REVIEW OF
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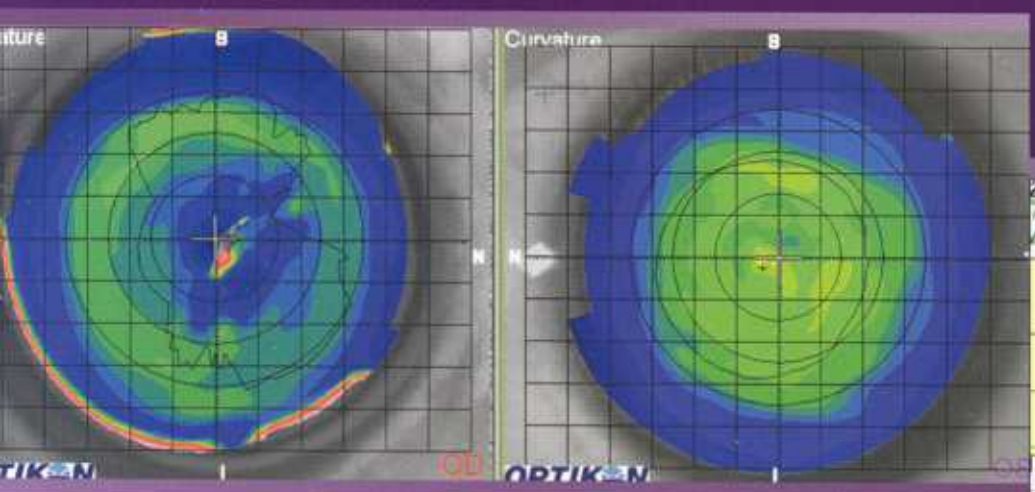
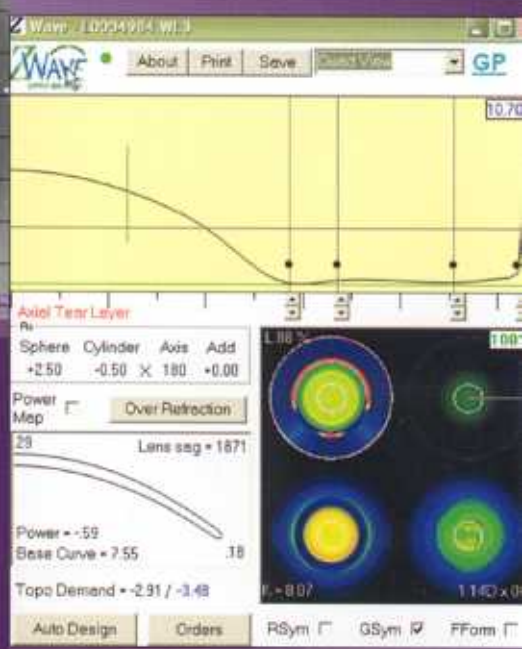
Using CAD/CAM LENSES for Orthokeratology





Using this system allows a greater degree of control over lens design and allows you to expand options for your patients.

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SUPPLEMENT TO
REVIEW OF OPTOMETRY
APRIL 2004

Using CAD/CAM LENSES for Orthokeratology

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ORTHOKERATOLOGY HAS UNDERGONE many transformations since its beginnings four decades ago. From the types of cases that we can treat to the very approach used in treating these cases, procedures, protocols and lens designs used today by orthokeratologists have very little in common with those of just a decade ago.

I have primarily used EyeQuip Wave lenses for my current orthokeratology cases because of the degree of control that this system affords in lens design. Wave is a CAD/CAM (computer-aided design and manufacture) system. In using this system, I have brought all of my previous gas permeable and orthokeratology knowledge to the table and I've been able to modify and expand my approach within the parameters of this system. Following are several ortho-k cases and how I managed them.

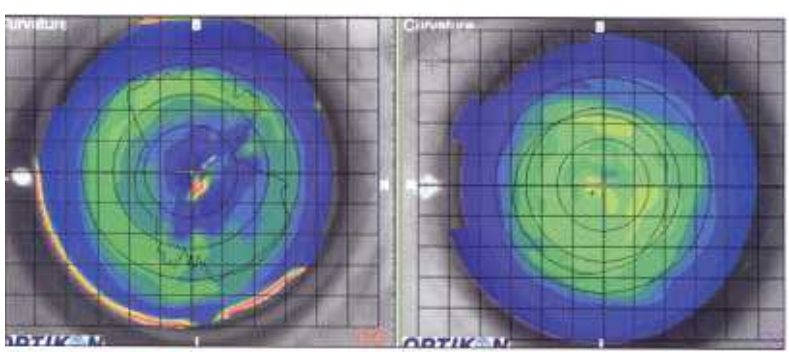

FIG. 1. OD ON THE LEFT, OS ON THE RIGHT. NOTE THE OD SCAR.

