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Teleoptometry: Contact lens consultation via the internet

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Pacific University
Teleoptometry: Contact lens consultation via the internet

Abstract
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Discussion: The agreement for the high majority of cases between evaluators and between live and compressed video observations suggest that teleoptometry for contact lens fit evaluations is feasible. When technology advances to the point at which large files can be sent quickly via the Internet, it is likely that the practice of sending video clips showing dynamic fluorescein patterns, lens movements and other information between doctors, experts, and laboratory consultants located at sites remote from each other can become commonplace.

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TELEOPTOMETRY: CONTACT LENS CONSULTATION VIA THE INTERNET

A Thesis Presented to

Pacific University College of Optometry
For the Degree

Master of Science
In
Clinical Optometry

By

JENNIFER L. SMYTHE

Committee Members:

Robert Yolton, Chair
Diane Yolton
Patrick Caroline

December 1999
TELEOPTOMETRY: CONTACT LENS CONSULTATION VIA THE INTERNET

Place: Pacific University, College of Optometry

Approved:

[Signatures]

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Jennifer Smythe received her O.D. degree from Pacific University in 1993. After completing a year long Industrial Fellowship in Contact Lenses at Pacific in 1994 she joined the faculty full time. Currently, Dr. Smythe is an Assistant Professor of Optometry and the Co-chief of Contact Lens Services. She team teaches the core didactic and laboratory contact lens curriculum and is the Coordinator of the Cornea and Contact Lens Residency. Dr. Smythe also is in private practice one day a week at Murrayhill Eyecare and is a proud mother of three children.
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KEY WORDS: Teleoptometry, Telemedicine, Contact Lens, RGP, Consultation, Internet
INTRODUCTION

Assume that you are practicing in a relatively isolated community and have a rigid gas permeable (RGP) lens grief patient. You have changed the lens parameters three times since the initial fit and still cannot achieve satisfactory performance. Your patient is motivated to wear RGP lenses, and you feel that optically and physiologically they are the best modality for him. However, the fitting has progressed beyond your expertise. At this point you have several options: (1) give up and try soft lenses or glasses, (2) refer the patient to see a colleague who specializes in difficult contact lens fitting several hundred miles away, or (3) use teleoptometry to consult with an expert via the Internet.

Telemedicine and teleoptometry

Generically, telemedicine involves the use of electronic information and communication technologies to provide and support health care when distance separates the participants. By extension of this concept, teleoptometry involves the transmission of digitized optometric information from a remote site for analysis by an expert. Although telemedicine is regarded by many as the coming revolution in health care, it is not really a new concept. What is changing is the technology that supports rapid data encoding and transmission.

Current applications

Medical uses of video communications in the United States started as far back as 1959 when clinicians at the University of Nebraska used two-way interactive television to transmit neurological exams and other info across the campus. By 1964, the University had a link with the Norfolk State Hospital to provide speech therapy, neurological examinations, diagnosis of difficult psychiatric cases, case consultations, and research seminars. Currently, the Internet is used as a vehicle for the formal and informal transmission of medical advice. Use of the Internet varies from use of electronic mail to send lab reports and narration, to more advanced applications involving transmission of digitized still photographs and video clips to experts for analysis.
Accessing expert opinions via the Internet appeals to medical practitioners in both rural and urban areas, but telemedicine is not without its critics who cite legal, moral, and ethical problems with the technique. For example, if the quality of data sent via the Internet leads to an incorrect diagnosis, whose fault is it? The doctor who provided the data, the expert who analyzed them, or the Internet service provider? Critics also worry about a lack of face-to-face communication between the patient and the expert, but medical specialties that depend heavily on images such as such as radiology have found telemedicine to be an effective means of providing expert consultations. ²

Teleoptometric Applications

Optometry is one of the specialized professions that lends itself well to the utilization of video consultation. Using teleoptometry, a single expert can assess and manage many patients without the need for expensive travel and excessive schedule disruption. When a timely diagnosis and treatment is a crucial factor, teleoptometry can become a formidable weapon in the battle against ophthalmic disorders and diseases. ³

Not surprisingly, most teleoptometric applications have involved the treatment and management of ocular disease. ²-⁵ When images are captured and digitized, they can be viewed for as long as the evaluator needs without having to cause excessive distress for the patient.

