrasonic welding in a common optical unit called the “microprism compensator for strabismus”.

The main difference between above rigid microprisms, the traditional 3 M flexible films and all other known microprisms is that the microrelief of new devices is protected from mechanical damages and contaminations by a special plate; therefore the optical properties of these microprisms do not change, even during prolonged usage.

Microprism compensators of different denominations comprise the diagnostic set *KK-42* [11], which is registered in Ukraine for usage in medical practice. The total number of microprisms in this set is 42, and the prism denominations are 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, and 30.0 prismatic diopters (Δ). There are two similar sets of 21 microprisms denominations for both eyes.

For the convenience of strabismus diagnostics, a set of diagnostic microprism bars *DNSK-01* [11] was also manufactured by IIR (Ukraine). The prism denominations in this set are 1.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 25.0, 30.0, 35.0, 40.0, 45.0, and 50.0 Δ . The denominations of the microprisms in each *DNSK-01* bar are formed by two identical rigid microprisms having the same prismatic strength. Pairs of microprisms in such a “symmetrical” strabismus compensator are hermetically coupled by ultrasonic welding. The microrelief is placed inside the device

and does not contact the external environment. Thus, the relief is protected from contaminations and damages even during the prolonged operation of the bars. Basic images of the diagnostic sets *KK-42* and *DNSK-01* are shown in Fig. 2(a) and (b), respectively.

Calculations [12] of the prism refraction angles according to Snell's law [5] showed that the change in the prismatic strength during the turn of such a “symmetrical” prism along its axis is almost four times smaller than that in the case where the value of prismatic action of an optical compensator is created by a single microprism. Thus, diagnostic bars with symmetrical compensators yield more accurate measurements of the strabismus angles. Therefore, *DNSK-1* diagnostic microprism bars are currently manufactured only with symmetrical compensators.

When the new rigid microprisms are used in complex prism-refractive eye-glasses [11], the flat microprism element is hermetically connected to the inner surface of the refractive lens by ultrasonic welding technology that is specially developed for this case.

The properties of the new rigid microprisms, diagnostic sets of prisms, and complex eye-glasses with prisms are described in detail in our monograph [12].

3. Characteristics of experimental setup

The main objective of our research was to determine the optical characteristics of different microprisms in one set of measurements using a new more precise electronic method.

In all previous studies [1–4,7,8] visual acuity was measured by the method of questioning patients, which is a typical procedure for ophthalmologists. We attempted [12] to correlate the psychophysical definition “visual acuity” attributed to human subject with physical quantity “optical resolution”. This will provide

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