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RELIABILITY OF THE WETTING VALUE OF TEARS

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Abstract—The wetting value is the length of a Schirmer strip wetted in millimetres for a 5 min test period plus the length of time in seconds for dry spots to appear and has been suggested as a better prognostic test than its components in isolation (Fanti and Holly, 1980). Parameters of these procedures are examined and important shortcomings in the derivation of wetting value discussed. Reliability figures are presented for the Schirmer, tear break-up and wetting value tests. The norms obtained for the tear break-up test are substantially different from those usually assumed and we recommend that practitioners should therefore rely on their own norms rather than published values.

INTRODUCTION

The introduction of gas-permeable materials heralded longer periods of contact lens wear. Providing the fit is correct, the extent by which contact lens wear compromises ocular integrity is generally proportional to wearing time. In order to minimize contact lens induced changes it is essential to screen patients carefully, to maintain a clean lens and a clean eye, and to ensure that both careful and extensive aftercare is implemented.

A broad spectrum of screening tests is available to facilitate prognosis (Table 1) and it is important to evaluate how useful such tests may be in enabling one to predict successful contact lens wear. Two commonly applied screening tests are the Schirmer and the tear break-up test (Ehlers, 1965; Kame *et al*., 1973; Lemp and Hamilo, 1973; Rengstorff, 1974; Vanley *et al.*, 1977; Cedarstaff and Tomlinson, 1983; Lydon and Guillon, 1984), although the wetting value has been suggested by Fanti and Holly (1980) as a better prognostic test than its components in isolation. The wetting value is defined as the length of Schirmer strip wetted in millimetres for a 5 min test period plus the length of time in seconds for dry spots to appear on the pre-corneal tear film.

Both the Schirmer and the tear break-up tests are inexpensive, relatively simple to apply using conventional instrumentation and are long established. However, they are both invasive techniques which may not always be applied uniformly between practitioners. It is sensible to question the repeatability or reliability of both tests, since this is an important consideration for many optometric techniques. In order to apply the Schirmer test one inserts a sterile Whatman paper into the lower tear rivus and measures the length of paper moistened by tears in a 5 min test period. The Schirmer test measures the basal tear secretion supplemented by random reflex tearing which in turn varies with the sensory stimulation of both the cornea and lid margins. The test is time consuming, uncomfortable and pre-corneal damage may also occur (Hamano, 1983).

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Table 1. Contact lens prognostic tests

Slit-lamp examination	Refs
Fluorescein staining	(Korb and Korb, 1970; Kikkawa, 1972)
Rose Bengal staining	(Norn, 1969, 1983)
Fluorescein dilution	(Milder, 1981)
Sequential staining	(Korb and Herman, 1970)
McDonald testing	(McDonald, 1969)
Meibomian expression test	(Rengstorff, 1980; Korb and Henriquez, 1980; Henriquez and Korb, 1981)
Tear analysis	(Schuller *et al.*, 1973)
Aesthesiometry	(Millodot, 1978–84; Millodot and O'Leary, 1981)
Tear film integrity evaluation	(Lydon and Guillon, 1984)
Patho-histology	(Allansmith *et al.*, 1978
Cytology	Hirji and Larke, 1981; Hirji *et al.*, 1984)
Conjunctival swabs	(Rauschl and Rogers, 1978)
Tear break-up	(Lemp and Hamilo, 1973; Rengstorff, 1974; Vanley *et al.*, 1977)
Tear volume	(Schirmer, 1902; Halberg and Berens, 1961; Kame *et al.*, 1976)
Wetting value	(Fanti and Holly, 1980; Hales, 1982)

The tear break-up test measures the evaporation time of the pre-corneal tear film between blinks and dry spots are timed on the fluorescent tear film viewed through a cobalt blue filter of a slit-lamp microscope. This test is also subject to a number of variables which influence the repeatability of the procedure. Factors include the manner in which the lids spread the tears on consecutive blinks and the congruity of the anterior corneal surface, in addition to temperature, humidity, air speed, diurnal variations, tear volume and fluorescein concentration (Lydon and Guillon, 1984).