A new application of teleoptometry involves consultation on contact lens problem cases. These cases often involve the use of RGP lenses, which for a novice fitter, can be a challenge to fit successfully in difficult cases. The benefits of rigid gas permeable (RGP) contact lenses are well-known. Among these benefits are ocular health, quality of vision, durability, surface wettability, oxygen transmission, presbyopic correction, reduction of myopic progression in young people, and patient retention. In spite of these benefits, RGP lenses comprise less than 12% of all new fittings in the United States. ⁶ One obvious reason for this low percentage of rigid lens fitting is practitioner inexperience, and the custom nature of fitting the lens
requires a greater skill level. This is particularly a concern with specialty lens fitting for presbyopia, high refractive error and astigmatism, as well as keratoconus, post-trauma and post-surgery. Tele-optometric consultation could provide a means for obtaining aid from a contact lens expert with rigid lens fittings from the basic spherical lens design to the more complex specialty designs.

Project Goals

The project reported here had two goals. The first was to assess the feasibility of electronically transmitting via the Internet digital information including video clips of dynamic fluorescein patterns and lens movement, topographical maps of the cornea, and lens parameters to a remotely located expert for analysis. The second was to determine whether the electronic compression and transmission of these data would significantly affect the ability of expert to use them to analyze lens performance.

In the project, 30-sec samples of dynamic RGP lens fluorescein patterns, topographic corneal maps, and basic information on lens parameters were analyzed "live" by a contact lens expert and again by two experts after digitization and electronic compression. The experts were asked to determine whether lens performances were acceptable, and, if they were not, how the lens parameters should be changed.

Subjects and Methods

Subjects
Sixteen normal adults served as subjects. Six were male and 10 were female; ages ranged from 21 to 52 years. One subject was Asian; the others were Caucasian. Subjects had corneal astigmatism less than 2.00 D, no known sensitivities to topical anesthetics and no systemic or ocular disease that would contraindicate contact lens wear. Corneal topography information is summarized in Table 1. No subjects reported problems with previous contact lens wear or a history of dry eye symptoms. All gave informed consent for participation in this project.
Table 1. Corneal Topography for Lenses Evaluated

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corneal Toricity</td>
<td>0.625 D</td>
<td>0 to 1.88 D</td>
</tr>
</tbody>
</table>

| Cylinder Axis | 31 With the Rule | 1 Against the Rule | 9 Oblique | 14 Spherical |

Lens Performance Evaluators

Evaluations of lens fits were made by two skilled contact lens clinicians. Evaluator One was a Cornea and Contact Lens Resident, and Evaluator Two was a contact lens faculty member.

Preliminary Data

Prior to lens selection and placement, videokeratography was performed using the Humphrey Atlas Corneal Topographer, and each subject’s horizontal visible diameter (HVID) was measured with a pd ruler. The topographic maps were digitized by the Humphrey unit; the HVID, patient age, and parameters of the trial lenses used were digitized into a short MS Word document.

Fitting set, Trial Lens Selection, and Lens Placement

The RGP fitting set from which lenses were selected had diameters of 9.6/8.0 oz and 9.2/7.6 oz with base curves ranging from 7.35 mm to 8.20 mm in 0.5 D increments. Lenses had an axial edge lift of 140 microns, a −3.00 D power and a center thickness of 0.13 mm.

Each subject wore several lenses during this project. One lens was selected on the basis of the manufacturers’ fitting guidelines using the Humphrey simulated keratometry readings and the parameters available in the fitting set. Up to five additional lenses were also selected with base curves ranging from 1.25 D flatter to 1.12 D steeper than “flat-K” and with differing overall diameters.

Prior to lens placement on the eye, one drop of 0.5% proparacaine HCl was instilled. The anesthetic was re-instilled at 20-minute intervals during the course of the evaluations and videotaping.
Anesthetic was used to reduce reflex tearing, lens awareness sensations, and excessive blinking.