Case 1

Patient R.S. is a 38-year-old African-American man who had photorefractive keratectomy (PRK) performed on his right eye in 1997. He had immediate problems after surgery: a central scar formed along the visual axis. He was placed on steroids and an analgesic for one month after surgery, but he was still left with an opacified scar in the visual axis. He did not proceed with surgery on the left eye. He presented wearing spectacles with a prescription of –1.50 DS OD and –3.00–0.25x175 OS. He was seeking options for his right eye because he was not happy with the quality of the vision in this eye with spectacles. His refraction that day was –1.50 DS 20/20- OD and –3.25 DS 20/20 OS. The patient struggled to read the letters on the 20/20 line, and he complained that they looked distorted. The remainder of the exam was unremarkable.

Orthokeratology came up when I discussed options with him. I explained that the left eye would do very well very quickly but that the results on the right eye were unpredictable. In fact, I told him, I was skeptical that we would

reach a satisfactory goal in that eye. Although I have successfully treated post-PRK eyes with ortho-k, the position, opacification and height of this particular scar greatly concerned me. After a lengthy discussion about my concerns with his right eye, the patient decided that he still wanted to move forward with ortho-k.

As you can see from the topography of the right eye (Figure 1), the scar is almost perfectly centered along the visual axis. This was the best topographical image I was able to obtain for this patient, and you can also see that the tears continued to break up adjacent to the scar. The height of the scar at its peak is about 65.00 diopters, whereas the surrounding valley created by the PRK at its flattest point is about 14.00 diopters. I felt that this great variability of the corneal shape along the visual axis and its effect on tears were greater contributing factors to the degraded image quality than was the scar opacification.

Because the central portion of the right eye was already very flat from the PRK, my goal with ortho-k was twofold: flatten the apex of the scar so that its curvature would be more aligned with the surrounding tissue and "homogenize" the already surgically flattened central optic zone while widening the treated area out to the reverse curve area. The left eye would be a very straightforward myopia reduction case.

The left eye responded as expected. A very sharp endpoint resulted in acuity of $20/10^{-2}$ in this eye throughout the entire day. This topography (Figure 2) was completed about eight hours after the lens had been removed. The map is very "clean" with a great deal of homogeneity in the central, reverse curve and peripheral areas of his cornea. The patient had not achieved this level of acuity in this eye with his best spectacle correction prior to treatment. This improvement in acuity is due to the cleaner nature of his central cornea subsequent to orthokeratology treatment.

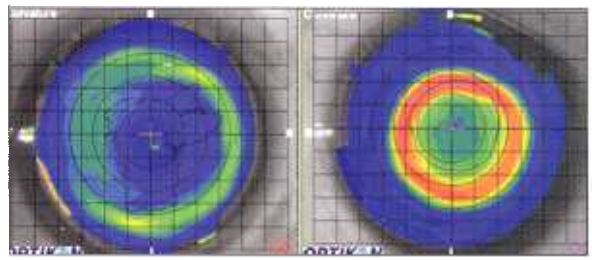

FIG. 2. TOPOGRAPHY EIGHT HOURS AFTER LENS REMOVAL.

The right eye has also shown some significant changes. The scar has been reduced to a peak of about 40.00 diopters. The surrounding area shows more regularity out to the area of the reverse curve with its flattest point at about 25.00 diopters. The quality of uncorrected vision still suffers, however, even though uncorrected acuity has now reached 20/30. With the lens on the eye, acuity is 20/20, with a great deal of improvement in subjective quality of the image. This patient has been treated with orthokeratology for almost a year. I reviewed additional options, including surgery, but he has already made it clear that he is very satisfied with the results thus far, and currently feels that the $20/10^{-}$ uncorrected crisp vision of his left eye combined with the 20/30 slightly distorted vision of the right eye is more than acceptable for his normal daily function and an adequate compromise to enjoy the freedom that night-wear only orthokeratology affords him.