MODE OF APPLICATION

In order to determine the uniformity of administration of the Schirmer and the tear break-up test, thirty questionnaires were distributed at the post-graduate contact lens clinics at UMIST and the London Refraction Hospital. It is appreciated that such a cross-section may not necessarily be truly representative of the profession as a whole. Twenty-four forms were returned and analysed.

The participants were first asked how useful they considered each of the tests to be and the replies were graded from 4 (very useful) to 0 (no value). The results indicated that participants considered the break-up test to vary between moderately and very useful, with a mean score of 2.9 points, twice that attributed to the Schirmer test which was judged to have limited value. Three-quarters of the respondents considered the two tests in isolation, not together.

The Schirmer was applied routinely in the preliminary examinations by half the participants compared with 90% for the break-up test. During after-care the Schirmer test was used more frequently, in 70% of cases compared to 50% for the break-up test. The latter could be extended to assess both the pre-corneal and the pre-lens tear film, this being, according to Lydon and Guillon (1984), a more useful application of the tear break-up test.

The Schirmer was applied without a local anaesthetic in all cases, never at the centre of the lower lid (which would stimulate reflex lacrimation) and in 95% of cases temporally with the eyes closed. However, the test was only repeated in 14% of cases, no doubt due to the time involved. All participants used fluorescein strips for the break-up test and approximately three-quarters used a broad scanning slit. The latter technique is probably most suitable, as dry spots which are liable to appear at random can best be seen using contrast between the fluorescent and non-fluorescent tears. In view of the shorter test time, one might anticipate repetition of the break-up test and the results showed 57% of participants repeating the test, with an average of three applications.

EXPERIMENTAL STUDY

This study was undertaken to assess the repeatability of both tests as they might be undertaken in practice and to see whether certain variables might affect the results. Up to 24 undergraduate optometry students were subjects, of whom two-thirds were female. The sample included six contact lens wearers who were asked to remove their lenses the night before the experiment.

Testing was performed on two different occasions in the same clinic between 1.30 and 4.30 p.m. by three examiners. The environmental conditions of temperature, humidity and air speed were similar on each occasion.

Experiment I: Schirmer test

The patients were divided into 12 groups of two and assigned at random to three examiners. The Schirmer test was administered to each group differently. There were three variables - eye open or eye closed, no local anaesthetic or local anaesthetic and position of Schirmer strip (temporal, nasal or central) — which were varied systematically between the groups. For each subject, only one eye was used and the test was carried out on it three times. An interval of 3 min was allowed between tests, as this was considered to be appropriate in general practice and to give a sufficient recovery time to ensure independent measures.

The results were analysed using a four-factor, repeated measure analysis of variance similar to three-factor design described by Winer (1962, p. 338). The ANOVA failed to reveal any statistically significant differences due to either between-subject or within-subject factors. Therefore our assumption that sufficient time for recovery had been allowed for was not contradicted and it also seemed reasonable to treat all 24 subjects and to estimate repeatability using the ANOVA technique (p. 127 of Winer, 1962). This analysis revealed a test-retest, Pearson product-moment reliability coefficient for the Schirmer of 0.69, or 0.93 if the average of the three tests on each patient was taken. Thus repeating the test three times and taking the average improved reliability from just under 50% agreement (0.69 squared) to just over 80% (0.93 squared). The corresponding standard error of measurement (p. 129 of Anastasi, 1961) for a single test was found to be 6 mm. Our sample of 24 patients had a mean of 17 mm and a standard deviation of 11 mm.

