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Accommodation in young adults wearing aspheric multifocal soft contact lenses

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The aim of the present project was to investigate accommodative behavior in young adults and adolescents fitted with an aspheric multifocal (center distance) contact lens with focus on evaluating whether these lenses can be an alternative treatment for subjects in which a reduced level of blur and thereby accommodation in near vision is aimed at. Twenty normal subjects aged between 21 and 35 years participated in the study. Aberrometry was perfomed using a Zywave™ aberrometer, first on the uncorrected eyes of all subjects, and again while the subjects wore a multifocal contact lens with a +1.00 add. A Shin-Nippon N Vision-K 5001 Autoref-Keratometer was used to measure accommodative response with two different refractive corrections: (1) habitual spectacle correction only, and (2) habitual correction and a aspheric multifocal (center distance) contact lens. Four hours of adaptation to the lens was allowed. The lag when wearing only the habitual spectacles was compared with the lag while wearing both the habitual spectacles and the aspheric multifocal contact lens. The mean lag of accommodation for the subject group was 0.85 D (±0.57 SD) and 0.75 D (±0.52 SD) without and with the multifocal lens, respectively. Statistical analyses showed no difference in lag ($t = 0.8479$, $p = 0.407$) with and without the lens. In conclusion, young normal subjects do not relax accommodation when fitted with aspheric multifocal center distance lenses when the addition is +1.00. It is therefore unlikely that subjects with accommodative ability, in whom the treatment purpose is to reduce blur and thereby accommodation, can be effectively treated with such lenses.

Keywords: accommodation; multifocal contact lenses; aspheric treatment; aberration

1. Introduction

A blurred retinal image is an indication to the visual system to change the dioptric power of the eye. By changing the dioptric power of the eye, the amount of blur will be reduced and a clear image will be present, this is called accommodation. Accommodation occurs when fixation is changed from distance to near and is part of a complex triad which is called the near response or the near reflex. The near response includes increased accommodation, convergence and pupillary constriction [1]. Within the accommodative system, different components contribute to the final accommodative response. These components are normally described as reflex accommodation, tonic accommodation, proximal accommodation, convergence accommodation and adaptation of accommodation [2–4]. However, when fixation is changed from one distance to another, reflex accommodation is the largest and most important component of accommodation in clearing the image, i.e. reflex accommodation is blur-driven and acts in response to blur [4,5]. The amount of blur is therefore a cue to reflex accommodation in order to determine the amount of change in accommodation that is needed. Cues are also needed for direction, i.e. in order to know if accommodation has to be increased or reduced in order to eliminate the blur. The main directional cues for the accommodative system are thought to be chromatic aberration and spherical aberration, but even proximity has been suggested, and under binocular conditions directional information is obtained through the convergence accommodative cross-link [4,6,7].

Reading addition, multifocal- or progressive spectacles are commonly used to reduce the amount of blur and thereby the amount of accommodative effort in young subjects with conditions such as: (1) reduced accommodation; (2) high AC/A; (3) pseudo myopia; and (4) myopia.

Reduced accommodative ability is a relatively common visual anomaly in children and young adults with a prevalence of about 5% [8–11]. Reduced accommodative ability often results in symptoms such as blur at near, headaches, asthenopia, and decreased performance after prolonged periods of

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near work (e.g. reading and computer work), despite having good visual acuity (either corrected or unaided) and lack of identifiable ophthalmic pathology [12]. There are two main choices of treatment for accommodative dysfunction: refractive correction, i.e. reading addition in order to reduce the amount of blur, and vision therapy (exercises) [13–20].

Subjects with a high AC/A ratio, i.e. subjects who have a large amount of convergence induced as a result of their accommodation, often suffer from vergence problems such convergence excess [21] at near which also can result in the same symptoms as those with reduced accommodative ability described above [22] or develop a near esotropia and consequently amblyopia [23]. Treatment is by means of reducing the accommodative effort in near vision by reducing the stimulus for accommodation, i.e. reducing blur [23].

Pseudomyopia may be defined as a reversible form of myopia due to spasm of the ciliary muscle where the subjective refraction presents myopia but cycloplegic refraction reveals emmetropia, hypermetropia or less myopia. The spasm can be intermittent or constant, and may be caused by sustained near vision. Treatment involves relaxing the ciliary muscle, the most common method involving the use of plus lenses for near vision in order to reduce blur and hence accommodation [24].