**Live evaluation of lens fit**

Lenses were placed on the eyes in a random sequence and allowed to settle for five minutes before evaluation. Following instillation of NaFl, the fit was evaluated “live” by Evaluator One. She observed the lens monocularly for 30 seconds through a yellow Wratten #12 filter using 10X ocular in a Nikon FS3 Photo Slitlamp.

The field of observation included the entire eye from superior lid margin to inferior lid margin and from nasal to temporal canthus. After observing several blinks in the primary position of gaze, the superior lid was lifted and the lens was manually pushed up with the inferior lid to show the relationship between the superior cornea and vertical lens movement. As the lens was moved up, the slitlamp system was also raised. The superior lid was then released and the remainder of the 30-second viewing consisted of the patient looking in the primary gaze position and blinking normally.

**Judgements Made by the Evaluator One**

The Evaluator judged the lens fit as either acceptable or unacceptable based on the 30 seconds of observation, inspection of the corneal map and HVID, and a review of lens parameters. For fits that were judged unacceptable, a recommendation was made for the parameter change(s) that would improve the fit. These recommendations included changing the base curve and/or diameter along with the direction of change (e.g., flatter, steeper, larger, or smaller).

Lens diameter changes were limited to the design parameters of the fitting set. If the subject was wearing a 9.2 diameter lens, the only alternative would be the 9.6 diameter, and vice versa.

**Number of Usable Evaluations**

Useable evaluations were made for a total of 55 patient/lens combinations. Of those, 33 were fit flatter-than-K, 2 were on-K, and 20 were steeper-than-K. The numbers of flatter, steeper, and on-K are unequal because of cases that were discarded for technical reasons prior to data analysis. The unequal distribution is not a significant concern because lenses were evaluated independently of
one another and no comparisons were made between lenses. For the lenses evaluated, 30 had a 9.2 mm overall diameter and 25 had a 9.6 mm overall diameter.

**Video Clip Recording and Data Folders**

Video clips were obtained immediately after the live observations and followed exactly the same protocols as the live observations. A beam splitter was used to send the slit lamp image to a Sony CCD-IRIS color video camera with enhancement from a Sony Video MultiColor Corrector XV-C900. Camera output was then digitized and compressed with an Iomega Buz. This device used a real time motion JPEG compression algorithm to produce files that were approximately 50 megabytes in size for each 30-sec clip. The files were then further compressed by Sparkle using software MPEG. This resulted in final file sizes of about 5 megabytes for the compressed 30-sec clips. The entire recording, digitization, and compression process took approximately 2.5 min using a 266 MHz Macintosh G3.

The video clip, a small Microsoft Word file describing the lens parameters, and a JPEG compressed image of the topographic corneal map were combined into a folder for each patient/lens combination.

Two methods of transmitting these folders were explored: e-mail attachment and CD-ROM. Initial attempts using e-mail failed because both the Pacific University computer system and the expert recipient site in California had filters that prevented transmission or receipt of large files. This was especially frustrating because the Internet service provider (ISP) in California simply deleted the incoming files and did not inform the addressee or sender that this had been done.

ISP's often delete large files because of the long download times associated with them. For example, it should theoretically take about 20 minutes to download each patient/lens folder using a 28.8 K modem, about 10 min with a 56.K modem, and 4 min with an ISDN line. In practice, however, these values underestimate actual download times that are often limited by phone line quality rather than modem speed. In an actual test, it took 27 min to download a single lens/patent combination folder into a computer with a 56K modem connected to a typical phone line.
Because of long download times, folders were eventually loaded onto CD-ROMs for distribution. There was no difference in quality of the video clips based on whether they were transmitted via e-mail or CD-ROM. Quality was determined when the clips were recorded and compressed. No significant loss of quality would be expected when folders were transmitted electronically, recorded on CD-ROMs, or played back.

Playback of each clip was accomplished at 24 frames per second using MoviePlayer and QuickTime that uncompressed the file and then played the video as a 352 by 240 image in thousands of colors. Although the videos were recording using millions of colors, the computers used for playback were capable of showing only thousands of colors.