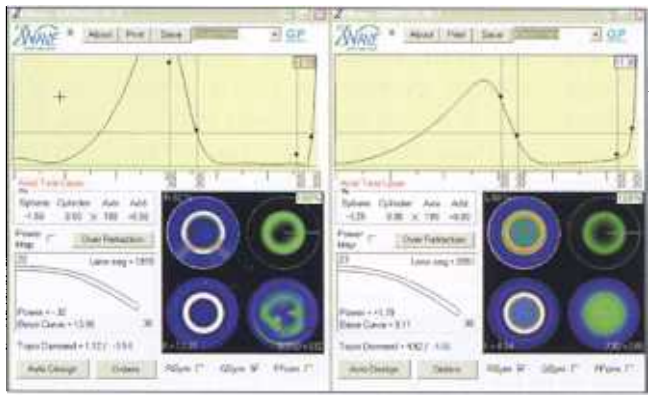

FIGURE 3. LENS DESIGN FOR PATIENT R.S.

The lenses that this patient is currently wearing (Figure 3) are designed as follows: the right lens is a geometrically symmetrical lens, which means that if you divide the back surface of the lens in half, it is symmetrical around that plane. Using this type of design allowed me to better align the back surface of the lens on the surgically altered irregular cornea. I needed a large diameter to keep the lens positioned properly, which can be seen as 12.10mm.

The graph in the upper half of the Wave window on the sodium fluorescein selection represents the inter-action at the tear layer of the back surface of the lens with the front surface of the cornea in the given semi-meridian. The green line at the base of the graph represents the curve of the cornea as a reference curve; the black line above represents the back surface of the lens with respect to the green corneal reference line. The space between the two represents the tear layer formed between the interaction of the back surface of the lens and the front surface of the cornea in that semi-meridian.

At the apex of the lens are 15.1µm of tear clearance. The peak of the reverse curve forms a circle with a diameter of 5.85mm and at its most shallow point has 86µm of tear clearance; at its deepest point it has 103µm of tear clearance. I was able to create this variability of tear clearance manually in this annulus by using the control points for design and taking advantage of the geometrical symmetry in this lens. In the 3.5mm-wide annulus between diameter 8.00mm to diameter 11.5mm, the lens is well aligned with the cornea and averages

about 3.5µm of tear clearance. This helps keep the lens well centered.

The left lens is a rotationally symmetrical lens, meaning that it is symmetrical throughout the 360 degrees around the lens. Tear clearance at the apex of the lens is 12.1µm with about 57µm of clearance at the peak of the reverse curve. The zones of the lens have the 3.0mm annulus from diameter 7.5mm to diameter 10.5mm, well-aligned with the cornea, with an average of about 3.0µm of tear clearance. This degree of alignment keeps the lens correctly centered. Centration is one of the keys to successful ortho-k.

The lower left of the screen shows a cross-sectional view of the lens and the controls for center and edge thicknesses. Both of these lenses have thick edges of 0.30mm—theoretically, the thicker edge helps facilitate the fluid dynamics driving cellular migration. I incorporate this edge thickness into all of my lenses for myopic orthokeratology cases.

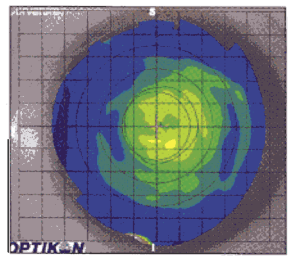

FIG. 4. CENTRAL AREA.

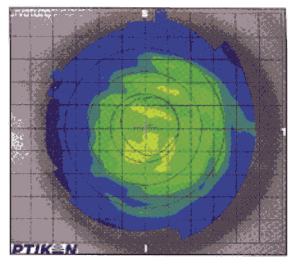

FIG. 5. BASELINE MAP.

Case 2

Over the years, ortho-k cases have been primarily aimed at reducing myopia. But what about *inducing* myopia? This technique has yielded fair results at best.

Case 2 is a 48-year-old Caucasian woman who currently has a refraction of OD Plano DS and OS +0.25–0.50x180 with an add of +2.25D. Six years ago, her refraction was OD +0.25D and OS +0.25D with an add of +1.50D. She had been wearing only progressive addition spectacles for near activities such as reading and computer work. At that time, she felt that she "needed" her glasses only for about half of her day. For that half, though, she was very unhappy about her vision. She asked me for alternatives to the glasses.

