Videokeratography for Quantitative Surface Analysis of Used Soft Contact Lenses

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Abstract: The greater utilization of soft contact lenses calls for the development of new and objective methods of evaluating the optical performance of the different lens types, in situ. We used videokeratography to examine the surface topography of soft contact lenses that had been worn for more than 1 year on 27 eyes of 23 patients, and compared the resulting color-coded maps and topographic indices as well as contact lens-corrected visual acuities, with those obtained with new replacement lenses on the same eyes. Visual inspection of the color-coded maps revealed differences in the surface characteristics of the used and new lenses. Comparison of quantitative indices including the SAI (Surface Asymmetry Index), IAI (Irregular Astigmatism Index), SRI (Surface Regularity Index), and SDP (Standard Deviation of Powers) showed that asymmetry, surface irregularity, potential visual acuity (derived from the SRI), and corneal power distribution were significantly poorer with the used lenses than with the new ($P = 0.0001$). The videokeratoscope is useful for evaluating the soft contact lens surface in situ, as an indicator of optical quality; it also permits the objective evaluation of lens cleaning techniques. **Jpn J Ophthalmol 1997; 41:235–239** © 1997 Japanese Ophthalmological Society

Key Words: Corneal topography, soft contact lens, surface regularity index, topographic index, videokeratography, videokeratoscope.

Introduction

Contact lens deterioration is caused by deposits, physical defects, and aging, which diminish the optical performance of the lens.[1] In the contact lens clinic, slit-lamp biomicroscopy and stereomicroscopy are generally used to evaluate the condition of the contact lens in a nondestructive, noninvasive manner to gain information about lens deposits, wettability, optical clarity, and lens surface irregularities, as well as ocular abnormalities associated with deterioration.[2] These findings, however, do not always correlate with contact lens-corrected visual acuity.

The optical performance of rigid gas permeable (RGP) lenses can be evaluated with the radiuscope, or simply by viewing a grid pattern projected through the lens.[3] It is difficult, however, to evaluate the optical performance of the soft contact lens objectively from these measures of lens quality because the soft contact lenses are deformed in situ. Optical performance of soft contact lenses, therefore, has been evaluated by comparing the best spectacle-corrected visual acuity with the best contact lens corrected visual acuity.

Recent developments in videokeratography have made significant contributions to corneal shape analysis.[4] This technology provides the clinician with color-coded maps and objective numerical measures that describe corneal surface irregularities. Additionally, a variety of specific topographic patterns characteristic of certain pathological conditions have been identified. This has brought videokeratography into widespread use for applications ranging from screening refractive surgery candidates for keratoconus,[5] to estimating the optical quality of the cornea with topographic indices[6] and ray tracing methods.[7]

We have found that it is possible to obtain a reli-

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able videokeratographic analysis of the contact lens surface in situ. We believe that this approach can supply useful information about the anterior surface of the lens in the form of topographic patterns showing surface irregularities and indices that signal changes in optical quality. In this study, we examined the corneal topography of used and new lenses in situ to develop an objective method for evaluating soft contact lens performance.

Materials and Methods

Subjects were selected from patients of the Hamano Eye Clinic, Osaka. Consecutive patients were evaluated for inclusion in the study according to the following criteria: use of a specific contact lens (38% water-content Menicon MA lens, Menicon, Nagoya) worn daily for more than 1 year; scheduled office visit for contact lens replacement; and replacement lens of identical type, giving visual acuity of 20/20 or better. Twenty-three patients (27 eyes) were selected, including seven men and 16 women, from 18 to 45 years old (mean ± SD: 32.2 ± 6.2). The wearing period for the used lenses ranged from 12–70 months (mean ± SD: 29.4 ± 13.1). Informed consent was obtained from all subjects; provisions of the Declaration of Helsinki were followed in this study.

Eyes were examined by videokeratography[8] (TMS-1, Computed Anatomy, New York, NY, USA) with the used lens in situ; the examination was repeated with the new replacement lens of the same parameters. Visual acuities with the used lenses ranged from 20/20 to 20/200. Three topographic maps of each used and new lens were obtained on the same day for each subject. From each set of three maps, the one with the best focus, alignment, and reproducibility was chosen for study.

Topographies of used and new lenses were compared by visual inspection of the color-coded maps using the Klyce-Wilson scale (1.5 diopter interval; axial power; 28.0–65.5 diopter range).[9] The maps were qualitatively assessed for irregular central patterns, abnormal central steepening, abnormal central flattening, and abnormal asymmetry.