Experiment II. Schirmer test

Twenty-four subjects were tested four times on different variants of the Schirmer test. The four variants were sterile Whatman Filters of 7 mm (Smith & Nephew), 4 mm (Cooper Vision), 2 mm widths (cut from a Cooper Vision strip) plus Hamano Threads (Hamano, 1983). The threads were 0.20 mm wide, Mule spun Egyptian cotton of length 70 mm and free from impurities and additives. The threads had been soaked for 1 h in a 0.05% solution of phenyl red dissolved in equal amounts of ethyl alcohol and saline and then dried in a controlled atmosphere of 60% humidity. When the thread is wet with tears the yellow acid colour changes to red, thus indicating the length of wetting. The filters and threads were inserted into the lower temporal tear rivus and measured without local anaesthetic with the eyes closed. The tests were given in a different sequence for each patient to compensate for any order effects and the left and right eyes were used alternately to minimize after-effects. There were three clinicians, each looking after eight patients. The interval between each test was again 2-3 min on average. Analysis of variance revealed a significant difference between the four tests ($F = 17.8$, $df = 3.6$, $P<0.001$), which a Scheffe test indicated was entirely due to differences between the thread and other tests. The former had a mean of 9 mm with a standard deviation of 6 mm, in contrast to 19 mm for the latter (SD = 8 mm).

Hamano reported no significant increase in wetting of the thread after 30 s and suggested that the test could be repeated in a shorter time with less artefacts due to ambient variables such as humidity. In our study there was little agreement between results obtained with the thread and any of the strips, with all three correlations less than 0.3 and failing to reach statistical significance. Correlations between the 7 mm and the other strips were greater, at 0.63 and 0.69, although that between the 2 mm and 4 mm was not significant, at only 0.29. It is possible that alternating the eyes complicated these results.

Experiment III: tear break-up test

The patients were divided up at random into 10 pairs. The between-group variables were type of illuminating beam (stationary broad slit, scanning broad slit, stationary circular beam, scanning circular beam and stationary large circular beam) and type of dye (fluorett or minim) and these were systematically varied between the groups. A minimum amount of fluorescein was instilled and the subject was asked to blink two or three

times. The interval between the last complete blink and the appearance of first dry spots was then timed and recorded. The test was administered to one eye of each patient ten times — first five times without local anaesthetic and then five times with. The interval between tests was 5 min, which was considered to be sufficient to ensure independent measurements.

The data were analysed using a four-factor complete and balanced analysis of variance with two between and two within factors *(cf.* p. 338 of Winer, 1962). The average time for the first dry spots (or streaks) to appear was 13 s and, as one might expect where the criterion is time, the data were skewed (p. 221, Winer, 1962). Because of this the raw data were first transformed by the taking of logarithms.

The distribution of log-transformed data was relatively symmetrical, giving a mean break-up time of 9.6 s, with two-thirds of measurements expected to lie between 4.3 and 21.3 s. An analysis of variance showed no significant differences between the different conditions, with the exception that for a large stationary circular beam there were significant interactions. This could have been operator error or may have been due to the fact that the diameter of the circular beam was approximately equal to the horizontal visible iris diameter, resulting in reduced contrast between fluorescent tears and the adjacent dark area. Our previous survey revealed that 75% of practitioners preferred to use a broad scanning beam, although one could equally apply a stationary broad slit, a stationary circular beam or a scanning circular beam.

For an average break-up time of 10 s there is a two-thirds probability that the true value lies between 6 and 16 s, a 95% probability that it lies between 4 and 26 s and a 99% probability that it lies between 3 and 36 s. Because of the skewed nature of the raw data these ranges are reduced for shorter and extended for longer breakup times, as shown in Table 2.

Table 2. Confidence limits for short, medium and long break up-times

Test time (s)	Probability 68%	95%	99%
4	4 – 10	2 – 16	2 – 23
10	6 – 16	4 – 26	3 – 36
21	7 – 25	6 – 41	4 – 57

Wetting value

In contact lens practice one clearly needs to evaluate both the quality and quantity of tears and the concept of the wetting value (Fanti and Holly, 1980) is undoubtedly simple to apply and clinically convenient. If we accept this concept then our results indicate a mean of 27 wetting value units with a standard deviation of 10.3, a test/retest reliability coefficient of 0.74 and a standard error of measurement of 5.3. This suggests that for an average raw measurement of 27 there is a 68% probability that the true amount will lie between 22 and 32. A patient with dry eyes would be expected to exhibit a wetting value of less than, say, 20 units. It is, however, contrary to basic statistics to add raw scores together, especially when the units of s and mm are different. This irregularity is further compounded when it is clear from our study that whilst the Schirmer values are symmetrically distributed about their mean, the break-up times are skewed. Strictly speaking, in these circumstances one should standardize the raw data first by subtracting the means from each raw score (log-transformed if necessary) and then dividing by the estimate of the population standard deviation. It should then be possible to maintain statistical principles and to show that a weighted addition of the two tests has a greater validity than a separate measurement.