**Evaluation of Lens Performances from Video Clips and Other Data**

Three months after the live observations were made, folders were transmitted via CD-ROM to Evaluator One who had made the live evaluations and to Evaluator Two who had not previously received any information about the cases. Fit acceptability or unacceptability and change recommendations were made independently by each Evaluator after reviewing information in the folders and playing the video clips.

**RESULTS**

**Comparison of Evaluations made Live and from CD-ROM by Evaluator One**

For Evaluator One who observed the lenses live and from CD-ROM, there was agreement on whether the fit was acceptable versus unacceptable for 78.2% of the subject/fit combinations. In 36% of the 11 cases for which there was a difference, the lens was judged as acceptable based on live observation and unacceptable based on the CD-ROM observation. For 64% of the 11 cases, the reverse occurred. The Evaluator was twice as likely to find the fit acceptable based on the video clip as opposed to the live observation.

For the instances in which there was disagreement, the modification suggested for the unacceptable fit was a change in base curve 82% of the time. (Table 2). This suggests that base curves were the most difficult for Evaluator One to assess, but the small
number of cases for which there was disagreement means that this result should be interpreted with caution.

Table 2. Lens Changes Suggested by Evaluator One When One Determination was Acceptable Lens Fit and the Other Determination Was Unacceptable Fit

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steepen Base Curve</td>
<td>4 (57%)</td>
<td>0</td>
</tr>
<tr>
<td>Flatten Base Curve</td>
<td>2 (29%)</td>
<td>3 (75%)</td>
</tr>
<tr>
<td>Change Diameter</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Change both BC and Diameter</td>
<td>1 (14%)</td>
<td>1 (25%)</td>
</tr>
<tr>
<td>Total</td>
<td>7 (100%)</td>
<td>4 (100%)</td>
</tr>
</tbody>
</table>

When Evaluator One concluded for both presentations that the lens fit was unacceptable, she recommended the same change in lens parameters 67% of the time. For the 12 cases in which the recommendations were different, 11 (92%) involved a change in both base curve and diameter. In one case the recommendation was for base curve change only; no recommendations of a diameter change alone were made.

Comparison of Evaluations made from CD-ROM by Evaluators One and Two

After independently reviewing the digitized and compressed video and other data in the case folders, the two Evaluators agreed 78% of the time on whether or not the fit was acceptable or unacceptable. For the 9 cases in which the Evaluators disagreed, 78% of the time it was because Evaluator One found the fit acceptable and Evaluator Two did not. (Table 3) Again caution is advised in interpreting this relatively small number of cases in which Evaluators disagreed.
Table 3. Lens Changes Suggested When Evaluator One and Evaluator Two Disagreed on Whether Lens Fit was Acceptable

<table>
<thead>
<tr>
<th>Parameter Change Recommendation for Unacceptable Fits</th>
<th>Unacceptable for Evaluator One and Acceptable for Evaluator Two</th>
<th>Acceptable for Evaluator One and Unacceptable for Evaluator Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steepen Base Curve</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Flatten Base Curve</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Change Diameter</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Change both BC and Diameter</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

When both Evaluators agreed that the lens fits were unacceptable, their recommended changes were the same for 48 (87%) of the cases. For the 7 cases in which the recommendations were not in agreement, all were because of recommendations to change both the base curve and lens diameter.

DISCUSSION

Acquisition, Compression, and Transmission of Information

The first goal of this project was to determine the feasibility of digitizing and transmitting contact lens performance information via the Internet for evaluation by a remote observer. This was relatively simple to accomplish for the topographic image and the Word document in each folder. The sizes of these files were minimal so they could be transmitted in a few seconds. The same relative ease of transmission would also hold for still photographs, X-ray images, lab test results, etc., all of which can be compressed into JPEG or GIF images.

In this project, the major challenge was to record a 30-sec video clip and then compress it sufficiently for transmission without losing so much information that the Evaluators could not assess the dynamic
fluorescein patterns and lens movements. If video is recorded at the traditional 30 frames per second for 30 seconds, the result is essentially the same as recording 900 single images.