The etiology of myopia has been studied extensively, with the relative importance of hereditary vs. environmental influences being the subject of ongoing debate. However, the well-established association between myopia progression and near work, i.e. accommodation, has led to several attempts to reduce myopia progression through prescribing near addition in order to reduce accommodation [25]. The use of progressive addition lenses is widely used and has produced some treatment effect [26–28].

Multifocal contact lenses are commonly fitted to pre- and presbyopic subjects ~40 years or older as an alternative to reading, multifocal or progressive spectacles when the ability to accommodate decreases. For younger patients with, e.g. reduced accommodative ability, high AC/A ratios, pseudomyopia and progressive myopia, who all have the ability to accommodate, these lenses might offer a new possibility of correction since they could relieve accommodation in the same way as reading glasses, yet still provide good distance visual acuity. However, the effect that these lenses might have on the accommodative response in younger subjects is still not fully known. Tarrant et al. [29] have found that young adult subjects (<35 years of age) fitted with bifocal soft center distance contact lenses do not relax their accommodation by the amount of the reading addition, i.e. the subjects continued to accommodate even though they did not need to. The development of multifocal contact lenses shows a trend of being based on aspheric lens design to achieve multifocality rather than bifocal design. The aim of the present project was therefore to investigate accommodative behavior in young adults and adolescents, with normal accommodation, fitted with an aspheric multifocal contact lens (Proclear multifocal center distance, Cooper Vision).

2. Materials and methods

In this study, 20 normal subjects aged between 21 and 35 years (mean age 25.9 ± 4.3 SD) were recruited among students at the School of Optometry, Karolinska Institutet, Stockholm, Sweden.

In order to be included in the study as a normal subject, the following criteria had to be met: (a) 35 years of age or younger (in order to ensure a reasonable amplitude of accommodation); (b) habitual spectacle correction within ±0.25 D of the refractive error determined as a part of the study (in order to ensure that the habitual correction could be used when measuring the study variables); (c) no ocular pathology or systemic disorder; (d) not taking any drugs with a known effect on accommodation or any other aspects of vision; (e) distance ETDRS visual acuity of 20/20 (1.0) or better monocularly; (f) stereo acuity with the TNO (random dot) stereo test of 60 s or better; and (g) no corneal abnormalities based on keratometry readings and slit lamp inspection. Ethical approval was given by the local ethical committee and the study adhered to the declaration of Helsinki. The patient received written information and informed consent was obtained from all the participants.

2.1. *Contact lens fitting*

The subjects were fitted with a Proclear^{TM} multifocal contact lens (Cooper Vision Ltd, Hamble, UK) which is based on aspheric design in which a more hyperopic refractive power is achieved in the peripheral parts of the lens. The Proclear lens is designed with a spherical power in the center (diameter 2.3 mm), an aspherical zone which creates a reading add of +1.00 at a diameter of 5 mm, and a concentric spherical zone with add +1.00 from +5 to 8.5 mm in diameter. Beyond the optical zones there is 5.9 mm rim which gives the lens a total diameter of 14.4 mm (see Figure 1). Since habitual spectacle correction was worn to optimize visual acuity, only plano center lenses were fitted. The lenses were inspected for acceptable movement, centration and corneal coverage. After four hours of adaptation to the lens, the lag of accommodation was measured and the visual acuity was checked monocularly and binocularly.

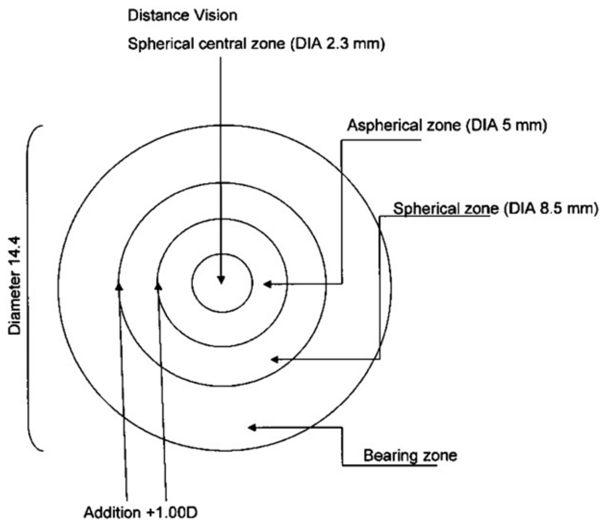

Figure 1. Design of the Proclear multifocal center distance contact lens. The transitions between powers are smooth and not abrupt.

