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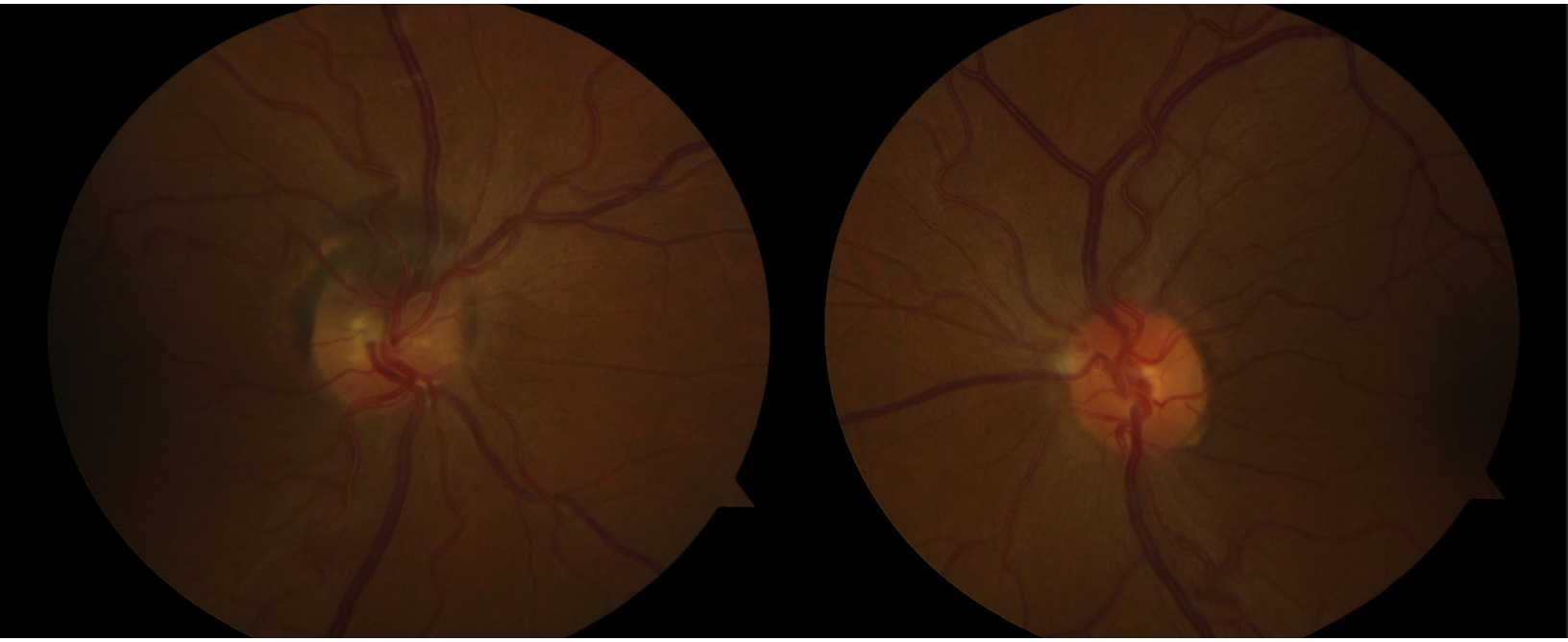

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Does Practice Make Perfect? Relating Student Performance to Training Hours

Yutaka Maki, OD, MS, FCOVD, and Brian K. Foutch, OD, PhD, FAAO | Optometric Education: Volume 45, Number 1 (Fall 2019)

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Background

We have all heard the phrase “practice makes perfect.” The Latin proverb “usus est magister optimus” translates to “practice is the best master,” and Aristotle said, “For the things we have to learn before we can do them, we learn by doing them.”[1] Emphasis on the importance of practice is seen clearly in every culture and century, and it seems safe to assume that the more one practices, the better one performs. If this assumption were true, it would make sense to assign students struggling in preclinical optometry laboratory courses additional practice outside of scheduled laboratory times. By extension, it would be reasonable to assume that additional practice should result in higher grades or evaluations on preclinical assessments. In this study, we examined whether students who practiced more hours outside of their assigned course laboratory performed better on high-stakes midterm and final proficiency assessments.

Methods

We retrospectively reviewed the course records of 130 first-year optometry students enrolled in the second semester preclinical course during Spring 2015 and 2016. The data were collected in the clinical laboratory facilities at the University of the Incarnate Word Rosenberg School of Optometry (UIWRSO), San Antonio, Texas, under the supervision of the course instructors.

TABLE 1
Course Laboratory Schedule

LAB SCHEDULE		
Lab #	**Topics**	**Checkout/Assessment**
1	Retinoscopy	Lensometry
2	Monocular subjective refraction	Retinoscopy
3	Binocular balance	Subjective refraction
4	Distance phorometry and vergences (phoria, vergence)	Binocular balance
5	Near phorometry (phoria, vergence, FCC)	Distance phorometry
6	**MIDTERM PROFICIENCY**	**Retinoscopy + Refraction**
7	Near phorometry (NRA/PRA, amplitude of accommodation, AC/A)	Near phorometry part one
8	Additional testing (prism bar vergences, Maddox rod, vergence facility)	Near phorometry part two
9	Tests of accommodation (MEM, facility, pull away)	Additional testing
10	Slit lamp #1	Tests of accommodation
11	Trial frame refraction	-----
12	**FINAL PROFICIENCY (first half of students)**	**Entrance Tests, Lensometry, Retinoscopy, Refraction, Binocular Testing**
13	Slit lamp #2	-----
14	**FINAL PROFICIENCY (second half of students)**	**Entrance Tests, Lensometry, Retinoscopy, Refraction, Binocular Testing**

FCC = fused cross cylinder; NRA/PRA = negative/positive relative accommodation; AC/A = accommodative convergence/accommodation; MEM = monocular estimation method

Table 1. *Click to enlarge*

The students learned new clinical skills (retinoscopy, refraction, binocular tests) each week in the three-hour course laboratory **(Table 1)**. To ensure they were reviewing the newly learned skills, all students were required to practice a minimum of four hours in the laboratory outside of instruction time through week 10. The newly learned skills were evaluated in the form of checkouts (short clinical skill assessments) throughout the semester (Table 1). The primary purpose of the checkouts was to provide students with formative feedback to learn from their successes and mistakes. A secondary goal was for students to practice more if they performed poorly. To ensure this was taking place, two additional hours were mandated for each checkout with a grade below 85%. Thus, students who passed or failed a checkout were required to practice a minimum of four or six hours, respectively. Beyond that, no additional assignments were given. However, all students were encouraged to practice more than the minimum assigned hours, especially if they felt they had not reached expected skill levels.

When students practiced outside of the scheduled laboratory, they were under the supervision of teaching assistants. Each student recorded the time he or she entered and exited the laboratory, and the teaching assistant confirmed the times. Each week’s logged hours were then submitted to the instructor of record in the subsequent course laboratory. The three scheduled hours they spent each week in the course laboratory were not included in the logged hours.

In addition to the checkouts, there was one midterm proficiency assessment (retinoscopy and refraction) and one final proficiency assessment (entire refractive sequence of lensometry, entrance tests, retinoscopy, subjective refraction and photometry). The rubrics used in checkouts and proficiency assessments were modeled after the Clinical Skills Exam evaluation forms used by the National Board of Examiners in Optometry.[2] Unlike weekly checkouts, no additional practice hours were assigned to students who scored below 85% for the proficiency assessments.

We recorded the number of hours each student practiced up to their scheduled proficiency assessments. Because the final assessments were administered during weeks 12 and 14 of the semester, we randomly divided the students into two groups for analysis. The students' cumulative grades from the midterm (33%) and final (67%) proficiency assessments were compared with the number of hours they practiced to determine whether there was any correlation (Pearson's r reported). Checkout grades were excluded from the cumulative grade for the purpose of this retrospective analysis because the mandated additional two-hour assignment for failing checkouts inevitably would have decreased any positive relationship between the grade and the practice hours. In our analyses, we defined statistically significant as p-value less than 0.05.

Results

Overall, the second (week-14) group had higher mean cumulative lab grades and mean number of logged practice hours (89.7±6.1%, 85.7±19.4 hours) than the first (week-12) group (85.9±7.3%, 73.0±16.8 hours). The differences were statistically significant ($p<0.01$) for both the cumulative lab grades and the logged practice hours **(Tables 2 and 3)**.

However, we found a negative correlation between cumulative grades and overall practice hours within each group. Within each group, the finding was statistically significant for the week-14 group ($r=-0.30$, $p=0.02$) **(Figure 1 and Table 4)** but not for the week-12 group ($r=-0.02$, $p=0.84$) **(Figure 2 and Table 4)**. Similar patterns were seen when comparing final proficiency grades with the *overall* practice time (Table 4) as well as the cumulative grades with *voluntary* practice time **(Table 5)**.

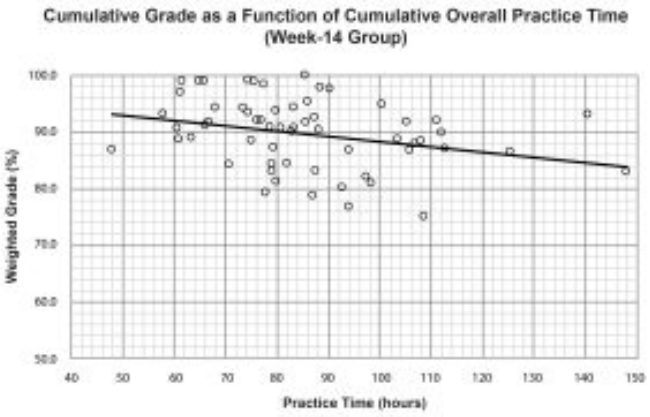

Figure 1. *Click to enlarge*

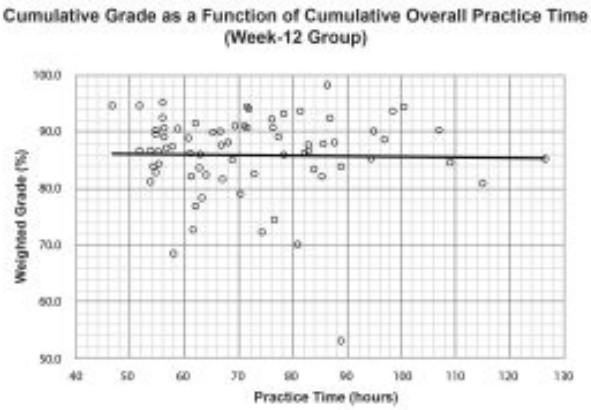

Figure 2. *Click to enlarge*

TABLE 2
Mean Practice Hours for Week-12 and Week-14 Groups

	Practice Time up to Midterm (Week 6)	Practice Time up to Last Checkout (Week 10)	Practice Time up to Finals Week (Weeks 12 and 14)	Practice Time between Midterm and Final
Week 12	36.92	64.39	72.95	36.04
Week 14	36.23	62.49	85.71	49.46
Difference (p-value)*	0.69 (0.718)	1.90 (0.487)	7.24 (<0.001)	13.42 (<0.001)

*Based on t-test comparison

Table 2. *Click to enlarge*

TABLE 3
Mean Assessment Grades for Week-12 and Week-14 Groups

	Checkout Grade	Midterm Proficiency Grade	Final Proficiency Grade	Cumulative Grade
Week 12	81.30%	81.51%	88.07%	85.88%
Week 14	82.60%	86.03%	91.48%	89.66%
Difference (p-value)*	1.30% (0.473)	4.52% (0.052)	3.41% (0.002)	3.78% (0.002)

*Based on t-test comparison

Table 3. *Click to enlarge*

TABLE 4
Pearson's Correlation Coefficients (p-value) between Cumulative Overall Practice Time and Each Assessment Grade (checkout, midterm, final and cumulative)

Practice Time (up to week 10) vs. Mean Checkout Grade	Practice Time (up to week 6) vs. Midterm Proficiency Grade	Practice Time (up to Finals week) vs. Final Proficiency Grade	Practice Time (up to Finals week) vs. Cumulative Grade
All students:		Week-12 group:	
-0.304 (<0.01)	-0.168 (0.06)	-0.052 (0.67)	-0.024 (0.84)
		Week-14 group:	
		-0.061 (0.64)	-0.301 (0.02)

Table 4. *Click to enlarge*

TABLE 5
Pearson's Correlation Coefficients (p-value) between Cumulative Voluntary Practice Time (i.e., mandatory practice hours removed) and Each Assessment Grade (checkout, midterm, final and cumulative)

Practice Time (up to week 10) vs. Mean Checkout Grade	Practice Time (up to week 6) vs. Midterm Proficiency Grade	Practice Time (up to Final week) vs. Final Proficiency Grade	Practice Time (up to Final week) vs. Cumulative Grade
All students:		Week-12 group:	
-0.223 (0.01)	-0.107 (0.23)	-0.001 (1.00)	0.033 (0.79)
		Week-14 group:	
		-0.042 (0.75)	-0.257 (0.047)

Table 5. *Click to enlarge*

There was no statistically significant difference in practice time between the week-12 and week-14 groups up to the midterm proficiency assessment or the last (week 10) checkout ($p=0.718$ and $p=0.487$ respectively, Table 2). Also, there was no statistically significant difference in checkout and midterm grades between the week-12 and week-14 groups ($p=0.473$ and

p=0.052 respectively, Table 3).

Further analysis of the correlation between post-midterm practice time and midterm proficiency grades revealed a statistically significant correlation for the week-14 group but not the week-12 group (p<0.01 and p=0.25 respectively) **(Table 6)**.

When correlations among each assessment grade were analyzed, the final proficiency grades for the week-12 group were significantly positively correlated with midterm proficiency and checkout grades (p<0.01 each). This was not the case for the week-14 group (p=0.42 and p=0.05 for midterm proficiency and checkout grades respectively) **(Table 7)**.

TABLE 6

Pearson's Correlation Coefficients (p-value) between Post-Midterm Practice Time and Each Assessment Grade (midterm, final and cumulative)

	Practice Time vs. Midterm Proficiency Grade	Practice Time vs. Final Proficiency Grade	Practice Time vs. Cumulative Grade
Week-12 group	0.139 (0.25)	0.004 (0.97)	0.079 (0.52)
Week-14 group	-0.354 (<0.01)	0.099 (0.45)	-0.217 (0.10)

Table 6. *Click to enlarge*

TABLE 7

Pearson's Correlation Coefficients (p-value) between Checkout, Midterm, Final and Cumulative Grades for Week-12 and Week-14 Groups

		Week 14			
		Checkout	**Midterm Proficiency**	**Final Proficiency**	**Cumulative**
Week 12	**Checkout**		0.390 (<0.01)	0.254 (0.05)	0.443 (<0.01)
	Midterm Proficiency	0.252 (0.04)		0.105 (0.42)	0.828 (<0.01)
	Final Proficiency	0.369 (<0.01)	0.327 (<0.01)		0.645 (<0.01)
	Cumulative	0.388 (<0.01)	0.789 (<0.01)	0.856 (<0.01)	

Top right = week 14 group; bottom left = week 12 group)

Table 7. *Click to enlarge*

Discussion

The study results supported the conventional wisdom: "practice makes perfect." The group given an additional two weeks increased their practice time and performed better. Although it could be argued that these results can be explained by the early group giving the latter group a "heads-up" on the proficiency assessments, we believe it would have given them little to no advantage. The final proficiency assessment was comprised of elements from all the checkouts, so there were few surprises. In addition, the same final proficiency assessment was given in previous years; therefore, students from either group could have asked upperclassmen about it.

At the individual level, we found different results within each group. Higher-performing students in the week-14 group practiced less than lower-performing students. This was not the case for the week-12 group, where we found no statistically significant correlation between practice and performance.

Many factors could explain this apparent contradiction in the week-14 group. First, students have different starting skill levels based on work or academic experience. Second, some learn new skills more innately than others, and we have informally observed that it is often the struggling students who practice more to compensate for their current lack of skills. In fact, the statistically significant negative correlation between post-midterm practice time and midterm proficiency grades of the week-14 group indicates that the outcome of the midterm proficiency assessment affected their practice behavior (Table 6). While we had anticipated that the effort shown by their increased practice time would be the predictor for their clinical performance, we have instead found their current clinical progress to be the predictor of their effort. That is, lower-performing students practiced more.

