Original Article

Impact of soft and rigid gas-permeable contact lenses on visual performance in mesopic conditions

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Context: Evaluation of visual quality in soft and rigid gas-permeable contact lens wearers, with an emphasis on twilight vision. **Purpose:** To assess the visual acuity and visual performance at dusk before and after soft and rigid gas-permeable contact lens (CL) correction in healthy subjects. **Settings and Design:** This prospective study was conducted in a tertiary eye-care center. **Methods:** Sixty eyes corrected with soft contact lenses (SCLs) and 30 eyes with rigid gas-permeable contact lenses (RGPCLs) were enrolled in this study. Patients underwent corrected distance visual acuity with spectacles (CDVAs), corrected distance visual acuity with contact lenses (CDVAcl), and twilight vision (TV) testing (Vista Vision Far-Pola, DMD MedTech charts). Parameters were evaluated before and after the CL fitting and repeated 3 months after the baseline visit. **Statistical Analysis Used:** MedCalc for Windows, version 11.4 (MedCalc Software, Ostend, Belgium). **Results:** Rigid gas-permeable CL wear showed significant improvement in CDVAcl compared to wearing spectacles on both visits ($P = 0.0039$ and $P = 0.0003$, respectively). TV with CLs was significantly better in both groups compared to the TV with spectacles at the baseline visit ($P = 0.0011$ in SCL group; $P = 0.0001$ in RGPCL group), and at the follow-up visit, this significance was proven for the RGPCL group ($P = 0.001$). Also, spectacle TV showed a significant improvement on the follow-up visit ($P = 0.0022$ in SCL group; $P = 0.0269$ in RGPCL group). **Conclusion:** Contact lens wear improves visual performance compared to spectacles. TV results showed superiority of CLs compared to the spectacles, without a statistical difference regarding the CL type.

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Rigid gas-permeable contact lenses (RGPCLs) show superiority in visual performance compared to the soft contact lenses (SCLs) and spectacles.[1-6] Visual acuity (VA) measurement is the most important step in evaluating visual capability.[7-9] However, twilight vision (TV) or night myopia represents a major functional problem for young adults, and it is caused by a phenomenon that leads to the effect of myopic shift.[10] Studies showed a significant decrease between high- and low-contrast VA.[11] The aim of this study was to assess visual performance before and after correction with SCLs and RGPCLs in healthy subjects, highlighting the effect on TV.

Methods

This prospective study included 60 eyes of 30 subjects who were corrected with SCLs and 30 eyes of 18 subjects corrected with RGPCLs. The patients were recruited during a 1-year period at a tertiary eye-care center. After detailed information was provided, an informed consent form was signed by all the subjects and parents of study participants who were under 18 years of age. The study followed the tenets of the Declaration of Helsinki, and all experimental protocols were approved by the Ethics Committee of the University Hospital Centre. Exclusion criteria included prior contact lens wear, dry eye disease and other anterior segment pathology, posterior segment pathology, amblyopia, use of any medications known to interfere with contact lens (CL) wear, and prior ocular surgery. Subjects who had a refraction over ±5.00 spherical diopters (Dsph) and/or a cylindrical refractive error over 3 cylindrical diopters (Dcyl) were also excluded. The study included healthy patients between the ages of 15 and 35, with a refractive error lower than the previously mentioned in exclusion criteria. The SCLs included in this study were made of comfilcon A and senofilcon A materials, while all RGPCLs were composed of enflufocon B. All participants underwent a slit-lamp examination, Schirmer test, non-invasive tear break-up time test, auto-refractokeratometry (Indo, eRK-10, USA), and corneal tomography (Pentacam, OCULUS, Wetzlar,

