

Yogesh Gupta
Meenakshi Gupta
S. Ali Raza Rizvi
Mohit Gupta

'Xerosis meter': a new concept in dry eye evaluation

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Y. Gupta · S. A. R. Rizvi · M. Gupta
Institute of Ophthalmology,
Jawaharlal Nehru Medical College,
Aligarh Muslim University,
Aligarh, U.P., India

M. Gupta
Department of Physiology,
Jawaharlal Nehru Medical College,
Aligarh Muslim University,
Aligarh, U.P., India

Y. Gupta (✉)
B-6, Medical Colony, AMU,
Aligarh, 202002, U.P., India
e-mail: yogibear3190@sancharnet.in
Tel.: +91-571-2721202
Fax: +91-571-2702758

Abstract *Background:* Dry eye is not only incapacitating to the patient but its treatment is also challenging. It would undoubtedly be more amenable to therapy if it could be detected at an early stage and its prognosis be recorded accurately and sensitively. In the past few years 'dry eye' and its sequelae have become the focus of attention of ophthalmologists world-wide. Whereas there has been a tremendous contribution by the pharmaceutical industry towards its treatment, its diagnostic and prognostic tests, such as Schirmer's test and tear film break-up time (BUT), appear primitive. With this in mind, we have designed a 'xerosis meter'—an electronic device that can detect and grade tissue dryness. *Methods:* This device is based on the principle that the electrical conductivity of any tissue is directly proportional to its wetness. The sensitivity of this instrument was compared with Schirmer's test and

BUT. *Result and conclusion:* The xerosis meter readings in normal eyes (control group) and dry eyes (test group) were compared statistically using the unpaired *t*-test ($p < 0.001$). The sensitivity of the xerosis meter (86.11%) was much higher than that of Schirmer's test (80.55%) and BUT (66.66%).

Keywords Xerosis meter · Dry eye · Schirmer's test · Tear film break-up time (BUT)

Introduction

The condition of dry eye has been known since time immemorial; the Greeks coined the term 'xerophthalmia'. Dry eye is a condition caused by insufficient moistening of the human eye, resulting in ocular irritation which is accompanied by a burning and a gritty sensation. Chronic disturbance in the quantity and composition of the lacrimal fluid causes structural changes in the conjunctiva and the cornea. Dry eye is not only incapacitating to the patient but its treatment is challenging for the ophthalmologists, often being long and arduous. It would be undoubtedly more

amenable to therapy if it could be detected in the early stages and its severity graded objectively.

Numerous tests have been devised to diagnose dry eye. The list is rather fancy and confusing. Some techniques are too cumbersome and expensive to perform, while others do not contribute much. The conventional investigations for dry eye that have stood the test of time are incapable of detecting the condition in its early stages. Though frequently used, they are not sensitive enough to diagnose an eye which is at potential risk of developing dry eye. They are also not capable of grading the severity of established dry eye cases with accuracy.

Keeping this in mind, we have designed a 'xerosis meter' which has a potential to screen dry eye patients in early stages with the minimum wastage of time and can be used even by unskilled personnel. The results of the xerosis meter were compared with those of Schirmer's test and tear film break-up time (BUT).

Materials and methods

In the present study, we have used the self-designed xerosis meter to detect the dryness of eyes in various cases. The xerosis meter is a sensitive analog ohmmeter. It can instantaneously measure resistance ranging from 0 to 20 M Ω . To get a comparable and standardized measurement in all the eyes, the space between the two test leads was fixed at 7 mm by attaching the two plastic handles of the leads together (Fig. 1). This instrument is based on the principle that the conductivity of any tissue is directly proportional to its wetness. In other words, the drier the tissue, i.e. cornea and conjunctiva, the greater will be the resistance offered to the flow of current.

The first step of the study was to standardize the instrument. It was imperative to establish the range of conjunctival resistance in normal individuals. For this purpose eyes of normal individuals were tested (group I, control). These eyes showed no signs and symptoms of dry eye. The basic procedure of the examination was explained to the subjects and consent was obtained in accordance with the Declaration of Helsinki. The leads were placed vertically on the unanaesthetized conjunctiva, lightly touching it and taking care that no pressure was applied (Fig. 2). They were kept in turn on the superior, inferior and temporal parts of the bulbar conjunctiva for only a fraction of a second each, and the resistance was recorded in kilo-ohms (k Ω). The overall mean value of these three readings was taken for each eye. Schirmer's test and measurement of BUT were also performed for each eye.