This type of self-adjusted practice behavior could be explained by emotional intelligence (EI), which is defined as the ability to monitor one's own and others' emotions, to discriminate among them, and to use this information to guide one's thinking and actions.[3] One model of EI proposed by Goleman and Boyatzis identifies four clusters of competencies: self-awareness, self-management, social awareness and relationship management.[4] All of these clusters appear to be important predictors of clinical success, and several authors have observed positive associations between higher EI and better clinical performance in dental, medical and nursing school students.[5-9] In one of the studies, self-management competencies were significantly correlated with student clinical performance (as measured by mean clinical grade).[5] A recent study of optometry students in the United Kingdom demonstrated a positive association between self-awareness and academic performance.[10] The characteristics of self-management include adaptability, initiative, persistence in pursuing goals, taking responsibility for personal performance, and striving to meet a standard of excellence.[11] This also may explain the practice pattern of our higher-performing students. Perhaps they based their decision to practice less on either positive feedback received during weekly checkouts, proper time management of overall curriculum demands, or awareness of their clinic skills.

While considering EI may offer insight into the week-14 group's negative correlation between practice and performance, we observed no statistically significant correlations between assessment grades (midterm proficiency, final proficiency or cumulative) and practice time (Tables 4-6) in the week-12 group. Because the major difference between the two groups was

the amount of practice time given, this suggests availability of time is a key factor in behavioral change in students. This also explains why statistically significant correlations appeared between checkouts and proficiency assessments (midterm or final) in the week-12 group, while no such correlations appeared in the week-14 group (Table 7). Because the week-12 group lacked sufficient time to adapt their learning and close the gap in their achievement, midterm proficiency performance became the predictor for their final proficiency result.

This suggests the importance of making struggling students fully aware of their initial (or current) status and giving adequate support and time to close any achievement gap. Although we initially believed that weekly checkouts and the midterm proficiency assessment would be sufficient to provide such awareness, some of the lower-performing students did not respond to this feedback as we expected. When analyzing the bottom 20% of the week-12 and week-14 groups, we found that 57.1% and 33.3% of students were practicing below the average practice time, respectively. In the week-12 group, the average group and bottom 20% practice times were 73.0±16.8 hours and 72.9±16.1 hours, respectively. In the week-14 group, the average group and bottom 20% practice times were 85.7±19.4 hours and 93.5±20.3 hours, respectively. This indicates that identifying and guiding low-performing students who lack self-awareness and/or self-management earlier in the course is essential. Convincing students of their status might be challenging, however, as at least two previous investigations of competence awareness have shown that lower-achieving students overestimate their competence and vice versa for higher-achieving students (an effect that held even after feedback was given, though to a lesser extent).[12,13]

When offering support to low-performing students, it is important to teach them how to practice. Studies show that expert performance is most effectively attained by deliberate practice (DP), where focused training is designed and arranged by teachers and coaches to optimize improvement.[14-16] This focused training also involves the provision of immediate feedback, time for problem-solving and evaluation, and opportunities for repeated performance to refine behavior. In a preclinical lab setting, perhaps the lower-performing students can be given individualized assignments based on their current performance and/or be paired with a teaching assistant or a high-performing student to focus on specific areas of struggle.

In the current study we did not provide any designed training, nor did we measure how each student actively engaged in DP. This certainly limits any inferences made about the effect of DP on performance. Further limitations of our study included a relatively small sample size and a retrospective period of only two years. Lastly, our study lacked any direct measures of EI or self-awareness. Further studies could and should do so by integrating focus group interviews with higher- and lower- achieving students and teaching assistants into the analysis.

Conclusion

Our study showed that individual performance depended on amount of practice and feedback from assessments. Although at the class level the group that had more time to practice performed better, at the individual level within each group students who practiced more did not necessarily perform better. Our findings suggested that students adjusted the number of hours they practiced according to their perception of their current skill set or a self-prescribed mastery goal. Ultimately, assessment performance and students' practice behavior influenced each other. In addition, we found it to be essential to provide sufficient time for students to adapt and reach the competency level, otherwise earlier assessment results become the predictor for their final outcome. Lastly, it is imperative to make struggling students aware of their status and provide enough support as early as possible. While our findings have implications for medical and optometric education, they will be strengthened by more direct measurements of DP, self-awareness and EI. As a result of this analysis, we have considered providing all students at least three weeks to practice before major assessments. In addition, underperforming students will be prescribed a deliberate practice plan and be scheduled in the later assessment week.

Acknowledgements

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Student Performance and Attitudes During the Transition from Paper to Computer-Based Examinations

Brian K. Foutch, OD, PhD, Lourdes Fortepiani, MD, PhD, and Richard Trevino, OD | Optometric Education: Volume 45, Number 1 (Fall 2019)

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Background

Standardized assessments used for professional licensure and to measure pre-professional aptitude have been administered electronically for decades. Computer-based test (CBT) platforms have also been introduced in many undergraduate and professional programs, and their use has coincided with the emergence of cognitive learning theories that stress integration of classroom teaching and assessment.[1]

Most health profession programs have multiple layers of learning outcomes. Specifically, optometric educators must consider individual course objectives, school or overall curriculum outcomes, and professional outcomes and attributes defined by the Association of Schools and Colleges of Optometry (ASCO),[2] the Accreditation Council on Optometric Education (ACOE)[3] and the National Board of Examiners in Optometry (NBEO).[4] While the 20th century paradigm of providing traditional lectures followed by static, multiple-choice paper-based tests (PBT) still exists and has value,[5] it makes it far more challenging and time-consuming to measure student performance on these learning outcomes across a curriculum. After all, PBT formats do not automatically generate reports of student performance according to learning outcomes in a course or across the curriculum. That process requires a significant time investment and coordination between instructors after a test is given. In contrast, CBT platforms allow evaluators to digitally assign learning levels and course or program levels to test questions, providing improved feedback when attempting to drive assessment-based curriculum or instructional changes.[6] Further, controlled studies and informal observations have shown that CBT formats provide additional advantages as well as some disadvantages for students and instructors. Additional advantages include automatic grading with nearly real-time score reporting to students[7] and higher-resolution feedback about specific subject content.[8] Disadvantages of CBT formats include computer eyestrain, compatibility and connectivity issues[8] as well as difficulties creating, navigating or grading in-depth questions.[9] Arguably, the most important barrier is the general skepticism among both instructors and students toward computerized testing until they achieve an initial positive experience.[10]

Previous studies of student academic performance using CBT are equivocal. At least two groups of researchers have concluded that simply administering an exam using a computerized format vs. a traditional paper- and pencil-based format had no significant effect on achievement[11,12] while another group has observed that test scores improved with CBT formats for both static-type (multiple-choice, true/false) and interactive problem-based questions.[13] Our institution recently implemented one such CBT platform, and computerized testing was highly encouraged (but optional) by our administration during a “hybrid” period of one academic year. At the end of that year, instructors were required to administer only computerized tests. That one-year period — when both PBT and CBT formats were used — provided us with a unique opportunity to better understand how student demographics, academic performance and attitudes influenced their transition to computerized testing. Our aim was to determine whether there was a significant difference between mean PBT and CBT scores and the extent to which various student factors and attitudes could influence performance. The results from this study could reveal different strategies for improving student performance and easing the overall transition to computer-based testing.

Methods

Subjects

We recruited 65 (39 females, 26 males) subjects with a mean age (±S.D.) of 24.7 (±1.87) years. Due to the high proportion of Hispanics in our student population, we wanted to analyze the results not only considering age, gender and race but also Hispanic ethnicity (10 Hispanic, 55 non-Hispanic). Volunteers were eligible if they were enrolled and in good academic standing (i.e., cumulative GPA of 2.0 or higher) in the Rosenberg School of Optometry’s second-year class during the fall semester of 2015. All subjects were recruited via a classroom announcement by the investigators and were all paid for their participation. All subjects provided informed consent. The study protocol was approved by the institutional review board at the University of the Incarnate Word and carried out according to the guidelines set out in the 1964 Declaration of Helsinki.

Research design

During the fall semester of their second year, 65 students completed two midterm examinations in two different courses (ocular physiology and organ pathology). These courses were selected because they were offered simultaneously in the same semester by the same instructor, and all exams were delivered in the same classroom setting. This could minimize the impact of different instructors using different question styles to assess student performance. These examinations were administered as regularly scheduled assessments in each course. In the first course (organ pathology), the students took the first midterm electronically via ExamSoft (ExamSoft Worldwide, Inc., Boca Raton, Fla.) and the second midterm using a traditional paper and pencil format (graded using Scantron forms and software; Scantron Corporation, Eagan, Minn.). The order was reversed for the second course (ocular physiology). The overall crossover design is shown in **Figure 1**. Despite the possible influence of test performance on student attitudes, students were unaware of this research opportunity until after the end of the second midterms. This was done for two reasons. We were primarily interested in student performance and attitudes after their initial exposure to CBT. Students in this cohort were not previously exposed to CBT (ExamSoft) in optometry school but rather used PBT (Scantron) during their first year. In addition, we did not want to create anxiety nor prompt concerns in students about the new CBT format.

While all examinations contained only multiple-choice items (both single and multiple response), the computerized format allowed for randomized ordering of questions and answer choices (i.e., multiple exam versions) while Scantron-graded exams were administered using a single version. Highlighting and backward navigation were the only additional features enabled on ExamSoft. In addition, students had access to scratch paper regardless of the testing platform. At the conclusion of the semester, study participants' attitudes toward paper and computerized exams were measured via a custom questionnaire with 5-rating scale semantic differential items (use and analysis described in a review of best practices in assessing student attitudes[14]).

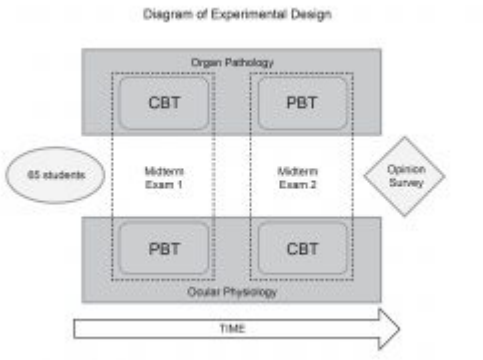

Figure 1. *Subjects took two midterms in two separate courses (organ pathology and ocular physiology). In organ pathology, the first midterm was administered electronically and the second midterm using a traditional paper and pencil format. The order was reversed for the second course. After both midterms, attitudes toward the examination formats were measured via a custom questionnaire.*
Click to enlarge

With our semantic differential items, respondents did not indicate a level of agreement with a statement (as in Likert scaled items); rather, they chose a position on a scaled line that connoted a preference for one method or the other. For example, survey question #1 asked subjects to indicate whether they were "…more stressed taking the test using the computer-based test" or "…more stressed taking the test on paper." Whether the direction (+ or -) corresponded to CBT or PBT preference was randomly assigned for each question. However, for analysis, "-2" (on the 5-rating scale) indicated a strong preference for the PBT (more stressed by the CBT) and a "+2" indicated a strong preference for CBT (more stressed by the PBT). Responses of "-1" or "+1" indicated less endorsement, and a "0" indicated no preference or endorsement at all. Students also completed a 16-item VARK questionnaire (VARK; available online at http://vark-learn.com/the-vark-questionnaire/) to determine the level to which they are visual (V), aural (A), read/write (R) or kinesthetic (K) learners, as different learning styles have been associated with student performance.[15]

Analysis

Our first goal was to determine the relationship between the CBT and PBT scores. We examined scores across the four examinations via repeated measures analysis of variance (ANOVA) with course and examination mode as fixed factors. We then pooled all the exam scores into a single variable representing each subject's difference between their average CBT and PBT scores. These differences were also analyzed by ANOVA with gender, race (White vs. non-White) and ethnicity (Hispanic vs. non-Hispanic) as fixed factors. The difference scores were also regressed on continuous variables such as age and academic parameters (Optometry Admission Test [OAT] scores, undergraduate grade point averages [GPAs], GPA thus far in the optometry program, and learning style and attitudes). Distributions of subjects by demographics are shown in **Table 1**.

We determined the level of endorsement (either for the CBT or PBT format) by comparing the medians for each survey question to zero via a Wilcoxon signed rank test. Ad hoc comparisons of students performing best on PBT or CBT were also performed, and these are described in detail in the Results section. Statistical significance was defined as a p-value less than 0.05 for all testing. All analyses were performed using SPSS (IBM Corporation, Armonk, N.Y.) and Excel (Microsoft Inc., Redmond, Wash.).

TABLE 1
Distribution and Age of Subjects by Gender, Ethnicity and Race (White vs. non-White)*

Overall (N=64)	All subjects			Hispanic subjects			Non-Hispanic subjects		
	All	White	Non-White	All	White	Non-White	All	White	Non-White
N (%)	64 (100%)	38 (59%)	26 (41%)	10 (16%)	7 (11%)	3 (4.7%)	54 (84%)	31 (48%)	23 (36%)
Male	35 (39%)	15 (23%)	10 (16%)	4 (6.3%)	2 (3.1%)	2 (3.1%)	21 (33%)	13 (20%)	8 (13%)
Female	39 (61%)	23 (36%)	16 (25%)	6 (9.4%)	5 (7.8%)	1 (1.6%)	33 (52%)	18 (28%)	15 (23%)
Age	24.7 (1.9)	24.8 (1.9)	24.7 (1.8)	24.5 (1.6)	24.4 (1.3)	24.7 (2.5)	24.8 (1.9)	24.8 (2.0)	24.7 (1.8)
Male	24.5 (1.7)	24.9 (1.5)	24.0 (2.0)	24.8 (2.2)	25.0 (1.4)	24.5 (3.5)	24.5 (1.7)	24.9 (1.6)	23.9 (1.8)
Female	24.9 (2.0)	24.7 (2.1)	25.1 (1.7)	24.3 (1.2)	24.2 (1.3)	--*	24.9 (2.1)	24.8 (2.3)	25.1 (1.8)

*Mean values (S.D.) for age are reported *Data not shown for single subject

Table 1. *Click to enlarge*

Results

All 65 second-year students consented to participation. The range of the difference between the computer-based and paper-based scores (C-P, for convenience) was -18.6 to 13.9 (refer to **Table 2** for summary of scores). One male subject scored 34.5 points (4.5 standard deviations from the mean difference) better on the PBT. His performance and survey data were excluded from all analyses, as his performance bias for paper-based testing was considered an outlier. All test scores for the remaining subjects (n = 64) were analyzed using repeated measures ANOVA. The main effect of course [$F(1,57) = 11.43$, $p = 0.001$] — with students scoring 3.4% higher in ocular physiology — and the interaction of course and exam mode [$F(1,57)=6.607$, $p=0.013$] were both significant, but there was no main effect of exam mode [$F(1,57)=1.740$, $p=0.192$]. So, while there was a bias (C-P=-2.30) in our subjects toward better performance on the PBT, the difference was insignificant.

TABLE 2
Exam Scores (PBT, CBT and difference) by Gender, Ethnicity and Race*

	All subjects			Hispanic subjects			Non-Hispanic subjects		
	All	White	Non-White	All	White	Non-White	All	White	Non-White
PBT	83.9 (7.4)	85.1 (7.2)	82.2 (7.5)	79.5 (7.9)	82.2 (5.9)	73.2 (9.7)	84.6 (7.1)	85.8 (7.4)	83.4 (6.6)
Male	81.4 (7.8)	83.5 (6.6)	78.1 (8.7)	76.1 (9.8)	84.5 (1.9)	67.6 (0.1)	82.4 (7.2)	83.4 (7.1)	80.8 (7.6)
Female	85.6 (6.7)	86.2 (7.5)	84.7 (5.6)	81.8 (8.3)	81.3 (8.9)	--*	86.3 (6.7)	87.5 (7.3)	84.8 (5.8)
CBT	81.6 (7.8)	84.1 (6.1)	78.0 (8.6)	77.7 (10.0)	83.0 (5.0)	65.1 (2.9)	82.4 (7.1)	84.3 (6.2)	79.7 (7.8)
Male	78.7 (9.2)	83.9 (7.4)	73.4 (8.2)	73.9 (13.4)	84.5 (9.7)	63.4 (0.4)	80.8 (8.2)	83.9 (7.5)	75.9 (7.1)
Female	82.9 (6.5)	84.2 (5.3)	80.9 (7.8)	80.1 (7.5)	82.5 (5.3)	--*	83.4 (6.4)	84.7 (5.3)	81.7 (7.3)
C-P	-2.30 (6.8)	-1.02 (6.4)	-4.17 (6.8)	-1.87 (7.1)	0.82 (5.6)	-8.17 (6.8)	-2.38 (6.8)	-1.43 (6.6)	-3.65 (6.5)
Male	-1.62 (7.3)	0.44 (7.1)	-4.76 (8.7)	-2.13 (7.1)	-0.82 (12)	-4.23 (0.3)	-1.52 (7.5)	0.51 (7.5)	-4.82 (7.6)
Female	-2.73 (8.2)	-1.96 (5.8)	-3.84 (8.7)	-1.70 (7.7)	1.16 (3.6)	--*	-2.92 (8.0)	-2.83 (6.2)	-3.03 (9.1)

*Mean values (S.D.) reported *Data not shown for single subject
PBT = paper-based test; CBT = computer-based test; C-P = CBT – PBT score

Table 2. *Click to enlarge*

For the two formats to be considered equivalent, it has been suggested that the two testing methods must yield similar dispersions and overall distributions of scores.[16] The scores from all examinations were distributed normally ($p>0.05$ on Anderson Darling testing), though the distributions were shaped somewhat differently **(Figure 2)**. The distribution most distinct from the others was for the ocular physiology PBT, where no student received a failing grade (<65%). However, 4.7% (3 of 64) of students failed the CBT in ocular physiology. This trend was reversed for organ pathology, where only 6.3% (4 of 64) failed the CBT, but 10.9% (7 of 64) failed the PBT. There does not appear then to be a systematic difference in test scores based on test platform. We then combined the two course test scores for each platform, and the relationship between the average scores from each platform is shown in **Figure 3**. Computer-based and paper-based scores were highly positively correlated ($r=0.62$, $p<0.001$), providing additional evidence that the two platforms are essentially equivalent in assessing student performance.