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Germany), whereupon appropriate CLs were fitted. The type of CL that was fitted depended on the amount of spherical and cylindrical refractive error and the patient's preference. SCLs were not fitted to the patients with a cylindrical refractive error over -0.75 Dcyl. After confirming that the subjects did not have any ocular pathology or irregularities on corneal tomography, a visual assessment with spectacles and CLs was obtained. It included the corrected distance VA with spectacles (CDVAs), corrected distance VA with contact lenses (CDVAcl), and TV (Vista Vision Far-Pola, DMD MedTech charts, Italy). The parameters were evaluated at a baseline visit (T0) and on follow-up visit after 3 months of CL wear (T1), with both spectacles and CLs. Distance VA and TV were assessed on each eye separately, first with spectacles and afterward with CLs after a settling period of 10–15 minutes. The follow-up visit was done in the morning hours, and patients were advised to come without CLs (wearing spectacles), which were removed the day before, so the visual performance can be measured first with spectacles. Monocular distance VA was tested using Early Treatment Diabetic Retinopathy Study (ETDRS) charts at a 4 m distance under photopic (100 cd/m^2) normal room lighting conditions.

As for the visual function, the TV was measured by the commercially available computerized mesopic VA test (Vista Vision Far-Pola, DMD MedTech charts, Italy). The patients were placed 3 m away from the chart, with their heads in alignment with the screen plane. Illumination of the environment was obscured to 1 lux. Test showed 1 line of letters with a light background of 1 cd/m^2, which was specified by the manufacturer. Each row consisted of five of the Sloan optotypes with values of VA ranging from 0.1 to 1.0. The subjects were allowed 5 minutes of adaptation to the ambient light conditions before the test, whereupon they were asked to read black letters on a dim screen plane. VA is verified starting from the first line of the optotype. Both VA and TV testing were scored letter by letter, with a termination rule of stopping after three or more mistakes within a single line.

Statistical analysis was performed using MedCalc for Windows, version 11.4 (MedCalc Software, Ostend, Belgium). Kolmogorov–Smirnov test was used to assess the normality of the distribution. A paired Wilcoxon test was used for repeated testing of the same individual, while a Mann–Whitney test was used to test for differences between groups. Categorical data were analyzed using a Chi-square test. *P* values less than 0.05 were considered significant.

Results

Ninety eyes of 48 subjects, in total, with a median age of 18.5 [inter-quartile range (IQR) 16–24] years old were included in this study. They were divided into two groups: SCL wearers and RGPCL wearers. The SCL group contained 60 eyes of 30 subjects with a median age of 18 (IQR 16–24) years, while the RGPCL group included 30 eyes of 18 subjects with the median age of 20 (IQR 16–23) years. Among these subjects, the SCL group had 76%, and the RGPCL group had 77% female participants.

The median spherical refractive error on T0 was -2.00 Dsph (IQR -1.25 to -3.25 Dsph) in the SCL group and -1.75 Dsph (IQR -0.75 to -5.00 Dsph) in the RGPCL group. On the first visit, subjects in the SCL group expressed no cylindrical power when calculating the median value, although the IQR for the majority was from 0 to -0.75 Dcyl. In the RGPCL group, the median cylindrical power was -0.75 Dcyl (IQR 0 to -2.75 Dcyl).

Visual acuity

All subjects in the SCL group achieved a maximum of 1.0 in the ETDRS chart with spectacles and CLs at both visits, showing no statistical change regarding visit or type of correction. Subjects fitted with RGPCLs showed statistically significant improvement in CDVAcl when compared to CDVAs on both visits. The median CDVAs and CDVAcl on both visits were 1.0 in the ETDRS chart, but the IQR differed. On the first visit, the IQR of CDVAs was from 0.8 to 1.0, with improvement to rank 1.0 with RGPCLs ($P = 0.0039$, Wilcoxon test), while those values on the follow-up visit ranged from 0.63 to 1.0 for CDVAs, being equalized to 1.0 with CDVAcl ($P = 0.0003$). The RGPCL group showed no significant improvement in CDVAs between visits, indicating that CL wear for a period of 3 months did not affect the VA acquired with spectacles.

Twilight vision

First, we compared the TV with spectacles (TV S) to TV with CLs (TV CL) between visits [Table 1]. At the T0 visit, results showed that the TV CL was significantly better in both the SCL and RGP groups compared to TV S ($P = 0.0011$ in SCL group; $P = 0.0001$ in RGPCL group, Wilcoxon test). During the T1 visit, the SCL group did not show a significant difference between TV S and TV CL, while in the RGPCL group, there was a significant increase in TV CL compared to TV S ($P = 0.001$).