Quantitative analysis of the topography involved four indices: SAI (Surface Asymmetry Index), SRI (Surface Regularity Index), IAI (Irregular Astigmatism Index), and SDP (Standard Deviation of Power). The SAI is a measure of the extent of radial asymmetry[6,10]; larger SAI values indicate greater asymmetry. The SRI measures the fluctuation of the radial corneal power distribution in the central cornea and is related to the corneal component of potential visual acuity[5]; higher SRI values indicate poorer estimated potential visual acuity. The IAI describes the fluctuation of the radial corneal power distribution across the entire measured surface[5]; higher IAI values indicate greater irregular astigmatism. The SDP is an index that computes the standard deviation of the corneal power distribution[5]; higher SDP values indicate a less uniform corneal power distribution.

Eyes were divided into two subgroups for analysis of the relationship between contact lens-corrected visual acuity and the four topographic indices. The 12 eyes in the stable contact lens corrected visual acuity group had similar visual acuity with both used and new lenses: 20/25 or better with the used, 20/20 or better with the new. The 15 eyes in the reduced contact lens corrected visual acuity group had poorer visual acuity with the used lenses (20/30–20/200) than with the new (20/20 or better).

Results

Case Reports

Case 1. A 32-year-old woman who had worn the same soft contact lens in the left eye for 29 months was seen for a complaint of reduced vision with her lenses and evaluated for lens replacement. Stereomicroscopy of the left contact lens showed deformation of the lens and a moderate amount of lens deposits. Lens power was −3.25 diopters, base curve was 8.40 mm, and diameter was 13.0 mm; best corrected visual acuity with the lens was 20/40 with an overcorrection of −2.0 diopters spherical. With a new lens of the same power, base curve, and diameter, visual acuity improved to 20/20 without additional correction.

The topographic map of the surface of the used lens (Figure 1, left) showed central steepening and an irregularity from the center to the superior part of the contact lens; the map of the new lens (Figure 1, right) showed a smoother and more uniform pattern. All four quantitative indices were abnormal for the used lens and within the normal range for the new lens. Values for the used and new lenses were SRI: 2.43, 1.08; IAI: 0.82, 0.52; SAI: 5.97, 0.30; SDP: 3.62, 0.62.

Case 2. A 33-year-old man who had worn a soft contact lens (power: −3.50 diopters; base curve: 8.70 mm; diameter: 13.00 mm) in the right eye for 30 months was examined. The lens had apparently been maintained carefully and stereomicroscopy showed no marked lens deposits or shape changes. With both the used and new lenses, visual acuity was 20/20 with no additional correction. Color-coded maps of the used and new lenses show few differences (Figure 2).

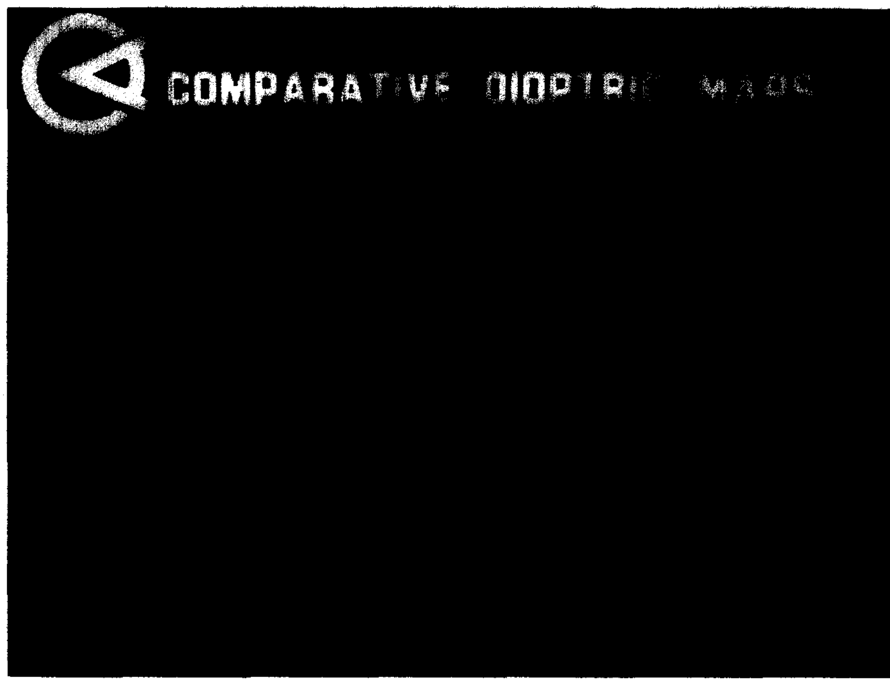

Figure 1. Case 1: Color-coded maps of used lens (left) and new lens (right). Contact lens-corrected visual acuity improved from 20/40 to 20/20 with new lens of same parameters. Steep central area and irregular pattern of used lens map are not visible on new lens map. Topographic changes correlated with improvement of contact lens-corrected visual acuity after change in lenses.