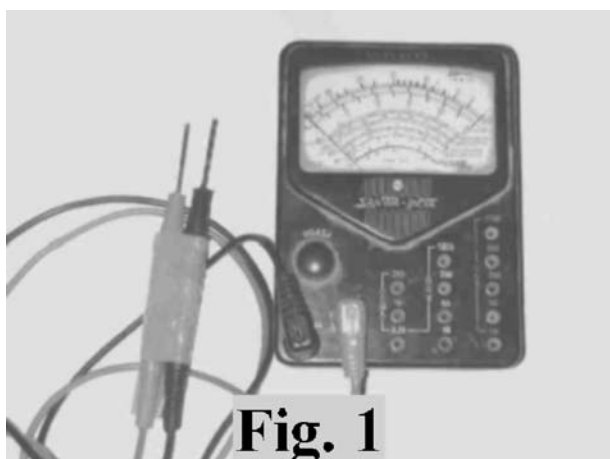


Fig. 1 The 'xerosis meter'



Fig. 2 Measuring conjunctival resistance with the xerosis meter

Factors like temperature and humidity could not be standardized, since the cases were studied all the year round in a temperature range of 25–37°C and humidity of 30–90%. All three tests were conducted at the same sitting, under similar conditions, to minimize the effect of the environment.

Group II (test group) comprised patients who showed overt signs and symptoms of dry eye. They were subjected to meticulous history taking regarding the symptoms of dry eye, any associated systemic diseases and the use of topical and systemic medications. Each eye underwent a detailed examination for tear film, conjunctival and corneal abnormalities. Along with this, Schirmer's test I was performed and BUT was measured. The symptoms and signs of dry eye were recorded (Table 1). The inclusion criteria were: (1) at least three symptoms with or without any positive signs and (2) positivity of at least one of the two tests (i.e. Schirmer's test reading < 5 mm or BUT < 10 s). The patients fulfilling these criteria were tested with the 'xerosis meter'.

Patients having dry eye-like symptoms with a negative Schirmer's and BUT were excluded from the study, as were uncooperative patients.

Table 1 Symptoms and signs of dry eye

Symptoms	Signs
(1) Irritation	(1) Decreased tear meniscus (normal approx. 1 mm, convex)
(2) Burning sensation	(2) Bulbar conjunctival vascular dilatation (interpallebral hyperaemia)
(3) Foreign body sensation/grittiness	(3) An increase in mucus strands or debris
(4) Stringy mucus discharge	(4) Conjunctival pleating
(5) Transient blurring of vision	(5) Corneal signs—superficial punctate keratitis, corneal filaments, scarring, loss of lustre
(6) Photophobia	

Table 2 Xerosis meter, Schirmer's test and BUT readings in group I (control)