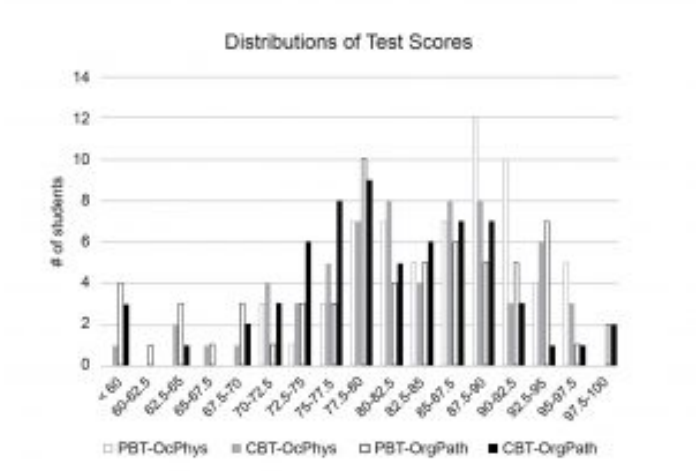

Figure 2. *Distributions of paper-based test (PBT) and computer-based test (CBT) scores. The shapes of the distributions were somewhat different among all four midterm examinations, but all were distributed normally.* *Click to enlarge*

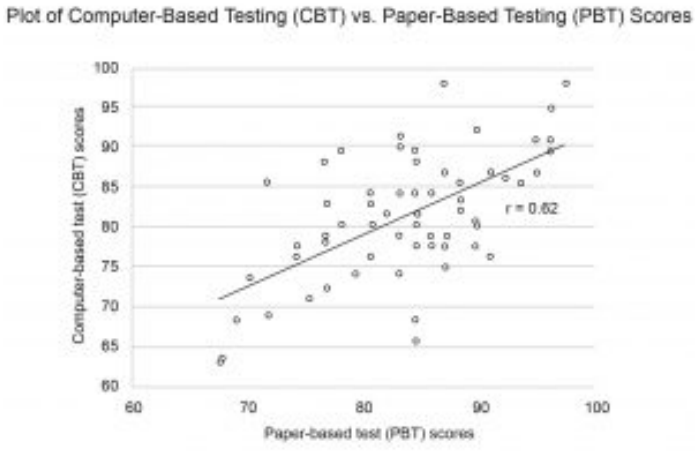

Figure 3. *Computer-based test scores and paper-based test scores were highly positively correlated.*
Click to enlarge

It has been argued, however, that any two methods that test the same parameter and provide wide variability in scores will

almost always be positively correlated.[17] It is better for us to calculate the difference (C-P) and plot this difference against the overall average of both methods.[18] This difference (or Bland-Altman) plot is shown in **Figure 4**. The mean difference (-2.30) is represented by the solid line. When the difference between the two methods was regressed on the average of all exams, we saw no relationship (r=0.06, p>0.9). That is, mean overall test performance did not systematically predict a performance bias for either testing platform. The differences were distributed normally (Kolmogorov-Smirnov statistic=0.10, p>0.05) with a median of -3.50 and 25th and 75th percentiles of -6.63 and 2.25, respectively. This slightly positively skewed distribution was seen when we computed the reference interval (or 95% limit of agreement) for the two testing methods (mean ±1.96 standard deviation of the difference). These values (10.3, -15.3) are shown in Figure 4 as thick dashed lines and indicated significant agreement between the two methods for all but six subjects (four performing significantly better on the CBT and two significantly better on the PBT).

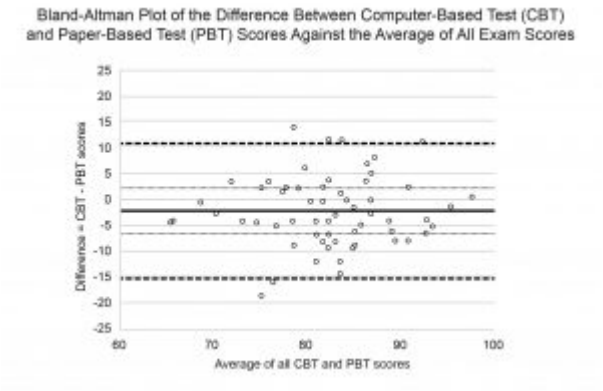

Figure 4. *Positive differences represent better mean performance on the CBT. The solid black line represents the mean difference between CBT and PBT scores (-2.30). The dotted lines represent the 25th percentile (-6.63) and 75th percentile (2.25). The heavy dashed lines represent the 95% confidence intervals below (mean -1.96 S.E.; -15.27) and above the mean (mean +1.96 S.E.; 10.57).* Click to enlarge

While the testing administration methods appeared to be equivalent, we were still interested in what factors may be responsible for the trend in our subjects to perform better on paper. We pooled all the exam scores into a single variable (C-P), which was analyzed by ANOVA with gender, race (White vs. non-White) and ethnicity (Hispanic vs. non-Hispanic) as fixed factors. We found a trend for the mean bias towards PBT to be more in non-White subjects than in White subjects [F(1,57)=3.093, p=0.053). When analyzed separately by one-sample t-tests, the bias toward PBT in non-White subjects was significantly less than zero [t(57)=-3.22, p<0.005] but not significant [t(57)=-0.98, p=0.33] in White subjects. The effects of gender [F(1,57)=0.609, p=0.439] and ethnicity [F(1,57)=0.272, p=0.604] were not significant. However, while neither gender nor ethnicity played a significant role on ANOVA, there was a difference when analyzed separately. That is, the mean difference for female subjects (-2.73) was significantly less than zero on a one-sample t-test [t(57)=-2.75, p=0.01]. This was not the case for male subjects [mean: -1.62; t(57)=-1.11, p=0.28]. Similarly, the mean for non-Hispanic subjects (-2.38) was significantly less than zero [t(57)=-2.65, p=0.01] but not for Hispanic subjects [mean: -1.87; t(57)=-0.84, p=0.42]. So — when analyzed separately — female, non-Hispanic and non-White subjects performed significantly better on paper-based tests than computer-based tests.

We then regressed the difference (C-P) onto the following predictors: age, OAT scores (academic average, total science and reading comprehension), undergraduate GPAs (total and math and science), GPAs in the first three semesters of our professional program, and learning styles. We found no significant correlations.

No validated questionnaire for determining attitudes toward paper and computerized examination formats is currently available. Therefore, we performed a factor analysis (via principal components) and found that the extracted communalities for all the survey question responses were significant (ranging from 0.65 to 0.96) and contributed to a single component that explained more than 37% of the variance in responses. It seems, therefore, that the survey questions represented, at least to some extent, student preference for one testing platform or the other. Therefore, we considered them all in our analysis.

The survey responses were not distributed normally, so we used a non-parametric test (Wilcoxon signed rank test) to determine whether the median responses were different than zero. A significant test and negative median indicated an overall preference (or endorsement) for the PBT format. If the median was positive, the endorsement was for the CBT. These results are summarized in **Table 3** and are shown for overall responses as well as broken down by gender and ethnicity (Hispanic or non-Hispanic). Subjects overall endorsed the PBT on 15 questions and the CBT on five questions. The results were identical for the 54 subjects who identified as non-Hispanic and similar for female subjects who endorsed paper examinations on two additional questions. Male subjects endorsed the computerized format for four questions but only endorsed paper for one question. Hispanic subjects endorsed paper testing for two questions and computer-based tests for one question.

Some commonly endorsed items for paper were questions 1 (less stressed by paper exam), 5 (more positive experience with paper) and 22 (prefer to mark tentative answers and go back before recording final answer). Endorsements for computer-based testing included questions 4 (prefer the feedback after taking the CBT), 8 (understand the need for CBT) and 18 (taking CBT prepares better for national licensure exams). To test whether these endorsements correlated in some way with a performance bias toward the paper or computerized formats, we created trichotomous variables for all survey questions, considering any negative response an endorsement for PBT, any positive response an endorsement for CBT, and any zero response to be "no opinion." Because we are really only interested in whether these endorsements predicted significantly better performance on one testing platform or the other, we only analyzed subjects that scored at least 2.25 points higher on the computer-based test (those who performed best on the CBT) or at least 6.63 points better on paper (those who performed best on PBT; refer to Figure 4). We then calculated the likelihood (via X^2 analysis) that the distribution (number of PBT endorsements, no opinion, or CBT endorsements) was the same between these two performance groups.

TABLE 3
Summary of Median (mean) Survey Responses for all Questions

Question # - Text	Overall	Male	Female	Hispanic	Non-Hispanic
1. More stressed by which platform?	-1.0 (-0.59)*	0.0 (-0.04)	-1.5 (-1.09)*	-1.5 (-0.44)	-1.0 (-0.83)*
2. Which platform easier?	0.0 (-0.33)*	0.0 (-0.12)	-1.5 (-0.62)*	0.5 (-5.00)	-0.5 (-0.28)*
3. More satisfied with my score using...	0.0 (-0.42)*	0.0 (-0.08)	-1.5 (-0.68)*	-0.5 (-0.44)	0.0 (-0.43)*
4. Preferred the feedback using...	1.0 (-0.84)*	2.0 (-1.28)*	1.5 (-0.72)*	1.5 (-5.70)	1.0 (-0.98)*
5. More positive experience for me with...	-1.0 (-0.44)*	0.0 (-0.08)	-1.5 (-0.77)*	-1.5 (-0.44)	-0.5 (-0.44)*
6. Would prefer taking all tests using...	0.0 (-0.13)	1.0 (-0.48)	-1.5 (-0.48)*	-0.5 (-0.44)	0.0 (-0.07)
7. More beneficial to school's curriculum...	0.0 (-0.08)	0.0 (-0.16)	0.0 (-0.18)	0.5 (-5.20)	0.0 (-0.02)
8. Do (do not) see the need for CBT	1.0 (-0.94)*	1.0 (-0.72)*	1.5 (-1.09)*	1.5 (-1.00)	1.0 (-0.83)*
9. Happy (angry) about using CBT	0.0 (-0.56)*	1.0 (-0.84)*	0.5 (-0.36)*	1.5 (-5.40)	0.0 (-0.67)*
10. Better to administer all tests using...	0.0 (-0.03)	0.0 (-0.16)	0.0 (-0.05)	0.5 (-5.30)	0.0 (-0.08)
11. I am more afraid of tests using...	0.0 (-0.33)*	0.0 (-0.08)	0.5 (-0.59)*	0.5 (-5.10)	0.0 (-0.41)*
12. This is a better overall test platform	0.0 (-0.34)*	0.0 (-0.20)	0.5 (-0.44)*	0.5 (-5.20)	0.0 (-0.37)*
13. I would like to take all tests using...	0.0 (-0.17)	0.0 (-0.04)	0.0 (-0.31)	0.5 (-5.40)	0.0 (-0.13)
14. I prepare more for this platform	0.0 (-0.03)	0.0 (-0.08)	0.0 (-0.10)	0.5 (-5.10)	0.0 (-0.02)
15. Offered choice, would take all tests using...	-0.5 (-0.28)	1.0 (-0.28)	-1.0 (-0.46)	0.5 (-5.20)	-1.0 (-0.28)
16. Experience more consistent with...	0.0 (-0.34)*	0.0 (-0.24)	0.5 (-0.41)*	0.5 (-5.10)	0.0 (-0.35)*
17. Glad if stayed with paper (switch to)...	0.0 (0.08)	0.0 (0.48)	0.0 (-0.15)	0.5 (-5.40)	0.0 (-0.02)
18. Better prepares me for licensing exams	1.0 (-0.58)*	1.0 (-0.56)	1.5 (-1.05)*	2.0 (-1.40)*	1.0 (-0.98)*
19. I retain information more using...	0.0 (-0.30)*	0.0 (-0.16)	0.5 (-0.58)*	0.5 (-5.40)	0.0 (-0.28)*
20. I am better prepared when we use...	0.0 (-0.09)	0.0 (-0.08)	0.0 (-0.10)	0.5 (-5.10)	0.0 (-0.12)
21. The timing of the exam better with...	0.0 (-0.02)	0.0 (-0.08)	0.0 (-0.26)	0.5 (-5.10)	0.0 (-0.08)
22. During tests, arrive at answers as I go	-1.0 (-0.80)*	-1.0 (-0.92)	-1.5 (-0.49)*	0.5 (-5.00)	-1.0 (-0.98)*
23. I am comfortable with technology	1.5 (1.09)*	2.0 (1.20)*	1.5 (0.81)*	1.5 (5.90)	1.5 (1.02)*
24. More comfortable platform (less eyestrain, etc.)	-1.0 (-0.88)*	0.0 (-0.48)	-2.5 (-1.13)*	-0.5 (-5.70)	-1.0 (-0.91)*
25. I have extensive experience with electronic testing	-0.5 (-0.33)	0.0 (-0.28)	-1.5 (-0.39)	-1.5 (-5.70)	0.5 (-0.22)
26. Prefer tests in lecture hall (electronic) or in testing rooms (paper & pencil)	0.0 (-0.18)	0.0 (0.24)	0.0 (-0.46)	-2.5 (-5.70)	0.5 (-0.09)
27. I learned more from the test using...	0.0 (-0.56)*	0.0 (-0.52)*	0.5 (-0.64)*	0.5 (-5.60)	0.0 (-0.56)*
28. Multiple response questions easier to navigate using	0.5 (-0.27)	0.0 (0.08)	-1.5 (-0.44)	-1.5 (-5.50)	0.5 (-0.22)
29. Heart (don't need) piece of paper during exams	-2.0 (-1.16)*	-1.0 (-0.36)	-2.5 (-1.67)*	-2.0 (-1.20)*	-2.0 (-1.16)*
30. Downloading exams prior to test helps me prepare (stressed me)	0.0 (-0.18)	0.0 (0.16)	0.0 (-0.41)	0.5 (-5.20)	0.0 (-0.18)
31. Better helped meet course objectives	0.0 (-0.25)*	0.0 (-0.04)	0.5 (-0.58)*	0.5 (-5.50)	0.0 (-0.24)*
32. CBT process is just fine the way it is (needs significant improvement)	0.0 (-0.34)*	0.0 (0.08)	-1.5 (-0.62)*	0.5 (-5.00)	-1.0 (-0.41)*
33. Was easier to read the exam using...	0.0 (-0.56)*	0.0 (-0.08)	-1.5 (-1.09)*	-1.0 (-0.80)*	0.0 (-0.54)*
34. This platform was fairer	0.5 (-0.13)	0.0 (-0.04)	0.5 (-0.25)*	0.5 (-5.10)	0.5 (-0.29)

Scores are scaled from -2 (full endorsement of PBT) to +2 (full endorsement of CBT)
* CBT or * PBT endorsements: median significantly different than zero at the p<0.05 level

Table 3. *Click to enlarge*

There were significant findings for eight survey questions representing perceived difficulty (question 2), "mood" toward platforms (questions 9 and 17), overall preference (questions 6, 10, 13 and 15), and which platform better prepares for national licensure exams (question 18). Four representative significant findings are shown in **Figure 5**. To check for a "goodness of fit" (as in X^2 analysis), we sorted the scaled predictors into ordinal variables by assigning the lower quartile as "1", second quartile as "2", third quartile as "3", and the upper quartile as "4." Only the distributions of current optometry school GPA differed significantly between students performing best on PBT or CBT (p=0.027; **Figure 6**).