2.2. *Aberration measurements*

All subjects underwent aberration measurement of both eyes with a Zywave^{TM} aberrometer (Bausch & Lomb, Surgical, Salt Lake City, Utah, US), which is based on the Hartman–Shack wavefront technique [30]. Wavefront aberrations were measured in the uncorrected eye and with the multifocal contact lens. Aberrations were measured in the relaxed eye, i.e. target set at infinity. Within a Zywave^{TM} measurement, five consecutive wavefront measurements are made, three of which were used to calculate the mean aberrations [31,32]. This wavefront measurement was done three times and the average wavefront aberration was then calculated [33]. Aberration measurements were done in a dark room and the subjects were covered with a dark cloth to get maximum pupil size without the use of dilation. For detailed description of the aberration method, see Lindskoog Pettersson et al. [34,35]. Aberration measurements were taken to evaluate the change in spherical aberration (SA) induced by the lens.

2.3. *Refraction, accommodation and visual acuity measurements*

A Shin-Nippon N Vision-K 5001 (Shin-Nippon, RyoSyo Industrial Co., Ltd, Japan) was used to obtain baseline over-refraction with distance fixation and for measurements of accommodative response of a near distance of 40 cm. The Shin-Nippon allows binocular fixation through the instrument (for detailed description of the Shin-Nippon, see Davies et al. [36]). Reported refraction and accommodation responses represent the average of 10 consecutive refractometer readings. The distance fixation target was a single 6/60 (0.1) Snellen visual acuity equivalent on the ETDRS chart. Distance measurements were obtained in the left eye only while fixating the target binocularly. The near accommodative target was a high contrast test equivalent to 6/6 (1.0) Snellen visual acuity. The near target was placed directly in front of the right eye and a physical septum was used to prevent the left eye from seeing the target. Accommodative response was measured in the left eye only, and was used to calculate the lag of accommodation. For all accommodative measurements subjects were instructed to report when the near target was seen clearly and to maintain clear vision of the target.

Distance over-refraction and accommodation were measured with two different refractive corrections: (1) habitual spectacle correction only, and (2) habitual correction and a plano Proclear multifocal contact lens with a +1.00 add.

2.4. *Procedure of accommodative measurements*

In the situation of only wearing the habitual spectacles distance over refraction of both eyes were obtained. Then accommodative response was measured with near fixation (target at 40 cm). The near target was placed directly in front of the right eye and a physical septum was used to prevent the left eye from seeing the target. The left eye saw a dark gray uniform field and accommodative response was measured in the left eye only. After adaptation to the multifocal lens distance over refraction of both eyes with lenses in both eyes were obtained. For near measurements the lens in the left eye was removed. Again the near target was placed directly in front of the right eye and a physical septum was used to prevent the left eye from seeing the target. The left eye saw a dark gray uniform field and accommodative response was measured in the left eye only.

Our primary interest was how the aspheric lens affected the accommodative lag. The lag when wearing only the habitual spectacles was therefore compared with the lag while wearing both the habitual spectacles and the aspheric multifocal contact lens.

2.5. *Statistical methods*

For statistical analysis of lag of accommodation, a paired *t*-test (InStat^{TM} GraphPad) was used with a significance level of 0.05.

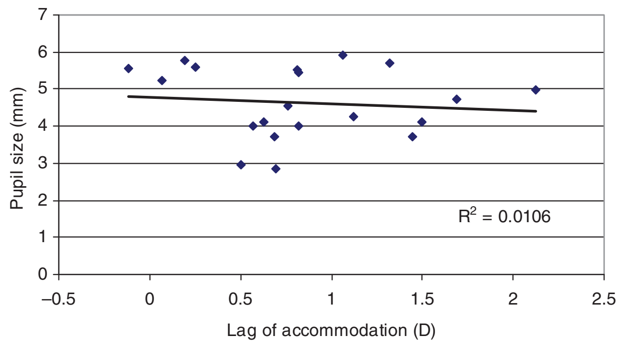

Figure 2. Correlation plot between pupil size and lag of accommodation in normal subjects. (Pupil sizes were obtained while performing autorefraction and the average room lightning was 500 lx.) (The color version of this figure is included in the online version of the journal.)