Second, the TV S between two visits was compared. In both groups, the TV S was significantly better at T1 ($P = 0.0022$ in SCL group; $P = 0.0269$ in RGPCL group, Wilcoxon test). The results are shown in Table 2.

Third, a similar comparison was done for the TV with CLs, which showed no significant improvement in the TV at T1 in either group [Table 2].

Table 1: Twilight vision values and comparison between spectacles and CLs at the T0 and T1 visits

	SCL			RGPCL		
	Median	25-75P	*P*	Median	25-75P	*P*
TV S T0	0.9	0.80–1.00	0.0011	0.85	0.60–1.00	0.0001
TV CL T0	1	0.95–1.00		1	0.80–1.00	
TV S T1	1	0.90–1.00	0.6387	0.95	0.60–1.00	0.0010
TV CL T1	1	1.00–1.00		1	0.90–1.00	

SCL – soft contact lens, RGP CL – rigid gas-permeable contact lens, TV S T0 – twilight vision with spectacles on the baseline visit, TV CL T0 – twilight vision with contact lens on the baseline visit, TV S T1 - twilight vision with spectacles on the control visit, TV CL T1 - twilight vision with contact lens on the control visit

Table 2: Twilight vision values with spectacles and CLs and their comparison between the two visits

	SCL			RGPCL		
	Median	25-75 P	*P*	Median	25-75 P	*P*
TV S T0	0.9	0.80–1.00	0.0022	0.85	0.60–1.00	0.0269
TV S T1	1	0.90–1.00		0.95	0.60–1.00	
TV CL T0	1	0.95–1.00	0.3736	1	0.80–1.00	0.1294
TV CL T1	1	1.00–1.00		1	0.90–1.00	

SCL – soft contact lens, RGP CL – rigid gas-permeable contact lens, TV S T0 - twilight vision with spectacles on the baseline visit, TV S T1- twilight vision with spectacles on the control visit, TV CL T0 - twilight vision with contact lens on the baseline visit, TV CL T1 - twilight vision with contact lens on the control visit

At the end, a direct comparison of TV between SCLs and RGPCLs was done, which showed marginal statistical significance in favor of SCLs at T0 ($P = 0.0462$, Mann–Whitney test) and no statistical difference between SCLs and RGPCLs at T1.

Discussion

Visual function defines how well the eye and visual system work, and it includes the VA, contrast sensitivity, central and peripheral visual fields, TV, and glare sensitivity. Impairment of any of these parameters compromises visual function.[12] Several studies have demonstrated that visual performance can vary substantially depending on the method of correction.[1-3] So far, it is widely accepted that the RGPCLs can provide better optical quality than SCLs or spectacles. According to studies, the main mechanism for that is to significantly reduce the ocular aberrations, including both lower-order aberrations (LOAs) and higher-order aberrations (HOAs).[13,14]

Our study analyzed the best corrected VA with spectacles and CLs. The SCL wearers showed no significant change regarding the visit or type of correction, while the RGPCL wearers showed statistically significant improvement in CDVAcl when compared to CDVAs on both visits. However, no significant improvement in CDVAs between visits was achieved, indicating that CL wear for a period of 3 months did not affect the VA acquired with spectacles.

In addition to VA, we reviewed TV as a better predictor of visual performance. Although photopic VA is the most commonly used determinant of visual function, studies have shown that measures of mesopic VA can provide additional insight into functional vision loss. Lin *et al*.[11] showed in their study a significant decrease between the mean VA at the photopic light level and three mesopic light levels. Mesopic vision refers to visual function at certain light levels (twilight) at which both the cone and rod system are active and it covers a luminance range from approximately 32 to 0.0032 cd/m^2.[15] The importance of a good vision in mesopic conditions is even emphasized by the law in some countries, where they have special directives concerning the driving license. The twilight test, which was used in this study, is specifically designed by the manufacturer for the verification of visual functions according to the legislative decree of the Italian Ministry of Health. Also, some regions have recommended a road luminance of 0.3 to 2.0 cd/m^2 in Europe and 0.3 to 1.2 cd/m^2 in the United States.[16]