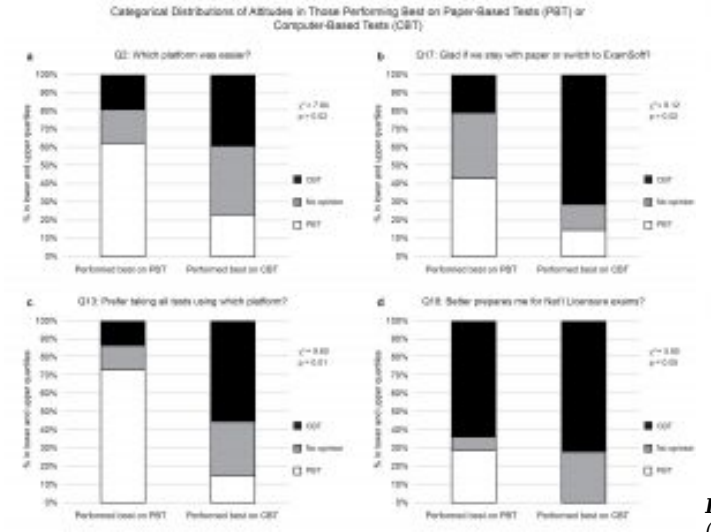

Figure 5. *Each column represents the students who performed best (75th percentile) on the PBT (left; n=14) or the CBT (right; n=14). The different bands represent proportions whose attitudes favored CBT (black bands), PBT (light bands) or no preference (gray bands). The graphs shown are representative of significant findings regarding perceived difficulty (a), "mood" toward platforms (b), overall preference (c), and which platform better prepares them for national licensure exams (d).* *Click to enlarge*

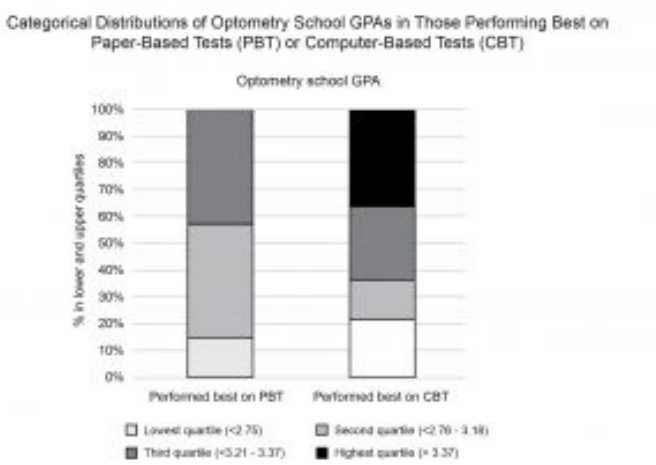

Figure 6. *Each column represents the students who performed best (75th percentile) on the PBT (left; n=14) or the CBT (right; n=14). When examining all academic predictors, only distributions of current optometry school GPA differed significantly between these two groups.* *Click to enlarge*

Discussion

This study found little difference in the performance of second-year optometry students on a computer-based test (CBT) compared with a paper-based-test (PBT) covering topics in organ pathology and ocular physiology. Overall, there was a trend

toward higher mean scores on the PBT. In addition, an opinion survey found student attitudes favored the PBT more highly than the CBT.

Our examination performance findings are consistent with some but not all prior studies that have found little difference in student performance between CBT and PBT (see Bugbee[19] and Vrabel[20] for reviews of the literature). Our results are consistent with those of Boevé et al.,[21] who conducted a study with a crossover design somewhat like ours. In their undergraduate psychology course, one-half of the class (n=199) took their midterm exam on a computer while the other half of the class took the exam using paper and pencil. The groups were switched for the final examination. The researchers found no significant difference in the mean number of questions answered correctly between the computer-based and paper-based modes for both the midterm and final exam. In another recent study, Karay et al.[22] evaluated the performance of 266 medical students on a standardized 200-question multiple-choice examination. Students were randomly assigned to take the exam on a computer or on paper. There was no significant difference in exam score between the groups, but students taking a PBT needed significantly more time to complete the test.

Perhaps the trend towards PBT performance in our study was influenced by real or perceived difficulty differences between the courses or the individual examinations used in our design. There was a statistically significant difference between the mean scores for ocular physiology (84.5%) and organ pathology (81.1%). This difference could be explained by an enhanced interest in the ocular physiology topics among optometry students. However, the disparity between the mean PBT and CBT scores was larger (and statistically significant on paired sample t-tests) in the ocular physiology course (86.4% for PBT vs. 81.1% for the CBT; p=0.003) than in the organ pathology course where the PBT and CBT scores (81.5% and 80.6%, respectively) were essentially equivalent (p=0.55). It is quite possible that the PBT in the ocular physiology course covered material that was easier to master or had been introduced in a previous course. Regardless of the cause, our ability to draw inferences concerning any PBT bias may be weakened by the main effect of course and its interaction with exam mode on scores.

It has been suggested that males find technology more appealing and thus are more self-confident using computers.[23] In addition, there are indications that girls achieve less well than boys on computer-based problem-solving tasks.[24] This has led to a concern that females may perform worse on CBT than males. We did find that females performed significantly better on PBT than CBT, while for males there was no significant difference between exam modes. Our results agree with Jeong[25] who studied test scores of Korean grade-school children and found the CBT scores of female students to be significantly lower than their PBT scores in three of four subjects studied. This similarity should be considered in light of the notably different cohorts. Indeed, others have found no gender differences in more applicable investigations. For example, Clariana and Wallace[26] compared student performance on a 100-question multiple-choice examination. Fifty-four college students took the examination on a computer while 51 students took it on paper. No attempt was made to match the two groups for gender, academic achievement or any other variable, and the investigators found that gender was not significantly associated with computer vs. paper test mode effects.

Ethnic background and race are additional factors that may influence exam mode performance. It has been reported that grade-school children from an ethnic-minority background may have less exposure to computers both in the classroom and at home than children from the majority population.[23] While our study subjects overwhelmingly endorsed computerized testing in reporting they were “comfortable with technology,” computer familiarity is one factor that has been identified as potentially influencing performance on CBT.[27] In our study, 10 students self-identified as being of Hispanic heritage and 54 who were non-Hispanic. Interestingly, we found that Hispanic students performed equally well on the CBT and PBT, while non-Hispanic subjects performed significantly better on the PBT. The 26 subjects who self-identified as non-White did perform significantly better on the PBT, but we found no performance bias among subjects who identified as White. These equivocal findings may indicate that disparities in computer familiarity may not be as much of a determining factor for this generation of students, at least not at the professional-school level.

No other individual student characteristic was significantly associated with exam mode performance in our analysis, in contrast with previous investigations. Watson[27] found that academically higher performing students benefited most from a computer-assisted learning program, while Clariana and Wallace[26] reported that higher attaining students performed significantly better on a CBT than a PBT, or conversely, PBT hindered the performance of high-attaining students more than low-attaining students. Our results may have been limited by a relatively low number of subjects; both previous studies involved nearly double the number subjects.

Following the second midterm examination, and after both midterm exam scores had been revealed to the students, each student completed a questionnaire. Responses from students with the greatest exam mode performance difference were analyzed for significant differences in their responses to survey questions. In general, we found that students indicated a strong preference for the exam mode that they performed best on (Figure 5c). When asked which exam mode best prepares them for national licensure exams (which are CBT in optometry), nearly equal proportions of students acknowledged that CBTs

were superior. This is not a surprising result, as NBEO Parts I and II (of III) are administered electronically. However, no student performing best on CBT acknowledged that PBT would better prepare them for licensing exams, and the overall distributions were significantly different (Figure 5d). These positive associations between performance and exam mode preference are not surprising. For example, it should be intuitive that more students who performed best on the paper-based test would think it was easier (Figure 5a) and that we should stay with that testing platform (Figure 5b). Our results differ from those of Washburn et al.[13] who used a very similar design and found that students overwhelmingly preferred paper-pencil over computer-based assessments. However, the students in their study performed significantly better on the computer-based test.

We found a trend suggesting that differences in test anxiety may have contributed to differences in performance between the exam modes. While Washburn et al.[13] found no association between test anxiety and test performance, it has been previously suggested that students with a lower comfort level with computers may experience greater test anxiety, and subsequent lower performance, with CBT.[28] In a study of 131 college undergraduate volunteers randomly assigned to computerized or paper-an--pencil versions of a battery of personality tests, Lankford et al.[29] found that female students and those with higher computer anxiety reported more depression when the test was administered on a computer. It is suggested that computer anxiety, like test anxiety in general, is not dependent on the degree of computer experience.[28] In our study, distribution differences in responses to questions such as “I was more stressed taking the test using…” and “I am more afraid of tests using…” approached significance, suggesting that anxiety levels were associated with exam mode performance difference. Perhaps our small study population and their foreknowledge of their exam performance prior to completing the questionnaire influenced our ability to detect a statistically significant correlation between anxiety and exam mode performance.

Strengths of our study include the 100% student participation rate, the crossover experimental design, and our access to student academic records, including undergraduate GPA and optometry school entrance exam performance. Furthermore, each student completed a VARK learning preference survey providing insight into their learning style.

Disadvantages that limit inferences from our study include the small sample size of only 64 students and a much smaller representation of Hispanic than non-Hispanic subjects. A further disadvantage is that to gain admission to optometry school students must perform well on the OAT, which is a CBT. Students that perform poorly on CBTs would not be expected to gain admission to optometry school. Although we found that OAT scores did not predict better performance on the CBT, we are dealing with a student population that is self-selected for good performance on CBT. One other disadvantage is that the two courses that were part of this experiment (organ pathology and ocular physiology) are not exactly equivalent. While the course material is similar (both covering foundational biologic principles) and were taught concurrently by the same instructor to the same students, there are differences in subject matter that may have influenced exam performance other than exam mode alone. For example, one course was 3 credit hours while the other was 2 credit hours. However, both courses were a continuation of first-year courses, and we believe that the difficulty of the course content was comparable throughout the semester within each course.

While some investigators have found no effect of question order on test performance,[30,31] others have demonstrated effects on scores[32] and score distributions.[33] In the current study, PBTs were administered in one version with a fixed order of questions and answer choices. There were, however, multiple versions of CBTs, which limits our ability to draw inferences about differences between the two formats. Lastly, we need to acknowledge that a better investigational approach may have been to administer each of the four midterms in both formats: PBT and CBT. Students could have been randomized into CBT and PBT for each exam and swapped for the second in each course. We decided against this approach for instructional reasons as students may have considered it unfair to take their first CBT while others in their class were being evaluated over the same material with the more familiar PBT.

Conclusions

In summary, we found no statistically significant difference in overall performance between PBT and CBT in this group of healthcare professional students. Females, non-White students, and non-Hispanic students performed significantly better on PBT. We also found that performance differences between the two formats predicted student perceptions of difficulty, preference and utility of the formats. In addition, we found trends suggesting that test anxiety may contribute to poor CBT performance among some students. These trends warrant further investigation. We plan to conduct a follow-up study on this same cohort of students to examine how their attitudes and beliefs toward CBT may have evolved with increased familiarity with this mode of exam administration.

Acknowledgement

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Development of a Polymeric Eye Model for Foreign Body Removal

Chau-Minh Phan, PhD, MSc, FAAO, Hendrik Walther, PhD, MSc, FAAO, and Lyndon Jones, PhD, DSc, FCOptom, FAAO |
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Introduction

Corneal foreign bodies, such as particulates of metal, glass, wood, plastic or sand, are among the most common causes of ocular injury.[1-3] When left untreated, they can potentially lead to tissue death, infections and vision loss.[1,2] Unfortunately, physicians are often poorly trained in the removal of corneal foreign bodies, which may lead to delayed or suboptimal treatment in the emergency room setting.[3]

The best approach to removing foreign bodies is under slit lamp magnification using a sterile large-gauge needle, followed by removal of the rust ring with an electric burr (AlgerBrush).[1,2] However, the slit lamp's degree of magnification and changes in depth of field can lead to exaggerated hand movements. The removal technique therefore requires precise hand-eye coordination and extremely fine motor skills, both of which are acquired through extensive practice.[4,5] For this reason, adequate instructions and training for corneal foreign body removal (FBR) is critical in ophthalmic and optometric programs.[3,6,7] Regrettably, there are not enough opportunities for students to gain the necessary practical experience.[3]

Studies have shown that students practicing FBR on simulated eye models improve their confidence levels and skills in that particular art.[3-5] One of the first simulated models, and perhaps the most common, are bovine eyes with embedded metal pieces from an angle grinder.[3] The embedded metal forms rust rings closely resembling those found in the human cornea. This provides a fairly realistic simulation of foreign bodies.[3] The bovine eyes can also be substituted for porcine eyes, depending on the availability from local slaughterhouses.

Deceased animal eyes are relatively cost-effective and readily available. Furthermore, the anatomies of porcine eyes and bovine eyes are relatively similar to that of human eyes. However, they are biological tissue. As such, disposal of these eyes, and the post-training disinfection process for the tools used, must follow rigorous procedures for biological hazards. The dead tissue will also release unpleasant odors. As a result, an alternative non-animal eye model is preferred.

Several approaches to using non-animal eye models for FBR have been tried. In general, these methods use a readily available polymer, such as paraffin wax, agar or ballistic gel, which is molded into the shape of an eye.[4,5,8] The foreign bodies, consisting of various small pieces, are embedded afterwards. However, these polymers do not mimic the consistency of the cornea, which has a high water content as well as a mechanical strength. Studies have shown that polyvinyl alcohol (PVA) can be used to create an artificial human cornea and vitreous humor.[9,10] PVA is ideal due to its low cost, ready availability, high water content (close to that of the cornea) and excellent mechanical properties.[11-14] It is commonly used in medical devices due to its favorable biocompatibility, chemical resistance and low protein adsorption properties.[14] The advantages of using a PVA eye model for FBR are that students can safely use their own equipment to practice the procedure, there are no rigorous disinfection procedures, and the "eyes" can be kept in storage for long periods of time without spoilage. To our knowledge, eye models using PVA have not been studied. The aim of this study was to create a simple eye model, using PVA, with embedded metal particles that would assist in the teaching of FBR.

Methods

Molds

The molds for the eyeballs were designed using a computer-aided design (CAD) program and were computer numerical control (CNC) machined from acetal plastic. The dimensions for the eye were 22.5 mm x 22.5 mm x 24 mm for height x width x axial length. The molds consisted of two parts, the anterior half for the front half of the eye, and the posterior half for the back of the eye **(Figure 1)**. Additionally, the posterior mold had two holes to allow for filling and the escape of any excess polymer solution. A quarter-inch diameter acrylic rod was used to create a cylindrical hole inside the eyeball to allow for mounting during FBR training.