DISCUSSION

In order for the Schirmer test to be reasonably effective one should minimize both corneal and lid stimuli and reduce spurious lacrimation. It is recommended that the patient looks upwards whilst the examiner instils the filter paper into the lower rivus away from the cornea. Although we were unable to find a statistical difference between the lower temporal and the lower nasal lid margins, the former is recommended simply because it is easier to insert the Schirmer strips away from the subject's nose. We also suggest that the measurements be taken with the subject's eyes closed, as this tends to be more comfortable and reduces eye movements whilst providing a stable test environment. If the tears wet 30 mm of filter paper in 5 min or less this may either indicate that the patient is a hyper-secretor or that there has been extensive sensory stimulation. In these circumstances it is advisable to repeat the test with a local anaesthetic, although experience and more dexterous application results in fewer cases of pseudo-hyper-secretors. The Hamano test is an attractive, clinical alternative to the Schirmer test. It is not as uncomfortable for the patient, produces less pre-corneal damage and is potentially quicker and therefore can be repeated more conveniently.

For the tear break-up test to be consistent one needs to control the ambient variables and reduce the invasive nature of the technique by using minimal fluorescein. The fluorescent tear film, however, needs to be thin and homogeneous and can be supplemented with a minimal amount of fresh fluorescein as and when required (Tomlinson, 1985). In a controlled laboratory experiment, closer monitoring of fluorescein would be recommended (Rengstorff, 1974). Contrast can be enhanced by employing a cobalt blue slit-beam approximately 4 mm wide and dry spots evaluated by employing a scanning beam. Desiccation sites, whilst random in nature, may nevertheless appear most frequently in the inferior and temporal regions (Rengstorff, 1974) or areas of incongruity or damage (Lydon and Guillon, 1984). It has been suggested that the tear break-up test may be most useful in assessing the pre-corneal and pre-lens tear film in contact lens after-care as opposed to a preliminary prognostic test.

The average for the raw tear break-up times in our sample was 13 s (10 s if log transformed) which is substantially lower than that reported in the literature. We therefore repeated the test on two separate occasions with different groups but found essentially the same results. It may well be that previous authors (Lemp and Hamilo, 1973; Rengstorff, 1974) analysed their data differently. However, 20% of our sample of optometry students were contact lens wearers which is known to reduce the value

(Lydon and Guillen, 1984). Furthermore, our measurements were taken in a clinic which was heated and ventilated by ducted air and although the environmental conditions were monitored and tested throughout the experiments, they may nevertheless affect the results (Norn, 1969; Elhurst, 1981; Lydon and Guillen, 1984). Despite this, we feel that the usually accepted norms may be misleadingly high, and from our experience it is therefore important for all practitioners to establish their own norms for their practice environment.

Mengher *et al.* (1985), employing a non-invasive method of assessing the tear film stability, recently reported significantly longer tear break-up times than those found by conventional methods. This suggests that fluorescein increases tear film instability and artificially shortens the tear break-up time. Shortening of the measurement may be advantageous. However, as Mengher *et al.* point out, prolonged eye exposure encourages reflex blinking which in turn might interfere with the apparent break-up time.

The observation of Rengstorff (1974), that a controlled volume of instilled fluorescein produces essentially the same average break-up time as a moistened fluorescein strip, suggests that providing non-invasive measurements are borne in mind then conventionally determined break-up times may still have some clinical value. Clearly, however, the association between non-invasive and fluorescein derived break-up times requires further study.

Addendum added in proof

The tear meniscus height has been suggested as an additional useful prognostic test [Osborn, G. N. (1986) Etiology of corneal staining with contact lenses. Paper presented at the European Symposium on Contact Lenses.] which may relate to tear wettability and could therefore be a useful addendum to Table 1.

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