All those guidelines highlight the importance of visual quality and visual performances above basic VA. Our study showed that TV performances were better with both types of CL correction when compared to the TV with spectacles on the baseline visit. Both groups showed an improvement of TV performances with spectacles after 3 months of CL wear, while the TV CL with both types of CLs remained similar during the baseline and follow-up visit, respectively. Such results may correspond to the fact that CL wear leads to changes in the corneal surface and tomography parameters, so spectacle visual performances, when combining with CL wear, may become better with time. Studies have reported that the vision in mesopic conditions is extremely sensitive to astigmatism, so even slight changes in the corneal surface, due to CL wear, can temporarily change astigmatism values and show significantly better results with spectacles.[17]

By direct comparison of TV between the SCLs and RGPCLs, we found no significant difference after a 3-month period of CL wear. On the baseline visit, the SCL showed marginal superiority when compared to the RGPCLs, but this might be explained by a greater variety of comfort on the initial fitting with RGPCLs and subsequent reflex tear production, which could affect the quality of vision. Patients who were fitted with the RGPCLs showed TV performances on follow-up visit that did not differ much from the SCL.

Studies have shown that degree of reduction in contrast sensitivity when wearing soft lenses is influenced by their water content – the lower the water content, the greater the disturbance in the contrast sensitivity function. On contrast grounds alone, higher-water content lenses are therefore to be preferred.[18] Patients in our study were corrected with silicone hydrogel SCLs, comfilcon A and senofilcon A, both having high water content and high oxygen transmissibility. However, different silicone hydrogel lenses may also vary considerably with respect to several characteristics: oxygen permeability, water content, material stiffness, thickness, edge profile, surface smoothness, surface treatments, hydrophobicity, size, and base curve. The effect of these characteristics on mesopic vision is not yet elucidated; nevertheless, there may be a considerable variation in the performance of different silicone lenses, which should be further investigated.[19] As for the RGPCLs in our study, all were composed of enflufocon B. Domínguez-Vicent *et al*.[20] assessed the optical quality of four Boston CL materials *in vitro* and concluded that no visual differences might be expected among Boston materials for a 3.0 mm optical aperture. However, they might be expected at a 6.0 mm optical aperture. *In vivo* studies are required to clarify these conclusions drawn from *in vitro* testing since differences in on-eye lens performance related to surface wettability, oxygen permeability, and the wearing modality may impact on the quality of vision.

What is worth noting is that the protective layer on the spectacle correction is also important when evaluating the visual quality. It is well known that benefits of an anti-reflective coating include transparent, clear, uninterrupted, and reflection-free vision for the wearer. At night, many people tend to have a halo effect around the headlight of the coming cars, and this layer can effectively help in driving at night and improve TV. On the other hand, lenses without an anti-reflective coating have a great deal of visible reflection for the wearer. A very popular coating nowadays is also an anti-reflective layer with a blue-light filter. Considering the blue light, while an excessive amount is theoretically harmful, adequate blue light is necessary for normal visual function.[21] Leung *et al*.[22] investigated how the blue-light filtering lenses affect visual and physiological functions and concluded that those lenses slightly attenuate scotopic sensitivity and melatonin suppression by 2.4–7.5% and 5.8–15.0%, respectively. However, most participants reported no subjective change in lens performance compared to the control lens. The limitations of this study are not randomizing our subjects based on different protective spectacle layers and that two types of silicone hydrogel SCLs were combined and evaluated as one group.

As to our knowledge, there are no previous studies that have evaluated visual performances in mesopic conditions using the twilight test by Vista Vision Far-Pola or compared the effect of SCL and RGPCL long-term wear on the visual performance in mesopic conditions.

Conclusion

In summary, when analyzing the TV, our results showed superiority of CLs to the spectacle correction, with no statistical difference regarding the CL type. To our knowledge, this is the first prospective study to simultaneously investigate the changes in VA and TV in SCL and RGCL wear, suggesting both types of CLs as the satisfactory correcting methods for achieving optimal visual performance.

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