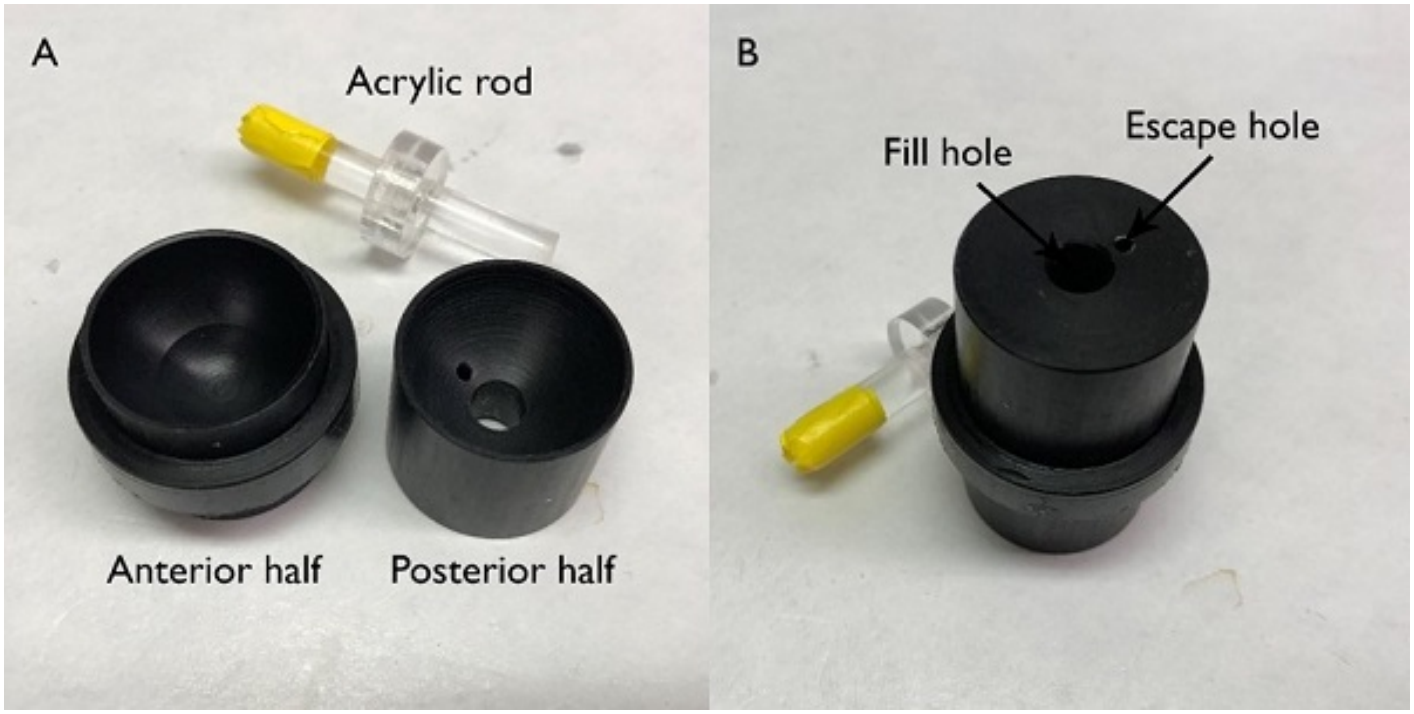

Figure 1. A: *Custom computer numerical control (CNC)-machined molds for the anterior half of the eyeball, the posterior half of the eyeball, and a quarter-inch acrylic rod used to make a hole in the eyeball.* ***B:*** *The molds assembled.*

Synthesis of polyvinyl eyeball

Dimethyl sulfoxide, and PVA with a molecular weight of (M_w) 89-98 kilodaltons (kDa) (99%+ hydrolyzed), were purchased from Sigma Aldrich (St. Louis, Mo.). The procedure was adopted from methods proposed by Hyon et al.[12] In brief, PVA was added to a mixture of dimethyl sulfoxide and Milli-Q water (8:2) to achieve a concentration of 15% weight/volume (w/v). Milli-Q water, commonly available in most laboratories, is ultrapure water obtained from filtering distilled water through a Millipore ion exchange system. The concentration can be increased if a harder eyeball is desired. The mixture was then lightly stirred for 5 minutes, and then heated in an oven at 115-120° C for 3 hours. After the heating step, the PVA turned clear and viscous, at which point it was poured into the eye mold and the acrylic rod was pushed into the back of the posterior mold to form a cylindrical mounting hole. Subsequently, the mold was held at -30° C for 3 hours for gelation to occur. The gelled eyeballs were then removed from the molds and placed in 500 mL of Milli-Q water, renewed daily, for 3 days to remove the organic solvents.

Foreign bodies

A universal milling machine was used to obtain fine steel particulates from a block of steel metal. The steel particulates were then filtered using 100 µm x 100 µm, and 300 µm x 300 µm, nylon Spectra Mesh Woven Filters to obtain particle sizes between 100 µm and 300 µm. Several fine particulates of steel were placed in the front half of the eyeball molds and heated at 115-120° C for 15 minutes. The molds were then removed from the oven, and the PVA eyeballs were pressed against the front half of the mold so the front surface of the polymer eyeball re-melted and the heated steel particulates could melt onto the front surface of the eye. The eyeball and the molds were frozen immediately at -30° C for 30 min for re-gelation. The eyeballs were then removed from the molds and stored in Milli-Q water until use. After approximately 24 hours, the steel particulate naturally formed a rust ring in the model eye.

Mount structure

A custom mount to secure the eyeball to a slit lamp headrest was designed using a CAD program. The mount was then cut from quarter-inch acrylic sheets, sourced from the local engineering workshop, using a laser cutter. The structures were assembled and glued together using methylene chloride. A quarter-inch acrylic rod was cut in a 2-mm length to easily mount and dismount the eyeball to the structure.

Students

A total of 50 eye models were used and tested by 90 third-year optometry students during their FBR lab. After the lab, an

online survey was sent to all students asking them to rate the usefulness and realism of the simulated eye model for FBR training.

Results

The model eyeball with embedded metal foreign bodies and rust rings are shown in **Figure 2**. The magnified view under the slit lamp clearly shows the foreign bodies and rust rings. The PVA at 15% w/v concentration has a semi jelly-like consistency that is also resistant to puncturing. **Figure 3** shows the custom acrylic structure used to mount the eyeball to a standard slit lamp headrest. Students can easily practice corneal FBR and rust ring removal using the eye model, as shown in **Figure 4**.

Of the 90 third-year optometry students who received the online survey after the FBR lab, 33 responded. More than 72% of the respondents thought the eye models were either very useful (48.48%) or extremely useful (24.24%) in learning FBR, while 70% of the respondents thought the models were fairly realistic **(Figure 5)**.

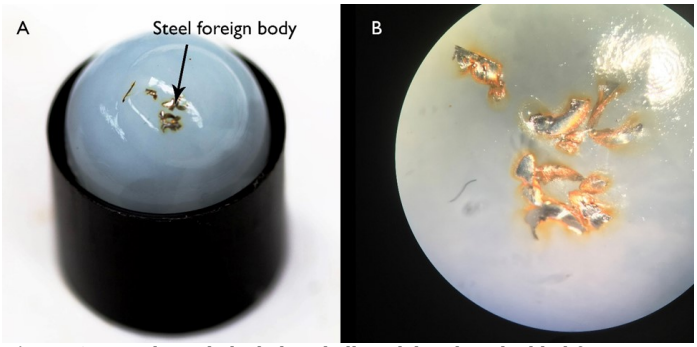

Figure 2. A: *Polyvinyl alcohol eyeball model with embedded foreign bodies and rust ring.* ***B:*** *The eyeball model viewed through a slit lamp under magnification.*
Click to enlarge

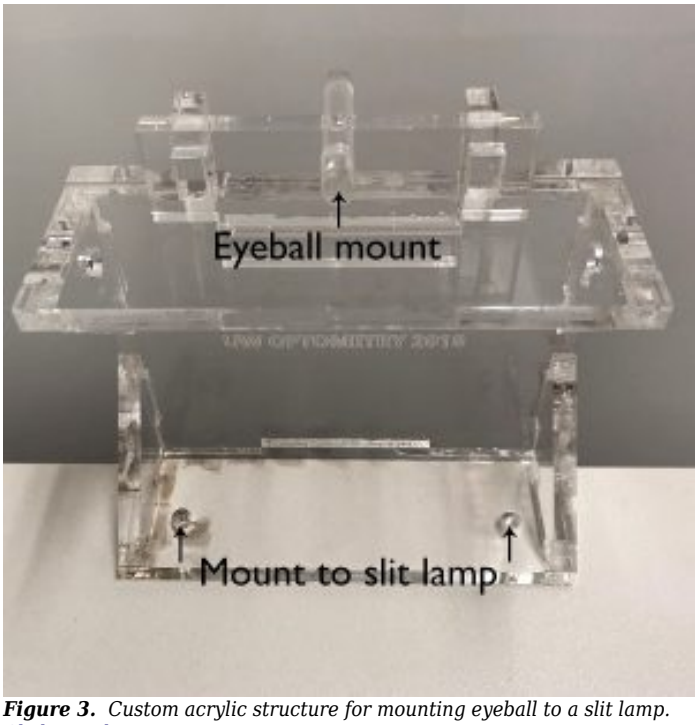

Figure 3. *Custom acrylic structure for mounting eyeball to a slit lamp.*
Click to enlarge

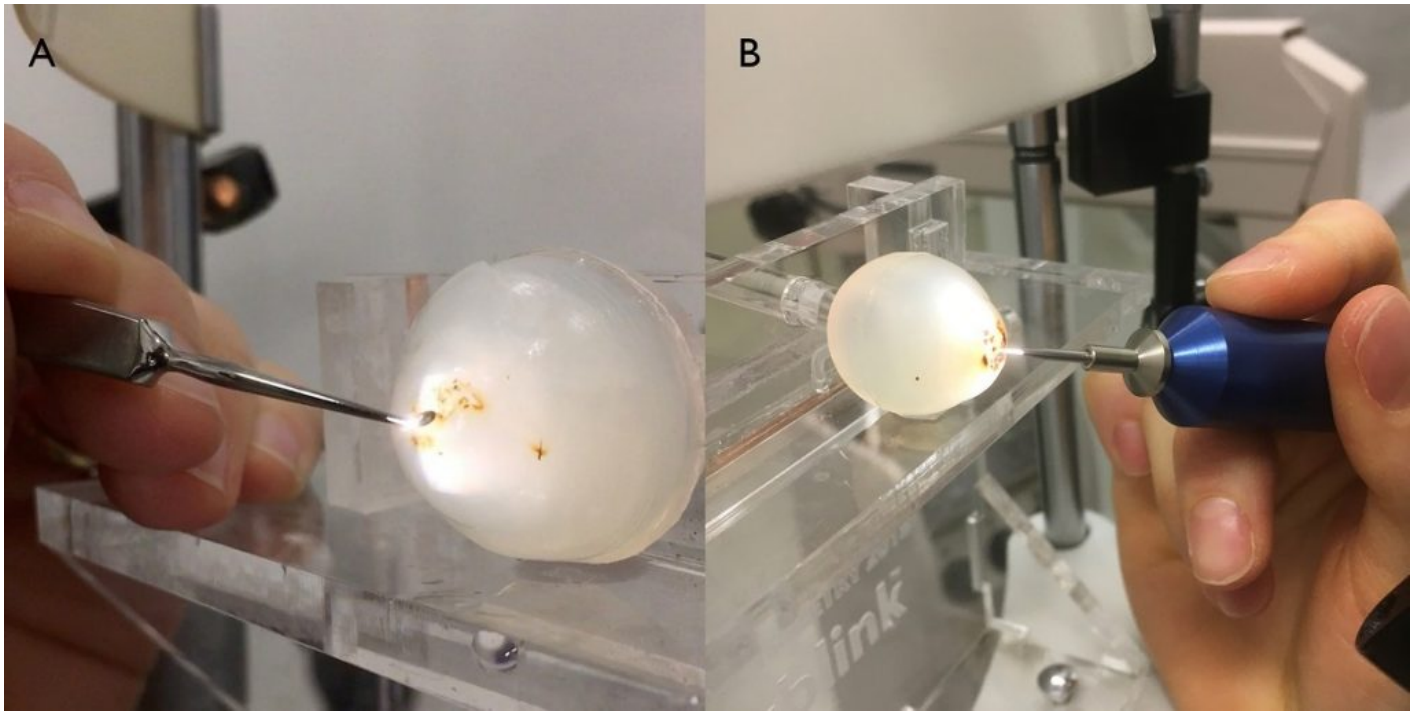

Figure 4. A: *A student practicing corneal foreign body removal.* ***B:*** *A student practicing rust ring removal.*

Discussion

The present study provides a simple method for creating eye models containing corneal foreign bodies. Multiple iterations of this eye model were vetted, tested and approved by the faculty members in charge of administrating the FBR lab. The final version of the eye model was tested on 90 third-year optometry students, and based on the survey, the overall response to this model was enthusiastic. More than 72% of the students thought the model was very useful, and 70% of the students thought the model was fairly realistic. The students initially found it challenging to remove the foreign bodies while under magnification from the slit lamp, but after a few attempts they quickly gained confidence in the FBR procedure.

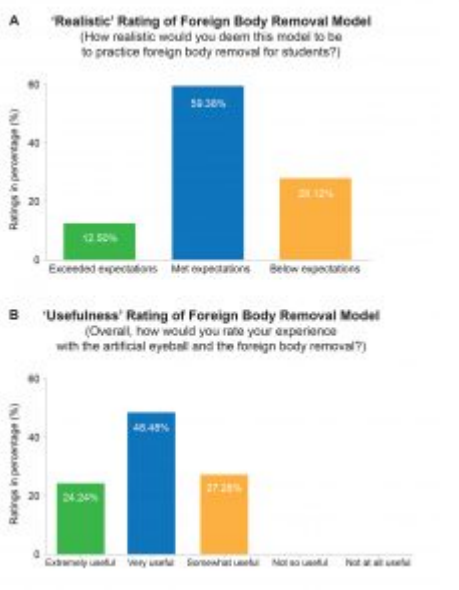

Figure 5. *Survey responses from 33 optometry students regarding the realism* ***(A)*** *and usefulness* ***(B)*** *of the eye model for learning foreign body removal.*
Click to enlarge

The most common conventional eye models for teaching foreign body removal are bovine or porcine eyes with embedded metal filings.[3] In the past, we had used porcine eyes, but the disinfection process post-procedure for dead animal eyes was-time consuming and rigorous, and the foul odors were undesirable. We also found that it was difficult to consistently create large enough foreign bodies that were also isolated enough from each other using an angle grinder.[3] Often there would be numerous clusters of extremely fine particles, which could be easily rinsed off with water.

Considering the importance of corneal FBR, very few studies have been published on alternative models to animal eyes.[4,5,8,15] Austin et al. created an eye model using marbles dipped in melted paraffin. The foreign bodies were made from snipping small pieces from an 18-gauge copper wire, and the rust rings were simulated using a rust-colored crayon.[4] Another model, proposed by Cheng et al., used expired agar plates, readily available from the local microbiology departments.[5] Materials such as gravel were used as the simulated foreign bodies.[5] In the past, we have tried both paraffin wax and agar, but found that both materials did not mimic the consistency of corneal tissue. Paraffin wax was too hydrophobic and sticky, while agar was too brittle and soft, and consequently the foreign bodies were removed too easily. An interesting model was proposed by Sayegh et al. It used ballistic gel made from silicone and corn starch.[8] Ballistic gels are a class of gels that mimic the consistency of muscle tissue, and they are typically used to simulate bullet wounds.[16] The foreign bodies were made from paper clips snipped in 2-mm portions using a wire cutter.[8]

We considered two important factors for creating a realistic eye model for FBR. The first was the consistency of the eyeball, which needed to have a high water content and resistance similar to an actual cornea. We chose PVA because of its low cost, high water content[13] and excellent tensile strength.[11] Studies also have shown that it can be used as a material for artificial corneas and human vitreous humor.[9,10] The material synthesis process that we proposed is also flexible. For instance, the concentration of PVA can be increased or decreased to obtain a stronger or weaker gel. Additionally, this approach to synthesizing PVA gels is thermo-reversible, which allows melting of the surface of the gels to incorporate the foreign bodies.

The second important factor we considered was the quality of the foreign body, which needed to be similar to the size of a foreign body typically seen in practice. In addition, the foreign body had to be embedded only on the surface, yet deep enough into the gel to be comparable with what is seen in real-life situations. To ensure similar sizes of our foreign bodies, we obtained filings of various dimensions from a steel block using a universal milling machine and then filtered the filings through 100-µm- and 300-µm nylon filters to obtain particle sizes between 100 µm and 300 µm. We embedded the particles by heating the metal filings to 120° C before pressing/melting them into the eyeball. By freezing the eyeballs rapidly afterwards, the foreign bodies became tightly embedded within the upper layers of the PVA material.

One of the main drawbacks of our eye model for FBR is the lack of Bowman's membrane to resist the penetration of the needle. Without this layer, a student is able to pierce deeper into the eye model than would normally be possible in a real eye. This layer could be simulated by incorporating another thicker layer, made from a higher concentration of PVA or a different polymer such as polydimethylsiloxane. Future studies will examine the synthesis of multiple layers representing different structures of the eye for a more realistic simulation.

Conclusion

This study tested a simple and versatile method for building an eye model to aid in teaching corneal foreign body removal. The eye model is made from polyvinyl alcohol molded into the shape of an eye and embedded with steel particles. The overall eye model has very high wettability and similar consistency to an actual eye, and the foreign bodies also form a natural rust ring. Students can easily use this model with a slit lamp to learn the necessary techniques to remove foreign bodies and rust rings. The advantages of using this model over the traditional bovine or porcine eye is a simpler cleanup, students can use their own equipment to practice, the eyes do not spoil in storage, and there is no unpleasant odor.