I reviewed the types of contact lens wear that might be appropriate for her needs, including multifocals and monovision, surgical intervention and ortho-k in a monovision fashion. After careful consideration, she decided to proceed with ortho-k.

I explained to the patient that she was going to wear one lens on the left eye during sleep hours only, and when this lens was off, she would still be able to do her close work comfortably. For a few years, she did quite well with this regimen, with a few updates in design.

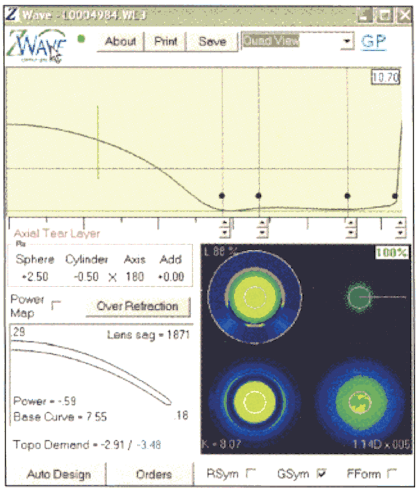

FIG. 6. NEW LENS DESIGN.

Earlier this year, however, her topography suggested that her centrally treated area was not "clean" enough, nor was there enough induced myopia and this was a limitation of her current lens (Figure 4). I explained that technology has progressed since she first started ortho-k, and that if I could start over with Wave, I could attain much better results for her. Although the patient was reluctant to give up her near vision for a month while her cornea returned to its untreated state, she agreed to do so at a more convenient time, five months later.

When that time came, the patient came in so that I could refract her and get baseline topography (Figure 5). Her refraction at this time was OD +0.25 DS, OS +0.50-0.50x180 with +2.00 add. I designed a new lens for her, which she began to wear on her nights-only regimen. Within two days of beginning this wearing schedule, she was back to normal function at her near activities for the entire day. This lens design is seen in Figure 6; the corresponding topography is seen in Figure 7. The patient remains in a sleep-only regimen, and she is happy to be independent of spectacle wear.

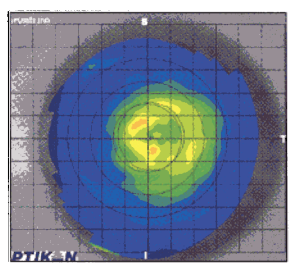

FIG. 7. MAP WITH NEW DESIGN.

Case 3

Colleagues often ask me about the limits of ortho-k. What degree of myopia can be reduced safely and effectively? The answer depends to some extent on patient variables, but there are certainly guidelines: I believe that modern orthokeratologists are comfortable in addressing up to –4.00D. I am comfortable reducing –6.00D, but I have often worked with significantly higher-myopia cases as well.

This is one such case. The patient is a 22-year-old African-American woman. She and her mother had done a great deal of research on ortho-k, and they had spoken by phone with several orthokeratologists before she came into my office. Her

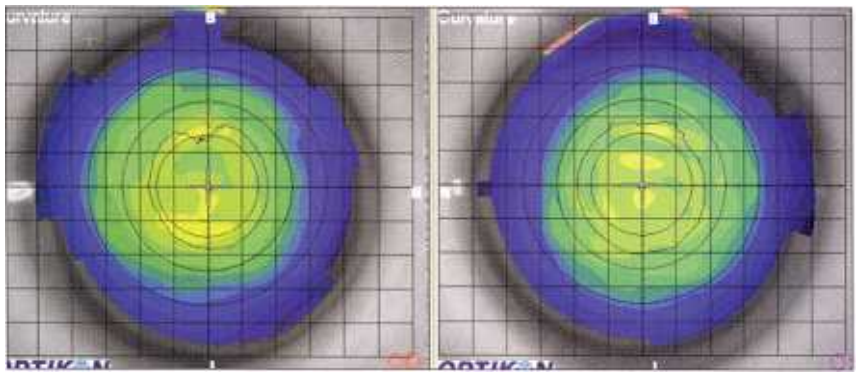

FIG. 8. BASELINE TOPOGRAPHY FOR BOTH EYES OF CASE 3 PATIENT.