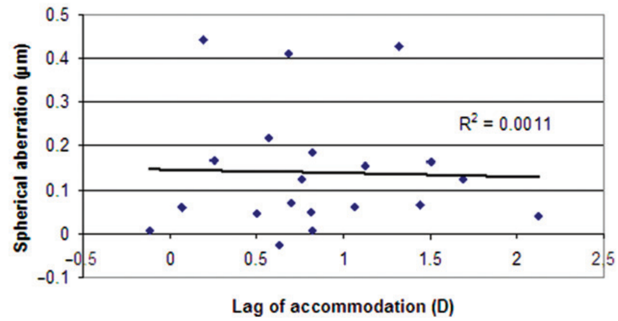

Figure 3. Correlation plot between spherical aberration and lag of accommodation in normal subjects. (The color version of this figure is included in the online version of the journal.)

3. Results

In order to evaluate the effect of the multifocal contact lens itself on visual acuity or the reliability of the autorefractor while wearing the multifocal lens, distance visual acuity with and without the lens and autorefractor values while fixating a target at 6 meters were compared. No difference in distance visual acuity with and without the contact lenses could be found, nor could any differences in autorefrractor values be found.

The mean lag of accommodation was 0.85 D (±0.57 SD) and 0.75 D (±0.52 SD) without and with the multifocal lens, respectively. Statistical analyses showed no difference in lag ($t = 0.8479$, $p = 0.407$).

There was no correlation ($R^2 = 0.0106$) between pupil size and the lag of accommodation while wearing habitual correction only (see Figure 2), nor was there any correlation ($R^2 = 0.0011$) between aberration and lag of accommodation while wearing habitual correction only (see Figure 3). For comparison no correlation between pupil size and lag of accommodation ($R^2 = 0.0159$) and between SA and lag of accommodation ($R^2 = 0.002$) could be found while wearing the multifocal lenses.

In the subject group, the aspheric contact lens changed the amount of SA on average by 0.093 µm (±0.110 SD). Average pupil size was 5.72 mm (±1.17 SD).

4. Discussion

The main finding of the present study was that normal young subjects do not relax their accommodation when fitted with aspheric multifocal center distance contact lenses. This was shown by the lag being the same with and without the lens. This is similar to the findings made by Tarrant et al. [29].

The relaxation of accommodation could be related to pupil size, since the aspheric design gives increasing addition with increasing diameter. However, no correlation in lag and pupil diameter could be found. The average pupil size in the subject group was larger than the zone of aspheric addition in the lens. It has previously been indicated that accommodation is influenced by the amount of spherical aberration [37], however, no correlation could be found between the amount of SA and lag of accommodation in the present study. It seems, therefore, that young normal subjects do not accommodate less when fitted with aspheric lenses such as the Proclear™. This is probably due to these subjects being able to accommodate and the fact that accommodation is driven by the central most part of the visual field, i.e. inside the spherical zone of the contact lens and that light from the more peripheral part of the contact lens will also strike the cones at an angle that is not along the cone axis and this effect, the Stiles–Crawford effect, has been shown to be important in accommodation [38].

Three of the subjects had large lags (in the order of 1.5 D or bigger) both with and without the multifocal lenses. This is surprising since they were told to indicate when the near target was seen clearly before measurements were made. It might be that these subjects have relaxed their accommodation as soon as they had identified the near object. It is therefore unlikely that they have seen the object clearly during measurements. Recalculation of the data excluding these three subjects did, however, not change the statistical outcome (mean lag of accommodation was 0.68 D (±0.43 SD) and 0.69 D (±0.52 SD) without and with the multifocal lens, respectively ($t = 0.098$, $p = 0.923$).

Based on our findings the aspheric contact lens used does not seem suitable to be fitted on young subjects with the ability to accommodate in order to reduce blur and their accommodative load and consequently achieve the same treatment effect that reading spectacles have [19–28]. However, a larger study should be conducted to fully evaluate this. Of the four conditions mentioned in which reduced blur and hence reduced accommodation is sought for treatment purposes, it might be that only the condition of reduced accommodative ability could benefit from these lenses since it is the only of these conditions in which the accommodative ability is reduced and not at its full amplitude. Further studies are ongoing to evaluate this. Furthermore, it might be worthwhile to evaluate the effect on accommodation with an aspheric multifocal center near lens, since the subjects would then need to use the more peripheral part of the lens to see clearly at distance and the reading addition would occupy the central part of the visual field.

In conclusion, young normal subjects do not relax accommodation when fitted with aspheric multifocal center distance lenses when the add is +1.00. It is therefore unlikely that subjects with accommodative ability, in whom the treatment purpose is to reduce blur and thereby accommodation, can be effectively treated with such lenses.

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