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Optic Nerve Melanoctyoma: a Teaching Case Report

Charles Lee, OD, Andrea Yiasemis, OD, FAAO, and Pauline F. Ilsen, OD | Optometric Education: Volume 45, Number 1 (Fall 2019)

PDF of Article

Background

Optic nerve head melanocytoma (ONM) typically appears as black or dark-brown tumors with feathery or “fuzzy” margins located on the optic disc that often extend into the adjacent retina, choroid and vitreous.[1] ONM was first reported in 1907 by Coats, who suspected melanocytomas were benign tumors. In 1962 Zimmerman and Garron described the histopathological characteristics of ONM as round or oval uniform pigmented melanocytes packed closely together. These histological features were consistent with a benign entity, not a malignant neoplasm as was once believed.[2-4] ONM is typically diagnosed clinically based on its characteristic clinical features, although ancillary testing may aid in the diagnosis and prognosis of the lesions. We present a case of optic nerve melanocytoma that was discovered on routine comprehensive eye examination in a 62-year-old patient. We review the clinical presentation, differential diagnosis, ancillary testing, natural history and potential complications of optic nerve melanocytoma. The intended audience is third- and fourth-year optometry students, optometry residents and current practitioners.

Case Description

A 62-year-old African American male presented for a comprehensive eye examination with no visual complaints. His last eye exam, which was three years prior, had been unremarkable. Family ocular history included a parent with glaucoma. Significant medical history included hypertension, post-traumatic stress disorder, osteoarthritis, gout, depression and polysubstance abuse. Medications included acetaminophen PRN for pain, allopurinol for gout, amlodipine for blood pressure, 81 mg aspirin for heart attack/stroke prevention, diphenhydramine for sleep, multivitamin/mineral for nutritional supplementation, pantoprazole for stomach acid, tamsulosin for prostate, topiramate for substance abuse cravings, trazodone for sleep, and ziprasidone for mood. Recent complete blood count, lipid profile, serum glucose, and hemoglobin A1c were within normal ranges. His most recent blood pressure measurement was 134/59 mmHg.

The patient’s best-corrected visual acuities were 20/20 OD and 20/20 OS. Pupils were equally round and reactive to light with no afferent pupillary defect. Extraocular muscle testing was normal. Confrontation visual fields were full to finger-counting in both eyes, and frequency-doubling screening perimetry with excellent reliability revealed no defects in either eye.

Slit lamp biomicroscopy was unremarkable with trace nuclear sclerotic cataracts noted in both eyes. Intraocular pressure was measured at 18 mmHg in both eyes by Goldmann applanation tonometry. Dilated ophthalmoscopy revealed a black pigmented lesion covering the superior half of the right optic nerve, extending just past the edge of the nerve onto the adjacent retina **(Figure 1)**. No significant findings were present in the left eye **(Figure 2)**. Color fundus photography was performed for baseline documentation.

Figure 1. *Fundus photograph of the right optic nerve.*
Click to enlarge

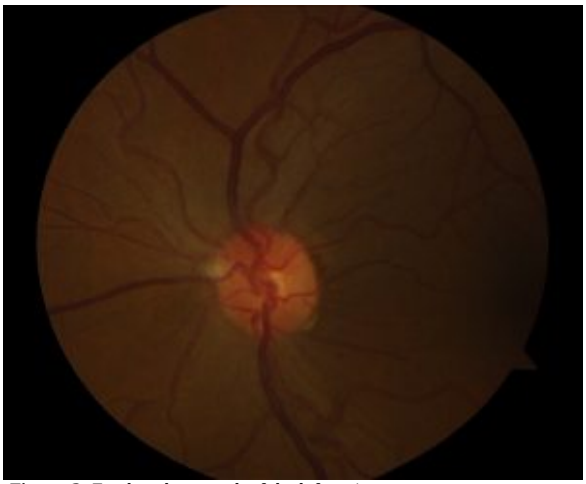

Figure 2. *Fundus photograph of the left optic nerve.*
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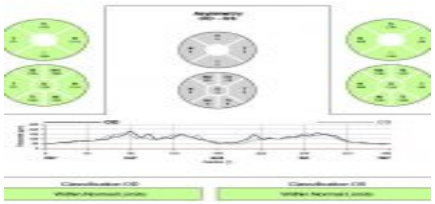

Figure 3. *Heidelberg Spectralis retinal nerve fiber layer scans and analysis OU. Click to enlarge*

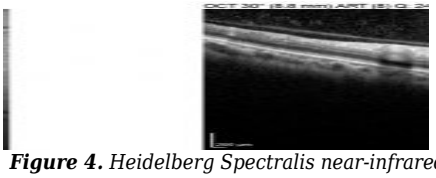

Figure 4. *Heidelberg Spectralis near-infrared photograph and vertical spectral domain OCT section through the right optic nerve. Click to enlarge*

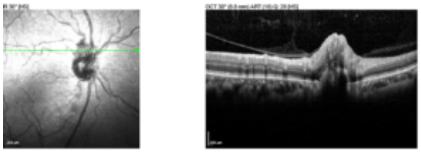

Figure 5. *Heidelberg Spectralis near-infrared photograph and horizontal spectral domain OCT section through the right optic nerve. Click to enlarge*

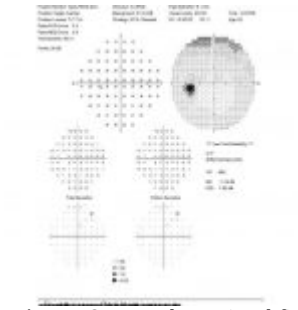

Figure 6. *Humphrey visual field test (central 30-2 threshold) in the left eye.*
Click to enlarge

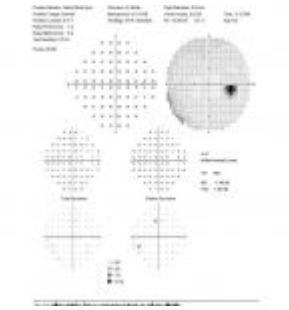

Figure 7. *Humphrey visual field test (central 30-2 threshold) in the right eye. Click to enlarge*

The patient returned a few weeks later for baseline optical coherence tomography (OCT) imaging **(Figures 3-5)** and automated Humphrey central 30-2 threshold visual field testing. The retinal nerve fiber layer (RNFL) was robust in both eyes, with global values of 119 µm in the right eye and 114 µm in the left eye. The superior quadrants (location of the ONM OD) did not differ significantly between eyes with values of 143 µm OD and 138 µm OS.

The Humphrey visual field test was moderately reliable in the right eye and reliable in the left eye. Visual field in both eyes was essentially clear **(Figures 6-7)**. The patient was advised of the findings and instructed to return for follow-up in six months to ensure stability and annually thereafter unless he experienced changes in vision or new ocular symptoms.

Education Guidelines

Learning objectives

1. Understand the typical presentation of optic nerve melanocytoma
2. Understand the clinical findings associated with optic nerve melanocytomas and differential diagnoses
3. How to use ancillary testing to aid in diagnosis and prognosis of optic nerve melanocytoma and potential complications

Key concepts

1. Visual complications may arise from optic nerve melanocytomas even though the tumors are benign
2. Critical thinking in differentiating optic nerve melanocytomas from other ocular tumors
3. Managing patients with optic nerve melanocytomas

Discussion points

1. Do optic nerve melanocytomas affect vision?
2. Do optic nerve melanocytomas affect pupil response?
3. Do optic nerve melanocytomas cause visual field defects and if so what kind?
4. What differential diagnoses should be considered in cases of suspected optic nerve melanocytoma?
5. What ancillary testing can aid in the diagnosis of optic nerve melanocytoma?
6. What is the appropriate management for optic nerve melanocytoma?
7. What is the natural history and prognosis for optic nerve melanocytoma?

Literature review

Optic nerve melanocytomas are benign tumors, with equal incidence among all races.[1,2] It is a longstanding misconception that ONM is more common in darker pigmented individuals.[1,5] The average age at diagnosis is 50 years, and there appears to be a slight female predilection, with one study reporting women having a 2:1 likelihood of having ONM.[1] Optic nerve

melanocytomas are unilateral, and in rare instances have been reported to occur bilaterally in children, which suggests a congenital etiology.[5-6] ONM has no systemic associations but may be associated with intracranial meningiomas.[1]

Discussion

Teaching instructions: Participants should read each question and consider how they would respond. Next, they should read the information provided in the text. Participants may work together in small groups or individually, either in real time or as part of a homework assignment. Learning objectives are to be assessed by comparing participants' responses with the information provided. This case may also be presented as a PowerPoint presentation detailing the case description, learning objectives, key concepts, literature review and discussion points.

Do optic nerve melanocytomas affect vision?

In most cases, ONM does not cause significant vision loss.[1,4] Lee et al. reported that 93% of patients with ONM had vision of 20/40 or better.[7] Up to 26% of optic nerve melanocytomas may cause mild visual impairment, usually as a result of disc edema, retinal edema or subretinal fluid involving the fovea.[1,4,8-13] Other potential causes of vision loss include compression of the optic nerve, tumor necrosis, juxtapapillary choroidal neovascularization, central retinal vein occlusion or malignant transformation.[1,4,8-13] Vision loss may be reversible in some cases.[6] Severe vision loss is rare and should be looked upon with close scrutiny as it may be evidence of malignant change.[3]

Do optic nerve melanocytomas affect pupil response?

An afferent pupillary defect (APD) is observed in 10-30% of all ONM.[1,6] Shields et al. reported that an APD may occur despite normal visual acuity.[1] Conversely, Lee et al. reported that an APD was present only in patients with vision equal to or worse than 20/50.[4,7] Afferent pupillary defects are likely the result of compression of the optic nerve fibers by the melanocytic cells.[1]

Do optic nerve melanocytomas cause visual field defects, and if so what kind?

Visual field defects are commonly reported with ONM and include enlarged blind spot and nerve fiber bundle defects.[1,4] The most commonly reported defect is enlargement of the blind spot, which is believed to be directly related to the amount of tumor extension and compression of the optic nerve axons.[1,4] Nerve fiber bundle defects include nasal steps and arcuate defects.[14] Ninety percent of all optic nerve melanocytomas are associated with abnormal visual field findings; thus, it is important to establish baseline visual fields at time of diagnosis.[1] Visual field testing may help detect ONM enlargement or malignant transformation.[5]

What differential diagnoses should be considered in cases of suspected optic nerve melanocytoma?

Differential diagnoses for ONM include choroidal nevus, juxtapapillary choroidal melanoma, metastatic melanoma to the optic nerve, and retinal pigment epithelium (RPE) hyperplasia of the disc. Optic nerve melanocytomas are believed to be variants of choroidal nevi that are located on the optic nerve.[1,19] Choroidal nevi are typically flat or minimally elevated and tend to be located juxtapapillary instead of overlying the disc as optic nerve melanocytomas do.[1] Choroidal melanomas may occur on the optic nerve and can be extremely difficult to distinguish from ONM. Choroidal melanomas tend to be lighter in color compared to optic nerve melanocytomas and may have associated subretinal fluid or overlying lipofuscin, which are not seen in ONM. Metastatic melanomas often present clinically as unilateral or bilateral optic nerve edema due to diffuse infiltration of the optic nerve, and a distinct darkly pigmented lesion is not observed.[1,19] Unlike patients with optic nerve melanocytomas that remain asymptomatic, patients with metastatic optic nerve melanomas typically complain of acute pain, reduced vision and diplopia.[20] Metastatic choroidal lesions, which appear as unilateral or bilateral creamy white or pale yellow elevated lesions, often accompany optic nerve metastasis.[20] RPE hyperplasia at the optic nerve margin may present similarly to ONM; however, the margins are typically more irregular and not as feathery or fuzzy as in ONM. A history of trauma or inflammation may be elicited from the patient, and there be accompanying chorioretinal scarring.

What ancillary testing can aid in the diagnosis of optic nerve melanocytoma?

Ancillary testing is not necessary for diagnosing ONM as the diagnosis is made by assessing the clinical features. However, ancillary tests can aid in diagnosis and be useful in monitoring the lesions and determining prognosis.

Spectral domain OCT through the ONM typically shows an elevated, dome-shaped lesion on the anterior surface of the optic nerve and characteristic posterior shadowing due to loss of light transmission through the pigmented tumor.[15-17] Like ONM, choroidal nevi also appear as dome-shaped lesions with deep shadowing on OCT imaging. However, unlike ONM, choriocapillaris compression overlying the nevus, photoreceptor loss and RPE atrophy are also noted on OCT imaging of

choroidal nevi.[21] Choroidal melanomas display similar OCT features to choroidal nevi, including deep optical shadowing and choriocapillaris compression. A distinguishable difference between the two is the presence of “shaggy” photoreceptors of choroidal melanomas due to the subretinal fluid that typically accompanies choroidal melanomas but not ONM.[21] Choroidal metastases display irregular “lumpy bumpy” lesions unlike the smooth dome-shaped lesions of ONM, choroidal nevi and melanomas.[21] Choroidal metastases also display RPE abnormalities and compression of the choriocapillaris.[21]

OCT angiography may be useful in identifying abnormal retinal vasculature on the tumor surface and in the peripapillary region, which has been described as a risk for tumor growth.[7,16] OCT is valuable in measuring tumor thickness for monitoring, as well as in detecting possible complications of ONM such as subretinal fluid.[5]

Fundus autofluorescence (FAF) of ONM reveals a characteristic hypoautofluorecence, while the remaining retina demonstrates isoautofluorescence.[15] Similarly, fluorescein angiography (FA) reveals hypofluorescence throughout.[1,18] Neither FA nor FAF are much help with ONM diagnosis.

B-scan ultrasonography is an important diagnostic and prognostic tool. Melanocytomas greater than 0.5 mm in elevation may be visualized with B-scan. ONM may be monitored over time with B-scan for change and malignant transformation. Gologorsky et al. observed 90% of optic nerve melanocytomas to have medium to high reflectivity on B-scan, 62% to be dome-shaped, and 28% to be mildly elevated.[19] Choroidal melanomas are also typically dome shaped on B-scan ultrasonography but exhibit low to medium reflectivity, whereas choroidal metastases are more irregular in shape and exhibit high reflectivity.[22] Choroidal nevi appear as thin choroidal masses with tapering margins that blend into the normal choroid with moderate reflectivity on B-scan ultrasonography.[23]

What is the appropriate management for optic nerve melanocytoma?

No treatment is indicated for optic nerve melanocytoma. Patients should be monitored annually with dilated fundus examination and fundus photography.

What is the natural history and prognosis for optic nerve melanocytoma?

Although ONM tumors are benign, they have a 1-2% risk of conversion to malignancy.[1,6] ONM may exhibit slow growth over time, but this does not always indicate malignant change.[1] Conversely, rapid tumor growth or necrosis with severe vision loss is highly suspicious for malignant transformation, and the patient should be promptly referred to an ocular oncologist.[4] The main predictive factor for growth is tumor thickness greater than 1.5 mm at initial diagnosis.[1]

Conclusion

Optic nerve melanocytomas are darkly pigmented benign tumors located partially or completely within the optic nerve head. Despite being considered benign tumors, they may cause vision loss and/or visual field defects due to various complications. Rarely, these lesions may convert to malignancy; thus, annual monitoring for change is recommended.

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Lymphoproliferative Disorders of the Ocular Adnexa: a Teaching Case Report of Conjunctival MALT Lymphoma and Lymphoid Hyperplasia

Ellen McCrary, OD, Andrea Yiasemis, OD, FAAO, and Pauline F. Ilsen, OD, FAAO | Optometric Education: Volume 45, Number 1 (Fall 2019)

PDF of Article

Background

Ocular adnexal lymphoproliferative disorders (OALD) range from the benign reactive lymphoid hyperplasias (RLHs) to the malignant lymphomas. Both benign and malignant ocular lymphoproliferative disorders typically affect the conjunctiva, orbit and lacrimal gland and are most often unilateral.[1-5] OALD has a slight female predilection and typically presents between the 5th and 7th decades.[4,6] Malignant lymphomas and benign lymphoid hyperplasias (LHs) often appear identical on clinical examination and imaging.

We present two cases of OALD that initially appeared similar on clinical examination, but after further evaluation with biopsy, immunohistochemistry and molecular genetics were found to be respectively malignant and benign. Local and whole-body imaging is needed to determine whether lymphoid disease is localized to the orbit or secondary to systemic disease.