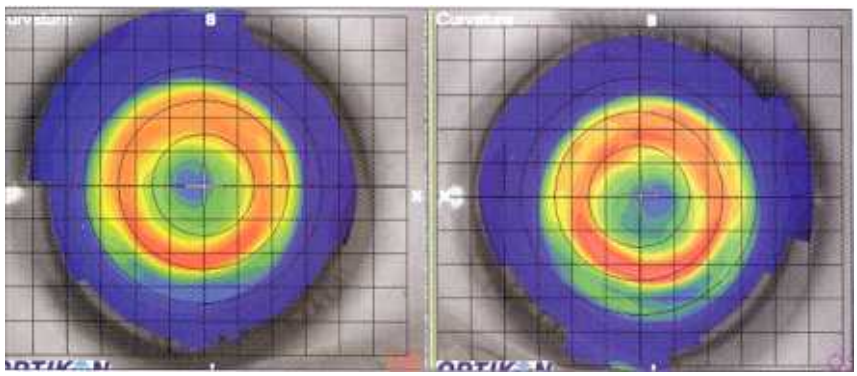

FIG. 9. TOPOGRAPHY TWO DAYS LATER, WITH LENSES OFF FOR SIX HOURS.

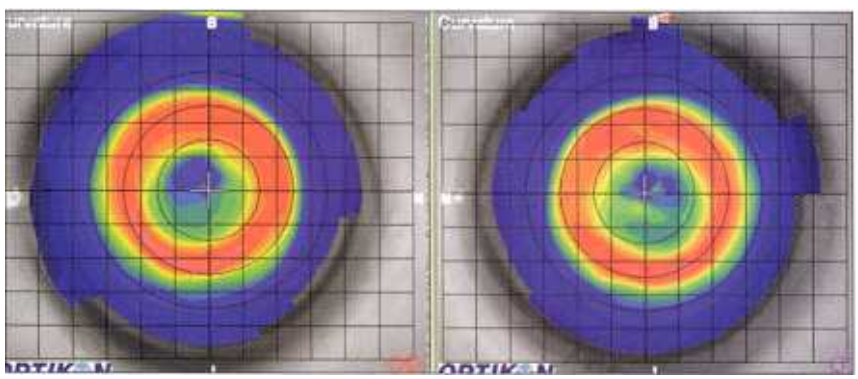

FIG. 10. FINAL TOPOGRAPHY, WITH LENSES OFF FOR EIGHT HOURS.

refraction that day was OD –7.75 DS and OS –7.50 DS. Other than her high myopia, her exam was unremarkable.

The patient also had the additional problem of having come from out-of-state, and she was leaving the area eight days after the visit. Although her high myopia concerned me, the main source of my stress was related to her schedule. I discussed my concerns about the restricted time period within which we had to work, especially in light of her high myopia. Ultimately, we decided to proceed with ortho-k.

The patient's baseline topography is seen in Figure 8. I designed a pair of Wave lenses and had them shipped to me to arrive the following day. After the patient's first night of wear, her uncorrected acuity was 20/25⁻ in each eye. Two days later, her acuity was already 20/20, and she felt that she had been able to see clearly for the entire previous day. She was very satisfied with her uncorrected vision. At this visit, her lenses had been off for about six hours (Figure 9). Since the patient had only had three nights of treatment at this point, I was not really expecting perfect maps just yet. I was concerned at this point with the positioning of the lenses, and whether I had addressed the whole amount of her myopia. I decided, based on the quality of her vision and the results of the maps, that she could continue with these lenses for the next three nights.

After that time had passed, the patient returned for a visit. She was ecstatic with her vision and said that she never had seen this well with her spectacles. At the time of this visit, her lenses had been off for eight hours. Her uncorrected acuity was 20/15 with a plano overrefraction in each eye (Figure 10). You can see in this topography that the reverse curve is becoming better defined. Since the patient's myopia had been so high, the treatment zone was relatively small, and fortunately, her pupil size is also relatively small. I asked her specifically whether she is bothered by haloes, especially at night when the pupil would be dilated. She said she noticed no haloes at any time and had clear vision from waking until sleeping.

Each of these cases entailed handling rather complex issues that I might not have attempted just a few years ago. With the control over design parameters afford by the Wave system, I can now treat a wider variety of cases and achieve a better final result. Since the Wave system continues to evolve—as does our understanding of ortho-k—I am certain that the same cases that we now do not attempt will soon not only be addressable, but will also yield successful results. RCL

Dr. Maller, an Illinois College of Optometry graduate, has a private practice in Fort Lauderdale focusing on contact lenses and the irregular cornea.