Patient	Age (years)/sex	Xerosis meter reading (kΩ)		Schirmer's test reading (mm)		BUT (s)	
		R	L	R	L	R	L
		S1	45/F	21.5	23.5	26	22
S2	22/M	28.75	26.25	20	22	50	56
S3	70/M	27.5	27.5	21	23	52	56
S4	35/F	25.5	29.5	23	23	51	47
S5	55/M	28.0	29.5	23	21	46	54
S6	90/M	29.0	31.0	22	19	41	40
S7	38/M	30.0	30.0	21	19	38	40
S8	60/F	31.5	28.5	20	22	38	41
S9	60/M	32.5	27.5	17	20	35	37
S10	35/M	31.0	29.0	17	19	34	36
S11	45/F	30.5	29.5	18	20	38	40
S12	45/F	31.0	29.0	19	22	36	39
S13	18/F	27.0	33.0	22	20	40	40
S14	35/F	31.5	28.5	21	24	40	42
S15	16/M	29.5	30.5	21	21	38	36
S16	35/F	30.0	30.0	18	22	35	37
S17	19/M	31.0	29.0	17	19	36	39
S18	65/M	32.0	28.0	18	22	35	37
S19	48/M	31.0	31.5	19	17	21	19
S20	16/M	35.0	30.0	16	20	28	34
S21	65/F	31.5	33.5	18	16	34	26
S22	50/F	32.0	33.0	20	18	33	29
S23	11/M	34.0	31.0	16	20	27	29
S24	12/F	33.6	33.0	17	19	20	20
S25	40/M	33.0	38.3	21	19	42	48
S26	18/F	36.0	34.0	15	18	21	24
S27	47/F	37.5	32.5	18	20	23	24
S28	25/M	35.0	35.0	18	17	25	22
S29	32/F	35.5	34.5	16	18	19	23
S30	30/F	33.0	38.0	20	15	24	21
S31	18/F	36.75	33.25	15	14	19	19
S32	25/F	36.0	36.9	17	15	22	20
S33	10/F	35.5	37.4	16	12	20	18
S34	32/M	39.0	35.0	13	17	13	17
S35	26/F	37.5	37.5	17	17	21	21
S36	13/M	39.0	36.0	13	18	17	21
S37	25/F	36.5	38.5	17	14	21	19
S38	32/M	38.0	37.0	13	15	17	19
S39	11/M	35.0	40.0	16	14	20	18
S40	11/M	37.0	38.0	16	13	20	17
S41	24/M	39.0	36.0	14	16	18	20
S42	65/F	37.5	37.5	14	15	18	18
S43	21/F	38.5	36.5	14	16	18	21
S44	15/F	39.0	36.0	13	14	17	19
S45	25/F	38.25	36.75	14	17	18	20
S46	30/F	40.0	37.5	12	14	15	17
S47	50/M	41.0	39.0	13	16	18	20
S48	55/M	39.5	40.5	16	15	17	14

Table 2 (continued)

Patient	Age (years)/sex	Xerosis meter reading (kΩ)		Schirmer's test reading (mm)		BUT (s)	
		R	L	R	L	R	L
		S49	45/F	40.0	40.0	15	14
S50	31/M	39.0	41.0	17	14	20	17
S51	18/F	38.5	41.5	17	15	20	18
S52	27/M	42.0	38.0	13	16	17	20
S53	45/M	41.0	39.0	14	15	16	18
S54	30/M	41.25	38.75	14	16	18	20
S55	23/M	42.0	40.5	13	16	17	21
S56	55/M	40.0	42.5	13	14	16	20
S57	30/F	41.5	41.0	14	14	16	18
Mean±SD		34.51±		17.31±		27.65±	
(in both eyes)		4.49		2.85		11.76	

Statistically, results of the xerosis meter were compared by using unpaired *t*-test between control and test group. The upper limit of significance was set at $p < 0.05$. The sensitivity and specificity of the xerosis meter and the sensitivity of Schirmer's test and BUT were also calculated using the following formulae:

$$\text{Sensitivity} = \frac{a}{a + c} \times 100$$

$$\text{Sensitivity} = \frac{b}{b + d} \times 100$$

where a = true positive; b = true negative; c = false negative; d = false positive

Results

This study comprised 150 eyes of 78 patients. The subjects were divided into group I (control) which included 114 eyes of 57 patients and group II (test) consisting of 36 eyes of 21 patients.

The subjects in group I were between 10 and 60 years of age, the mean age being 34.6 ± 17.8 years. The age of patients in group II varied between 22 and 71 years, with a mean of 42.2 ± 14.5 years. The two groups were compared for age difference by means of the *t*-test for independent variables (using SPSS version 11) and the difference was found to be insignificant ($p > 0.05$).