This teaching case report is aimed at fourth-year optometry students, residents and current practitioners. Eyecare providers should be aware of the clinical presentation, diagnostic techniques, management options and outcomes for the lymphoproliferative disorders of the ocular adnexa as they may present without prior known history of lymphoma. OALD may be easily mistaken for other conditions, and the eyecare provider may play a significant role in co-management with other disciplines.

Case Descriptions

Case report 1: MALT lymphoma of the palpebral conjunctiva

A 61-year-old black male presented for a routine eye examination with a chief complaint of blurry vision at distance and near. His last eye exam was 35 years ago and the only vision correction he was wearing were over-the-counter readers. He had no history of eye injury or surgery and no personal or family history of ocular disease. His medical history was positive for hypertension, a benign liver mass, hepatitis C, chronic obstructive pulmonary disease, peptic ulcer disease, anemia and past substance abuse. His best-corrected visual acuity was 20/15 for both the right and left eye.

Slit-lamp biomicroscopy revealed a large, red, fleshy and gelatinous conjunctival mass in the left eye that was present in almost the entire inferior fornix, palpebral conjunctiva and encroaching onto the bulbar conjunctiva. The patient was unaware of the mass and was asymptomatic. Lymphoproliferative disease was suspected, and photographs were taken at the initial visit **(Figure 1A)**. All other examination findings were unremarkable.

The patient was referred to the ophthalmology department for evaluation but did not follow up until the next year. At time of presentation with ophthalmology one year later, he was still mostly asymptomatic, although he reported an occasional mild foreign body sensation. The left lower lid now exhibited a slight fullness, and his blink was abnormal with a tendency toward entropion. The pink conjunctival mass involving most of the lower lid and fornix measured approximately 12 mm x 6 mm on the bulbar conjunctiva and 25 mm horizontally on the palpebral conjunctiva. A complete blood count (CBC) with differential was ordered, and the patient was referred to the oculoplastics clinic for biopsy. The CBC revealed a mild elevation of monocytes and basophils but was stable compared with baseline testing over the past 14 years.

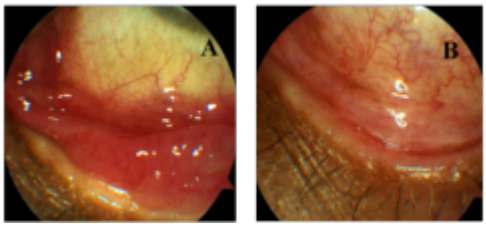

Figure 1. *A 61-year-old black male with MALT lymphoma of the inferior palpebral conjunctiva and fornix before* ***(A)*** *and 2 years after* ***(B)*** *treatment with radiotherapy. Click to enlarge*

An incisional biopsy was performed one month later. Histology revealed "a uniform population of lymphocytes with occasional lympho-epithelial islands within the subepithelial tissue." Flow cytometry showed CD19+, CD20+ and CD22+ cell markers and lambda light chain restriction. A diagnosis of B-cell lymphoma consistent with mucosa-associated lymphoid tissue (MALT) lymphoma was made. Positron emission tomography (PET) showed no systemic involvement, and the final diagnosis was stage IE extranodal B-cell marginal-zone lymphoma of the left inferior conjunctiva. Intensity-modulated radiation therapy (IMRT) was performed with a total of 36 Gy split into 18 fractions over 26 days. The conjunctival mass completely resolved without recurrence at the 9-month follow-up exam.

The patient returned to clinic 2 years later with a complaint of worsening vision in the left eye and glare with nighttime driving. Vision was correctable to 20/20 in the right and left eyes but with glare testing declined to 20/80 in the left eye. Asymmetric cataracts were found, with a denser, milky nuclear sclerotic cataract and a small posterior subcapsular cataract in the left eye. There was no evidence of MALT lymphoma recurrence or systemic involvement **(Figure 1B)**.

Case report 2: lymphoid hyperplasia of the palpebral conjunctiva and fornix

A 68-year-old white male known to the eye clinic presented with a complaint of a "bump" inside his left lower lid for the past 10 days. He noted that initially the lesion felt hard and small, but 4 days prior to the exam it had become flatter and more spread out. The patient had no pain or other associated symptoms. His medical history was positive for hyperlipidemia, hearing loss, erectile dysfunction, chronic kidney disease, migraines and basal cell carcinoma on the left cheek that was removed 1.5 years prior. His last eye exam was 6 months ago at the same clinic and was unremarkable. Best-corrected visual acuity was 20/20 in the right eye and 20/25+2 in the left eye.

Slit-lamp examination revealed a 12-mm horizontal by 5-mm vertical firm, fleshy mass encompassing almost the entire lower palpebral conjunctiva and fornix with no tenderness on palpation. The remainder of the examination was unremarkable. An atypical chalazion was suspected and aggressive hot compresses were initiated. A 1-week follow-up visit was scheduled due to the sudden onset and atypical fleshy appearance of the lesion.

At the 1-week follow-up, the patient reported that the lesion was reduced in size, but examination revealed spreading of the lesion more nasally and into the fornix and inferior bulbar conjunctiva. Best-corrected visual acuity was stable in both eyes. Photographs of the lesion were taken, and the patient was referred to the oculoplastics clinic on the same day for evaluation **(Figure 2)**. The lesion was biopsied, and a pathology evaluation was performed. Immunohistochemistry showed "mixed CD3 and CD20 lymphocytic populations with negative bc12 stain on germinal centers and positive CD10 stain almost exclusively by the follicular center cells." Immunophenotyping showed a mixture of 36% T cells (CD3+) and 62% B cells (CD19+ and CD20+) and an elevated CD4:CD8 ratio of 6:1. A diagnosis of benign RLH was made.

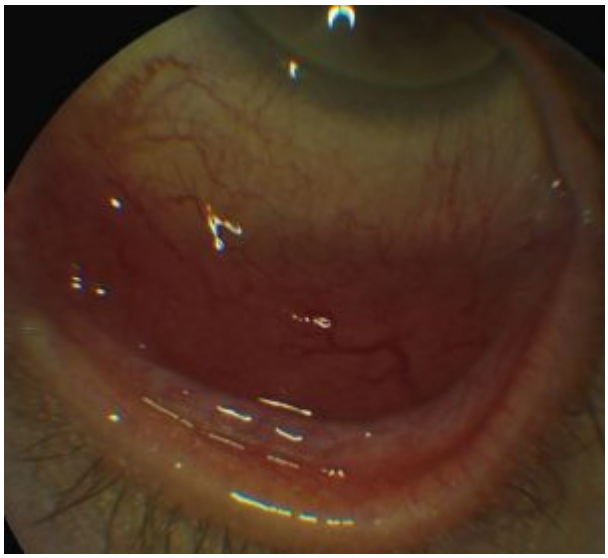

Figure 2. *A 68-year-old white male with benign reactive lymphoid hyperplasia of the inferior palpebral conjunctiva and fornix. Click to enlarge*

When the patient returned to the oculoplastics clinic 2 weeks later, the treatment options were discussed with him and he chose observation only at that time. A plan was made to monitor the lesion every 3 months and to consider steroid injections in the future if any growth occurred. However, the patient was lost to follow-up for 8 months. When he returned, the conjunctival lesion was not appreciated. The patient reported that the lesion had resolved on its own approximately 3 weeks after being biopsied.

Education Guidelines

Learning objectives

1. Understand the spectrum of ocular adnexal lymphoproliferative disease and be familiar with its typical appearance
2. Be aware of differential diagnoses for lymphoproliferative disorders
3. Become familiar with how to manage a patient with suspected ocular adnexal lymphoproliferative disease
4. Become familiar with traditional and emerging immunotherapy treatments for ocular adnexal lymphoproliferative disease

Key concepts

1. Recognize that RLH is clinically indistinguishable from ocular lymphoma
2. Recognize that lymphoproliferative disease is often asymptomatic; however, clinicians should be familiar with common signs and symptoms
3. Become familiar with appropriate workup of suspected ocular lymphomas, including imaging and histology

Discussion points

1. What is the clinical presentation of OALD? What are the differential diagnoses?
2. What additional tests/workup are indicated when OALD is suspected?
3. What is the pathogenesis of lymphoproliferative disease?
4. What is the treatment for OALD?
5. What is the prognosis for OALD?

Literature review

Ocular adnexal lymphoproliferative disease refers to a spectrum of lymphoid disorders affecting the eyelid, conjunctiva, lacrimal gland and orbit. Histopathology classifies the ocular adnexal lymphomas as either benign RLH or malignant lymphoma.[7]

Ocular adnexal lymphoma (OAL) is the most common type of OALD and accounts for 68-98% of all lymphoid lessions.[1,6,8] OAL is considered primary if it is located solely in the ocular tissues, while secondary lymphoma represents metastasis from another location in the body that is found either subsequently or simultaneously to the systemic lesions.[2,9-10] OAL is further categorized into Hodgkin disease and non-Hodgkin lymphoma (NHL).

The majority of OAL is non-Hodgkin B-cell lymphoma, the most common of which is extranodal marginal-zone lymphoma, commonly referred to as MALT lymphoma (46-75%). This type of lymphoma was highlighted in the first case description. Other common types of OAL include follicular lymphoma (4.5-18%), diffuse large-B-cell lymphoma (4.7-16%) and mantel-cell lymphoma (3-9%).[2-3,11-13] Studies have either found no gender predilection, or a slight female majority.[2-4,13-16] The lymphoproliferative disorders are most common in older adults, with a median age of 59-71.[1,4,8,13] Over the past few decades, OALD has been on the rise in Western countries. Studies show annual increases of 3.4-6.5%, mainly due to an increase in ocular adnexal MALT lymphoma.[13,16] This increase may be due to advances in diagnostic techniques but does not account for the fact that the increase of systemic NHL has already peaked while OAL is still increasing.[13]

RLH is a proliferation of lymphoid tissue, usually with a polyclonal mix of small lymphocytes, and is a benign condition.[14] It has a predilection for the orbit and adnexa but only accounts for approximately 7-15% of OALD.[1,8,11-12,15] RLH is essentially indistinguishable from NHL clinically, and it requires biopsy for diagnosis as demonstrated in the second case description.

Discussion

Teaching instructions: Participants should read each question and consider how they would respond and then read the information provided in the text. Learning objectives are to be assessed by comparing participants' responses to the information provided.

What is the clinical presentation of ocular adnexal lymphoproliferative disease? What are some differential diagnoses?

Lymphoma is most common in the 5th to 7th decades.[4,6] LH typically presents 5-10 years earlier.[3,6] Both of the patients in the cases presented were in their 6th decade. Lymphoproliferative disease has a slight female predominance.[1,3-5] The clinical appearances of benign LH and malignant lymphoma are also similar, and they are indistinguishable on clinical examination.[1-2,6] Lymphoproliferative disease can be asymptomatic and found on routine exam but often presents as a slowly enlarging, painless mass. Common symptoms include proptosis, swelling, diplopia, ptosis, and mild to no pain and inflammation.[1-2,5,11,17] Vision loss is rare as these lesions mold to the globe and orbit rather than invade the surrounding tissues.[17-18] The median duration of symptoms before diagnosis is 6-7 months but can range from 1 month to 10 years.[4,11]

The most common locations involved in lymphoproliferative disorders of the ocular adnexa are the orbit/lacrimal gland (33-46%), conjunctiva (23-42%) and eyelid (10-25%).[1-4] Conjunctival location usually offers the best prognosis, while eyelid lymphoma is usually secondary to a more aggressive systemic lymphoma,[3,15] and lacrimal lymphoma is most likely to spread to the lymph nodes.[19] The majority of OALD is unilateral; only 10-25% is bilateral, which often signifies a poorer prognosis.[4,12,17]

Orbital and lacrimal gland lesions usually present as a firm or rubbery mass that can lead to proptosis.[4] Conjunctival lymphoproliferation is often a characteristic "salmon-colored" lesion that is well-circumscribed and either nodular or smooth, as evident in the anterior segment photographs of both patients. It arises from the conjunctival stroma; therefore, the overlying epithelium is unchanged, which is one way of differentiating it from squamous-cell neoplasia.[14,20]

Differential diagnoses for the clinical presentation of these lesions range from benign entities such as pinguecula, conjunctivitis and pterygium, to malignant ones such as Kaposi sarcoma, ocular surface squamous neoplasia, and amelanotic melanoma.[4,20] It is important to refer any suspicious or atypical lesions or any non-resolving conjunctivitis for evaluation and biopsy, especially because clinical presentation alone cannot differentiate lymphoma from benign LH.

What additional tests/workup are indicated when ocular adnexal lymphoproliferative disease is suspected?

A thorough workup is needed to diagnose a lesion as lymphoproliferative disease. Careful staging of the disease is needed to determine whether the lesion is localized to the ocular adnexa or if there is concurrent systemic disease. Additional testing should include a physical examination with emphasis on the lymph nodes. Laboratory testing includes a CBC with differential, serum protein electrophoresis, serum lactate dehydrogenase and B_2-microglobulin. Tissue biopsy with histological, immunophenotypic and molecular genetic evaluation is necessary, as are orbital and whole-body imaging.[4,18] In some cases, a bone marrow biopsy may also be necessary if invasion of bone is suspected with more aggressive tumor types.[6]

While neither patient in the cases presented underwent magnetic resonance imaging (MRI) or computed tomography (CT), MRI and/or CT may aid in making the diagnosis as well as in assessing the exact location and extent of lesions. MRI and CT should be performed with contrast and thin slices through the orbit. On imaging studies, lymphoproliferative lesions typically appear as unifocal, well-circumscribed, homogenous masses that are either isodense or slightly hyperdense to muscle, and they mildly enhance with contrast. The lesions usually mold to solid structures, such as the globe and orbit. Bone destruction is always absent in LH and rare with lymphomas and usually signifies a more aggressive lymphoma, such as diffuse large-B-cell lymphoma.[4,21]

Additional whole-body imaging is also necessary to look for systemic involvement and to stage the disease. Traditional imaging is performed using CT of the chest, abdomen and pelvis to look for any systemic lesions in lymph nodes, organs or other mucosal sites. Valenzuela and colleagues found that imaging with fluorine 18 deoxyglucose positron emission tomography (FDG PET) upstaged 66% of patients compared with traditional CT scan, which led to a change in the ultimate management of these patients.[5] Similarly, a study by English et al. demonstrated that FDG PET detected systemic lesions in 31% more cases than CT imaging.[22] Conversely, FDG PET is less sensitive at detecting orbital lesions compared to CT (27-79% vs. 73-97%, respectively).[5,22] It has been suggested that combined PET/CT imaging could enhance the detection of the location and extent of disease and ultimately aid in management and final outcome.[5]

Ocular adnexal lymphoproliferative disorders are clinically and radiologically indistinguishable for the most part, and a full pathological evaluation including histology, immunophenotyping and molecular genetics is needed to confirm the exact type of lymphoid proliferation and to distinguish between benign and malignant disease.[12] Morphologically, LH is seen as a dense infiltration of small B and T lymphocytes organized into well-defined reactive follicles.[23] T cells are usually found to be the predominant cell type with immunohistochemistry, which differs from B-cell lymphomas — the majority of OALD. The reactive germinal centers contain "tingible body" macrophages filled with cellular debris, while Dutcher bodies are absent, differentiating LH from marginal-zone lymphomas such as MALT lymphoma.[14,23] The presence of an infiltrate of small, mostly B-cell lymphocytes surrounding reactive follicles also characterizes MALT lymphoma (distinguishing it by definition from diffuse large-B-cell lymphoma) although a few large cells may be present as well.[23] Immunophenotyping may also aid in differentiating it from other malignant lymphomas. The cells usually express the B-cell antigens CD19, CD20 and CD22 but are negative for CD5, CD10 and CD23, while follicular lymphoma is positive for CD10 and mantle-cell lymphoma is positive for CD5.[16] Flow cytometry in the first case presentation showed CD19, CD20 and CD22 cell markers, which is consistent with a diagnosis of MALT lymphoma, while the second case presentation revealed CD10 cells consistent with a diagnosis of benign RLH.

What is the pathogenesis of lymphoproliferative disease?