The topographic indices of the used and new lenses were also similar (SRI: 0.63, 0.71; IAI: 0.47, 0.40; SAI: 0.44, 0.36; SDP: 0.43, 0.34).

Group Comparisons

Table 1 summarizes the abnormal topographic findings from the color-coded maps. Irregular central pattern and central steepening were found with significantly greater frequency on maps of used lenses than on maps of new lenses. The incidence of abnormal central flattening and abnormal asymmetry did not differ significantly in used and new lenses.

Table 2 summarizes the four topographic indices obtained for the used and new lens surfaces. The used lenses had significantly higher indices. New lens values were similar to values for the normal cornea. When mean values for the new lenses were slightly

Figure 2. Case 2: Color-coded maps of used lens (left) and replacement lens (right). Contact lens corrected visual acuity was 20/20 with both lenses. Note also that there is little change in topographic maps.

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Table 1. Incidence of Abnormal Findings on Color-Coded Topographic Maps

Topographic Feature	Used Lenses (N = 27)	New Lenses (N = 27)	*P* Value[a]
Irregular central pattern	18 (67%)	1 (4%)	0.0001
Abnormal central steepening	6 (22%)	0 (0%)	0.0206
Abnormal central flattening	2 (7%)	0 (0%)	0.2398[b]
Abnormal asymmetry	6 (22%)	3 (11%)	0.2525[b]

[a]McNemar test.
[b]Not significant.

larger than for the normal cornea, the difference might have been related to faster tear breakup time on the contact lens.

Topographic indices of the used lenses in the reduced visual acuity and stable visual acuity subgroups are shown in Figure 3. The SRI and IAI were significantly higher in the reduced group, but differences in SAI and SDP were not significant. With the new lenses in place (Figure 4), there were no significant differences in any of the indices.

Discussion

Evaluation of soft contact lenses is necessary to ensure a high standard of optical quality. However the parameters that can be quantitatively assessed are limited (base curve, water content).[11] The ex vivo parameters of the lens may change when on the eye and may also vary from eye to eye because of differences in corneal shape.

The development of videokeratography now permits topographic analysis of the contact lens surface in situ. A previous study[12] analyzed the effect of contact lens design on lens surface topography, using visual inspection of the color-coded maps and comparison of the topographic indices. Videokeratography has also been used to investigate toric soft contact lens use for neutralization of astigmatism.[13]

In this study, this new method was used to evaluate surface differences of used and new soft contact lenses on the eye. Visual inspection of the color-coded maps of used lenses frequently revealed an irregular pattern in the central area or an abnormal central steepening, but these were rare in the new lenses. Although the topography of the old lenses often appeared to be more asymmetrical with abnormal central flattening, the frequency of these findings in the used and new lenses was not significantly different. In new lenses, irregular patterns could be the result of tear film breakup and asymmetry could be the result of the underlying corneal topography. Eyelid compression may also influence these findings.

Analysis of the topographic indices showed significant differences between used and new lenses. SAI comparison suggests that new lenses are more symmetrical than used lenses. The IAI comparison indicates that the new lenses had less irregular astigmatism than the used lenses. Differences in the SDP implied that new lenses had better optical surface quality than used lenses and, as expected, the SRI comparison showed that new lens surfaces provided better potential visual acuity than the used lens surfaces.

For further evaluation of the relationship of lens quality to visual acuity, the maps and indices of two subgroups were compared: one had similar visual acuities with used and new lenses and one had

Table 2. Topographic Indices (Mean ± SD)

Topographic Index	Standard Values for Normal Cornea	Used Lenses (N = 27)	New Lenses (N = 27)	*P* Value[a]
SAI	0.26 ± 0.08	1.28 ± 1.21	0.38 ± 0.13	0.0001
SRI	0.28 ± 0.14	1.18 ± 0.47	0.68 ± 0.22	0.0001
PVA[b]	(20/15 to 20/25)	(20/30 to 20/40)	(20/25 to 20/30)	
SDP	0.84 ± 0.16	1.52 ± 1.25	0.74 ± 0.27	0.0001
IAI	0.34 ± 0.05	0.62 ± 0.11	0.49 ± 0.06	0.0001

SAI = surface asymmetry index. SRI = surface regularity index. SDP = standard deviation of power. IAI = irregular astigmatism index.
[a]Comparison of used and new lens values, Wilcoxon's signed rank test.
[b]Potential visual acuity derived from SRI.