Strategies that were evaluated to compress the volume of data created included reducing the number of recorded video frames per second that were recorded (or played back) from 30 down to 15. This made the video file smaller but at 15 frames per second the lens movements appeared artifactually jerky. Using 24 frames per second proved to be a good compromise between saving space and playback realism. Both Evaluators felt that the quality of compressed, 24 frame per second video from the CD-ROM was sufficient to make their assessments of lens fluorescein patterns and movement.

Video compression was made in several stages due to hardware and software availability. A compression factor of 10 was achieved but the ultimate patient/lens combination folder sizes of 5 Meg were still too large to transmit via conventional e-mail systems. This will probably be a limiting factor until technology improves to the point at which transmitting compressed or even live video via the Internet becomes commonplace.

Reliability of Lens Fit Determinations by Evaluator One

Examiner One provided a demonstration of how well the live and compressed video clips could be used to determine acceptability of lens fit and recommended changes. She reached the same conclusion regarding acceptability or unacceptability for nearly 80% of the cases. When she changed her opinion, it was usually because of a base curve change recommendation. Although an 80% reliability rate is good, it is interesting to speculate on why the Evaluator reached different conclusions on lens acceptability 20% of the time. Explanations include differences in image quality or size between the live and video observations so that she made more "mistakes" when using one of the viewing modes. It is also possible that the difference resulted from the ability of the Evaluator to move the slitlamp during live viewing as opposed to only being able to view the video passively.

Another possibility is that her fitting philosophy changed over the three months between the live and video viewing sessions or that the differences simply represent random "noise" inherent in contact
lens fitting. It was the general impression of both evaluators that
apical bearing was more difficult to discern than apical pooling in the
digitized videos. In light of this challenge to discern between the subtle
differences, it is likely that the evaluator may have interpreted lenses
with minimal apical bearing on video as being aligned. This could have
resulted in a higher rate of acceptability determinations for the video
clips versus the live observations.

**Comparison of Results from Evaluators One and Two**

Comparing the results from Evaluators One and Two provides a
perspective against which to view the accuracy of Evaluator One's lens
fit recommendations.

When both Evaluators made lens fit determinations based on the
case folders containing the CD-ROM video clips, they agreed on the
acceptability or unacceptability of the fit nearly 80% of the time. This
is the same percentage of agreement found for Evaluator One for live
versus CD-ROM video clips. It might represent the noise level or
inherent variability of contact lens evaluations.

When the Evaluators disagreed, 78% of the time it was because
Evaluator One found the lens acceptable and Evaluator Two did not.
When they agreed that a lens change was required, they also agreed on
what that change should be made nearly 90% of the time. This
suggests that there was a difference in fitting philosophy or a range of
tolerance for about 10% of the cases.

It is also possible that the video images were not good enough to
use in making accurate determinations in these cases, but a review of
the clips for which different recommendations were made suggest that
this was not true. Both Evaluators agreed that there was sufficient
clarity in the clips to make accurate determinations and both still
disagreed on their determinations.

When the Evaluators disagreed on what changes to make for
unacceptable lens fits, 60% of the subjects had relatively spherical
corneas. It is likely that an evaluator with a strong bias against fitting
a spherical cornea would reject a higher number of lenses observed on
this type of topography, and deem the patient not suitable for a rigid
contact lens, whereas another evaluator may accept a fit as the most
acceptable in light of the situation.
Also observed was a greater consistency between evaluator's conclusions of unacceptable fits when lenses were fitted flatter than flat-K (88% agreement) as opposed to steeper than flat-K (12% agreement). The challenge of discerning between apical bearing versus apical alignment on video may have resulted in a higher frequency of agreement. It was also shown that the evaluators were more consistent when the base curve to cornea fitting relationship differed by more than 0.50 D than when a lens was fitted closer to alignment (less than 0.50D flatter or steeper than "flat-K"). This is consistent with clinical observation of NaFI patterns in the slit-lamp.

In summary, the agreement for the high majority of cases between evaluators and between live and compressed video observations suggest that teleoptometry for contact lens fit evaluations is feasible. When technology advances to the point at which large files can be sent quickly via the Internet, it is likely that the practice of sending video clips showing dynamic fluorescein patterns, lens movements and other information between doctors, experts, and laboratory consultants located at sites remote from each other can become commonplace.
REFERENCES