Lymphoproliferative disease likely arises initially as an immune response to an antigen as the tissue architecture resembles that of a stimulated lymph node.[14] Both LH and MALT lymphoma occur in locations where lymphocytes are not normally located but converge at the site in response to an antigen. Such stimuli are either from chronic infection, which has been

shown with *Helicobacter pylori* in gastric tumors, or an autoimmune disease, such as Hashimoto's thyroiditis in thyroid tumors.[4,6] Infection with *Chlamydia psitacci* has also been proposed as a precipitating factor in OALD, but studies have shown wide geographic variability, including variability within the same region, and there is no consensus.[4,24]

In the case of LH, it has been hypothesized that T-cell imbalance drives B-cell proliferation because T cells are often the main cell type in LH and the CD4:CD8 ratio is usually elevated.[23] Also, it has been shown that LH can progress to NHL in cases of helicobacter gastritis, Sjögrens disease and Hashimoto's disease.[23] It is hypothesized that sustained B-cell proliferation in LH leads to increased mutations and translocation of genes until there is unrestrained proliferation of a monoclonal B-cell population (essentially the definition MALT lymphoma). However, not all lymphoid proliferations progress to lymphoma.[23]

The exact pathogenesis of OALD is still unknown and investigation into the precipitating factors and the genetic mutations involved are ongoing.

What is the treatment for ocular adnexal lymphoproliferative disease?

The management of OALD involves multiple specialties and depends on tumor classification, extent of disease and prognostic indicators.[2,4] It should only be decided after a rigorous examination, pathological evaluation and staging process.

The traditional treatment for primary OAL is radiotherapy, with a mean total dose of 32 Gy (range 15-46).[25] The patient in our first case report received a total of 36 Gy. The 5-year survival rate can be as high as 95-100% for orbital MALT lymphoma; however, higher doses of radiation or adjuvant treatment are usually needed in higher-grade tumors.[19] Radiotherapy has also been used for LH, but at lower levels, typically 15-25 Gy. Standard treatments in the past have included systemic or injected steroids.[14] Other treatments for OALD include observation only, which may be more appropriate in cases of LH as demonstrated in the second case report, and is not recommended for lymphoma unless the patient is particularly elderly and frail.[26] Surgical excision of encapsulated lesions is another treatment option, although excision has a high rate of recurrence and risk of possible systemic dissemination, especially if no adjuvant radiation or systemic treatment is added.[4,11,26]

Adverse effects from radiotherapy can be categorized as acute (either during or within 3 months of treatment) or late (more than 3 months after treatment) and can occur in up to 70% of patients.[19,26] Acute complications are mostly transient and often resolve spontaneously.[25,27] Late effects are often chronic and more severe and may include dry eye syndrome, loss of eyelashes, cataracts, retinopathy and optic neuropathy. Radiation retinopathy typically occurs with doses of 45-60 Gy but may occur with doses as low as 18 Gy when there is underlying vascular compromise such as diabetes.

For secondary orbital lymphoma with systemic involvement, systemic chemotherapy is typically the first-line treatment. Treatment of low-grade lymphoma often involves a single drug such as chlorambucil, while a multiagent regimen such as CHOP (cyclophosphamide, doxorubicin, vincristine, prednisone) is used for more aggressive histological types.[10] Combination treatment with both local radiation and systemic chemotherapy, termed chemoradiotherapy, may offer more favorable outcomes in patients with more advanced disease, but there have been no large trials confirming the optimal protocols.[28] Complications from systemic chemotherapy include nausea, anemia and neutropenia, which may be life-threatening.[29]

In a small, retrospective study by Paik et al. in 2012, researchers compared 24 patients with non-conjunctival ocular adnexal MALT lymhpoma.[28] Nine patients received chemotherapy only, eight received radiotherapy only (30-40 Gy), and seven received adjuvant radiotherapy (30-36 Gy) after chemotherapy provided insufficient response. They scored the ophthalmologic outcomes based on six main criteria that they deemed most common and important: decreased vision, dry eye, cataract, intractable intraocular pressure, retinopathy and blepharitis. They found that visual outcomes, as well as dry eye and blepharitis, were more common and serious in patients who received either radiotherapy alone or chemoradiotherapy vs. chemotherapy alone. Overall, patients treated solely with chemotherapy had better ocular and visual outcomes, and it should be considered as an alternative to radiotherapy.[29] Other case reports have also shown superior ophthalmologic outcomes with chemotherapy for primary disease. Dimitrakopoulos and colleagues stated that "although radiotherapy is preferable for localized lymphoproliferative lesions, chemotherapy also should be considered as an effective treatment that preserves the integrity and function of the ocular adnexa."[29]

Immunotherapy, most notably using the monoclonal antibody rituximab, is an emerging treatment for OALD. Rituximab targets the CD20 cell-surface receptor, which is found on all normal B cells and the majority of malignant B cells, leading to apoptosis. Single-agent systemic treatment with rituximab for patients who have received no prior treatment shows overall response rates of 50-100%, with either partial or complete remission.[4,26] Unfortunately short-term recurrence is common, although a small case series by Annibali et al. showed improved results with maintenance therapy.[4,10,26] Therefore, despite its better toxicity profile, rituximab is usually not used as monotherapy but rather is often added to chemotherapy, which may reduce the risk of failure.[9,25] Rituximab is also used to treat LH when steroids or radiotherapy has failed. Cases of complete remission have been reported after use of rituximab as a first-line treatment.[10,14]

Radioimmunotherapy is another new treatment option that adds a radioactive isotope to an anti-CD20 antibody. The radiation is emitted over an area greater than 100 cell diameters. Nearby tumor cells that are CD20-negative are also affected, a process called the 'crossfire effect'.[10,14] Response rates are as high as 90%, but studies of long-term outcomes are still needed.[10]

What is the prognosis for ocular adnexal lymphoproliferative disease?

The prognosis of OALD ultimately depends on type of lesion, extent of disease and treatment modality. Studies have shown that 31-44% of patients with OAL also have systemic lymphoma at the time of diagnosis. Systemic involvement is more likely in patients with bilateral disease and in patients diagnosed with high-grade tumor types.[11-20,20] Based on the Kaplan-Meier survival analysis, studies have shown that systemic disease is likely to occur in 7-8% of patients at 1 year, 15-17% at 5 years, and 28-33% at 10 years with a greater risk in patients with bilateral involvement.[11,20] A study by McKelvie et al. found that lymphoma-related deaths occurred in 18% of patients with OAL over 5 years of follow-up, but only in 2% of patients with MALT.[15] Mortality was higher for follicular lymphoma (33%) and diffuse large-cell lymphoma (38%), but was 100% for the more aggressive types, such as mantel-cell lymphoma, peripheral T-cell lymphoma and natural killer-cell lymphoma.[12]

In general, the risk of systemic involvement and death is greater in the more aggressive histological types of lymphoma and in patients with a more advanced stage of disease. MALT lymphoma usually has an indolent course with low likelihood of systemic involvement and lymphoma-related death regardless of the treatment modality selected. However, due to the risk of metastasis and possible transformation to a more aggressive lymphoma, all patients with OAL should be followed every 6 months for at least 5 years, including physical exam, laboratory tests and imaging.[11]

Conclusion

We presented two cases of OALD that initially appeared similar on clinical examination, but after further evaluation with biopsy, immunohistochemistry, and molecular genetics were found to be respectively malignant and benign.

Advances in diagnostic techniques have allowed for better differentiation and classification of OALD. However, benign and malignant OALD are still indistinguishable on clinical examination and further testing is required. New MRI protocols may begin to be able to differentiate between benign LH and malignant lymphoma, but a histomorphological and immunohistochemical evaluation is still needed to confirm the exact histological type, which ultimately guides management. Whole-body imaging is needed to discover any systemic involvement, and combined PET/CT might prove to be the most sensitive way to simultaneously detect both orbital and systemic disease.

In addition to the traditional treatments of radiotherapy and chemotherapy for primary and systemic OALD, respectively, emerging treatments might offer better outcomes with less adverse effects. Immunotherapy with rituximab and radioimmunotherapy show promising results, especially when added as an adjunct to traditional treatments. New insights into the underlying etiology of lymphoproliferative disorders might also shed light on new treatments such as antibiotics, but there is no conclusive evidence at this time.

Benign lymphoid hyperplasia and MALT lymphoma of the ocular adnexa have an indolent course, and systemic involvement and tumor-related deaths are rare given their favorable response to treatment. However, progression and metastasis are risks, and patients should be monitored closely for at least 5 years, even after remission has occurred.

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The Use of Social Media to Enhance Academic Careers

Aurora Denial OD, FAAO | Optometric Education: Volume 45, Number 1 (Fall 2019)

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Aurora Denial, OD, FAAO

In June 2019, I had the opportunity to attend a conference, "Writing, Publishing, and Social Media for Healthcare Professionals," sponsored by Harvard Medical School and the Massachusetts Psychological Association. The conference was interesting and educational. The most enlightening aspect was information presented on the use of social media to enhance health professionals' careers. I like to think of myself as a moderately technologically savvy person; however, when it comes to social media, I am a digital baby, a dedicated Facebook stalker, who rarely posts any information. Nevertheless, the topic captured my attention because I recognized the enormous impact of social media in dissemination of scholarship, collaboration and networking.

Why Social Media?

Social media allows impact and visibility through exposure to a large audience, control of your message and a stage to advocate for your prospective. As a Department Chair, I am often in the position of mentoring and guiding faculty who are seeking promotion and tenure at various points in their careers. The achievement of promotion and tenure usually involves the demonstration of excellence and impact in the areas of teaching, service and scholarship. Traditionally, scholarly activities for promotion involve the production of high-quality scholarship and sharing the work via dissemination in peer-reviewed journals and presentations at national meetings. These activities eventually result in opportunities for national recognition and the development of a reputation for high-quality, impactful work in a particular area. Although faculty still need to follow this road map, the message from the conference was clear: In today's world the traditional path alone is not sufficient.

Elsevier, a major participant in publishing and information analytics, reports that "more than 2.5 million scientific articles are published each year," and "it has never been more important to ensure that your article stands out."[1] Faculty interested in promotion and tenure need to take control to ensure their message gets out in a timely manner to an appropriate audience. Social media allows for the design, distribution and collaboration of material that can be measured.[2]

Social media includes social networking sites, which are defined as "web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system."[3] Social networking can be earned ("exposure obtained by earning your way onto another's platform"), rented ("a presence or content you control but lives on someone's else's platform") or owned ("any channel where you fully own the connection to your audience").[4] Owned media include your website, blog and e-mail list, assuming they live in a domain that you own. Owned media provides an opportunity to develop your own audience. Rented media includes Facebook, Twitter, LinkedIn, Instagram etc. These sites provide opportunities to collaborate, network and post your latest accomplishments, which can include research findings, articles, images, videos and audio recordings. Earned media such as an interview on a podcast gives you instant access to an existing audience. However, the downside is that you need to be invited. Academic careers are impacted when faculty understand and utilize all three types of networks.[4] According to Elsevier, "every day scholarly articles receive thousands of new mentions across social media, news and blogs."[1]

Where to Start

Social media presents opportunities as well as challenges for academicians. It can seem overwhelming to learn and navigate as well as time-consuming to maintain. That said, many institutions have dedicated staff to help faculty efficiently and effectively use social media. Elsevier has provided extensive information on what you can do to get your article the attention it deserves.[1] Embracing social media as a means of career enhancement may seem foreign and disruptive to many. Using more traditional methods of building a career may initially seem more comfortable. However, faculty and mentors need to be open-minded and aware of the current landscape. Opportunities that arise from social media use may take years to achieve by more traditional means. It is a disservice to the faculty members we mentor to not explore all avenues that may be beneficial to their careers.

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ASCO's Public Awareness Campaign "Optometry Gives Me Life" Surpasses Benchmarks

Keshia Elder, OD, MS, FAAO | Optometric Education: Volume 45, Number 1 (Fall 2019)

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In the eight months since its March 2019 launch, ASCO's public awareness campaign — *Optometry Gives Me Life* — has gained impressive momentum. The online, e-mail and social media ads associated with the campaign have been viewed nearly 35 million times.[1] According to the media and communications agency partnered with ASCO on the initiative, the percentage of people who see the ads and click on them, known as the "click-through rate," is 80% higher than the benchmark typically achieved with this type of campaign. *Optometry Gives Me Life* also surpassed the benchmark for the percentage of people who watch campaign videos in their entirety. At 85.41%, the campaign's rate is 187% higher than the 30% benchmark.[1] In addition, nearly 99,000 people visited the campaign landing page, https://futureeyedoc.org/,[1] in the initial eight-months.

Why Doesn't Everyone See the Campaign Ads?

Optometry Gives Me Life is a multipronged and highly targeted campaign. Its intended audience is college juniors and seniors pursuing STEM degrees who have expressed an interest in a health profession. Internet users whose age and online activity don't match the target audience criteria won't see the ads. The ads present to those who fit the criteria and direct them to the https://futureeyedoc.org/ landing page. There, they see the campaign videos and can access additional information.

Also as part of the campaign, each ASCO member school and college of optometry received a toolkit containing *Optometry Gives Me Life* materials they can customize and use to promote optometry, recruit optometry students and expand the reach of the campaign.

The Impetus for *Optometry Gives Me Life*

The *Optometry Gives Me Life* campaign supports one of ASCO's key strategic objectives, which is to attract a robust, highly qualified and diverse pool of applicants pursuing the education necessary for providing optometric vision care, thus improving the overall health of patients everywhere. The campaign addresses the concern that a recent decrease in the number of optometry school applicants and the resulting increase in seat availability may lead to less competition for optometry school acceptance and a less-qualified applicant pool. The number of optometry school applicants has been on the decline since 2015-2016,[2] and the applicant-to-matriculant ratio decreased from 1.53 (2503:1639) in 2010 to 1.39 (2527:1822) in 2018.[3]

The Applicant Pool Development Task Force (APDTF) is the steward of ASCO's applicant development efforts. Formed in 2017, it includes representatives from schools and colleges of optometry with expertise in admissions, marketing and communications; industry partners; and a representative from the ASCO Diversity and Cultural Competency Committee. In the Association's Strategic Plan 2018-2022, applicant pool development is tied to measurable results:

- recruit at least two applicants with an undergraduate grade-point average higher than 3.0 for every available training slot in a United States-based optometry program by June 2022
- increase by 100% the number of highly qualified applicants from Hispanic/Latino and African American/Black backgrounds by June 2022
- maximize the percentage/number of high school students who are aware of optometry as a career option

Off to a Good Start

It's too early to determine the overall impact *Optometry Gives Me Life* will have, but the early indicators are promising. By promoting and renewing interest in optometry as a career, the campaign is moving ASCO and its member institutions closer to the important goal of increasing the quantity, quality and diversity of optometry school applicants.

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Two Join ASCO Journal as Associate Editors

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Jamie Althoff, OD, and Keshia S. Elder, OD, MS, FAAO, have been selected as Associate Editors for ASCO's journal, *Optometric Education*.

Dr. Althoff, a 2007 graduate of the Ferris State University Michigan College of Optometry, is currently an Assistant Professor at the Nova Southeastern University College of Optometry where she also serves as the Director of Outcomes Assessment and Faculty Development. She teaches theoretical optics, clinical gerontology, and optometric theory and methods, and her academic interests include the scholarship of teaching and learning and the use of technology in education. Dr. Elder, a 1998 graduate of the University of Alabama at Birmingham School of Optometry (UAB), is currently an Associate Professor at UAB where she is also Director of the externship program. She precepts students in the Contact Lens and Primary Care clinics and is the course director for Clinical Management. Dr. Elder is a member of the American Academy of Optometry's Lectures and Workshops Committee and works with ASCO as the Applicant Pool Development Task Force liaison to the Diversity and Cultural Competency Committee. She is also Chair-Elect for the ASCO Diversity, Equity and Inclusion Special Interest Group.

Jamie Althoff, OD

Keshia S. Elder, OD, MS, FAAO

Both Dr. Althoff and Dr. Elder are long-time members of the *Optometric Education* Journal Review Board. Dr. Elder says she wants to be more involved with the journal because it has the ability to positively impact the entire field of optometric education. "The publication is important because it's the only journal focused solely on optometric education," she says. "It's a place to go to learn about innovative teaching methods, brush up on clinical knowledge by reading the teaching case reports, and stay abreast of scholarship in optometric teaching and learning."

Optometric Education Editor Aurora Denial, OD, FAAO, says Drs. Elder and Althoff will be involved with implementing new projects, collaborating in selection of Journal Review Board members, soliciting manuscripts and assisting with the development of journal content. "I'm honored to have the opportunity to continue the hard work of those who have developed the journal into what it is today," Dr. Althoff says. "My colleagues and I are always striving to find the best way to teach and motivate the future optometrists in our programs, but most of us have little or no formal training in education. *Optometric Education* serves as a valuable resource for us to share our experiences and inspire each other. I hope to help it continue to adapt to meet the ever-changing needs of optometry and optometric education."