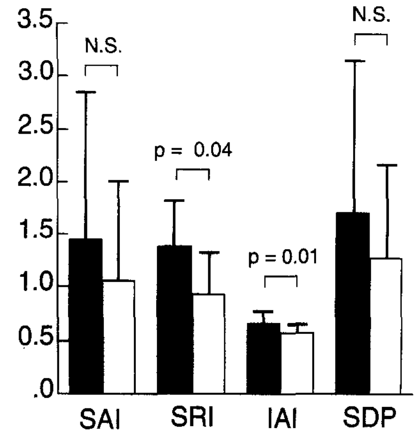

Figure 3. Used lenses. In the group with reduced contact lens-corrected visual acuity (N = 15; solid bars), SRI and IAI are significantly higher than in the group with stable contact lens-corrected visual acuity (N = 12; open bars). Error bars are standard deviations. SAI = asymmetry index. SRI = surface regularity index. IAI = irregular astigmatism index. SDP = standard deviation of power.

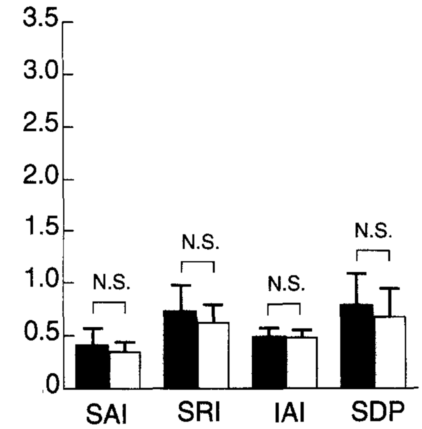

Figure 4. New lenses. No significant differences in indices for the group with reduced contact lens-corrected visual acuity (N = 15; solid bars) compared with stable contact lens-corrected visual acuity group (N = 12; open bars). Error bars are standard deviations. SAI = asymmetry index. SRI = surface regularity index. IAI = irregular astigmatism index. SDP = standard deviation of power.

poorer visual acuity with the used lens. There were no significant differences in the four topographical indices of the two groups obtained while wearing the new lenses; while wearing the used lenses, SRI and IAI were significantly higher in the reduced visual acuity group. Changes in these indices—an abnormal SRI (irregular central pattern) or an abnormal IAI (overall irregular pattern)—represent a reduction in the optical capability of the contact lenses in situ.

Many factors affect contact lens corrected visual acuity, including lens deposits, deformation, change in water content, change in hydrophilicity of the lens surface, and tear film breakup. All seem to reduce the optical quality of the lens by altering the shape of the wetted anterior lens surface. Videokeratographic analysis of the contact lens surface in situ may be useful in evaluating the optical performance of the soft contact lens. This approach may be useful for the objective evaluation of various soft contact lens cleaning modalities.

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References

1. Tripathi RC, Tripathi BJ, Silverman RA, Rao GN. Contact lens deposits and spoilage: Identification and management. Int Ophthalmol Clin 1991;31(2):91–120.
2. Tripathi RC, Tripathi BJ. Lens spoilage. In: Dabezies OH, ed. Contact lenses: The CLAO guide to basic science and clinical practice. Orlando: Grune & Stratton, 1984:45.1–45.33.
3. Koeniger E, Dabezies OH. Other types of lens verification. In: Dabezies OH, ed. Contact lenses: The CLAO guide to basic science and clinical practice. Orlando: Grune & Stratton, 1984:20.1–20.6.
4. Klyce SD, Wilson SE. Methods of analysis of corneal topography. Refract Corneal Surg 1989:5:368–71.
5. Maeda N, Klyce SD, Smolek MK, Thompson HW. Automated keratoconus screening with corneal topography analysis. Invest Ophthalmol Vis Sci 1994;35:2749–57.
6. Wilson SE, Klyce SD. Quantitative descriptors of corneal topography: A clinical study. Arch Ophthalmol 1991;109:349–53.
7. Camp JJ, Maguire LJ, Cameron BM, Robb RA. A computer model for the evaluation of the effect of corneal topography on optical performance. Am J Ophthalmol 1990;109:379–86.
8. Rabinowitz YS, Wilson SE, Klyce SD. Color atlas of corneal topography: Interpreting videokeratography. New York: Igaku-Shoin Medical Publishers, 1993:8–17.
9. Wilson SE, Klyce SD, Husseini ZM. Standardized color-coded maps for corneal topography. Ophthalmology 1993; 100:1723–7.
10. Dingeldein SA, Klyce SD, Wilson SE. Quantitative descriptors of corneal shape derived from computer-assisted analysis of photokeratographs. Refract Corneal Surg 1989;5:372–8.
11. Harrison KW, Cook P. Office evaluation and verification of soft lenses. In: Stein HA, et al, eds. Fitting guide for rigid and soft contact lenses: A practical approach. St. Louis, C.V. Mosby, 1990:81–6.
12. Watanabe K, Maeda N, Hamano H. The evaluation of soft contact lens design using corneal topography. Invest Ophthalmol Vis Sci 1992;33(Suppl):1293.
13. McCarey BE, Amos CF, Taub LR. Surface topography of soft contact lens for neutralizing corneal astigmatism. CLAO J 1993;19:114–20.