The mean reading of the xerosis meter in group I was 34.5 ± 4.4 kΩ. The range was 22.5–41.25 kΩ (Table 2). The mean xerosis meter reading in group II was 44.7 ± 6.3 kΩ. The range was 36.7–80 kΩ (Table 3). The mean readings in group I and group II were compared statistically by un-

Table 3 Xerosis meter, Schirmer's test and BUT readings in group II (test)

Patient no.	Serial no.	Age (years)/ sex	Xerosis meter reading (kΩ)	Schirmer's test (mm)	BUT (s)
C1	1	45/M	37.5	12	8
C1	2	45/M	37.5	11	7
C2	3	27/M	45	4	15
C2	4	27/M	51.7	4	18
C3	5	45/M	40	10	7
C3	6	45/M	45	9	5
C4	7	25/F	53.3	0	4
C4	8	25/F	57.5	0	2
C5	9	71/F	60	0	0
C5	10	71/F	53.3	0	5
C6	11	25/M	41.7	4	12
C6	12	25/M	45	4	12
C7	13	26/F	48	4	16
C7	14	26/F	51.7	3	16
C8	15	25/F	41.7	3	15
C8	16	25/F	36.7	12	5
C9	17	40/F	42.5	3	8
C9	18	40/F	56.7	0	0
C10	19	28/M	46.7	3	6
C10	20	28/M	50	0	0
C11	21	55/M	45	0	5
C12	22	32/M	40	0	6
C12	23	32/M	40	0	6
C13	24	52/F	40	4	8
C13	25	52/F	40	4	6
C14	26	65/F	40	0	5
C14	27	65/F	42.5	3	5
C15	28	48/M	40	4	12
C16	29	42/M	43.3	4	15
C17	30	53/M	38.3	12	8
C17	31	53/M	56.6	11	4
C18	32	40/M	43.3	5	5
C19	33	28/F	38.3	4	11
C20	34	65/F	40	4	12
C20	35	65/F	41.6	4	12
C21	36	50/F	41.6	0	15
Mean			44.77±6.34	4.0±3.84	8.22±4.84

Table 4 Sensitivity and specificity of the xerosis meter

Screening test results	Diseased eyes	Non-diseased eyes
Positive	31	22
Negative	5	92
Total	36	114
*Sensitivity/**specificity (%)	*86.11	**80.70

Table 5 Sensitivity of Schirmer's test and BUT in group II (test)

Screening test results	Schirmer's test	BUT
Positive	29	24
Negative	7	12
Total	36	36
Sensitivity (%)	80.55	66.66

paired *t*-test and the difference was found to be statistically significant ($p < 0.001$).

The mean 'Xerosis meter' reading in control group was 34.5 ± 4.4 kΩ (30.1–38.9). The +1SD value of 38.9 kΩ was taken as the cutoff, i.e. values above it were considered positive for dry eye, while values below it were considered normal. On this basis, the sensitivity of the xerosis meter was 86.11% and the specificity was 80.70% (Table 4).

The mean Schirmer's test and BUT values in group I were 17.30 ± 2.85 mm and 27.65 ± 11.76 s, respectively (Table 2). The mean value of Schirmer's test in group II was 4.0 ± 3.84 mm and that of BUT was 8.22 ± 4.84 s (Table 3). The distance of 5 mm in 5 min was taken as the cut-off value for Schirmer's test in dry eye, as accepted internationally [2]. On this basis the sensitivity of Schirmer's test in our study was 80.55%. Using the accepted cut-off value of 10 s for BUT [5, 6], we found its sensitivity to be 66.66% (Table 5).

Discussion

Dry eye is an incapacitating disease. With an increase in the ageing population along with various environmental factors it is becoming increasingly prevalent. The symptoms cause significant discomfort and substantially reduce the sufferer's quality of life.

Various tests are used to detect this condition, but are not sensitive enough to detect early dry eye. Bearing this in

Table 6 Variable xerosis meter readings with 0 mm Schirmer's test reading

Serial no.	Patient	Schirmer's test (mm)	Xerosis meter reading (kΩ)
1	C4	0	53.3
2	C4	0	57.5
3	C5	0	60
4	C5	0	53.3
5	C9	0	56.7
6	C11	0	50
7	C11	0	45
8	C12	0	40
9	C12	0	40
10	C14	0	40
11	C21	0	41.6

mind we have designed a 'xerosis meter' which is capable of detecting dry eye in the initial stages. We have compared it with the conventional tests of dry eye, viz. Schirmer's test and BUT.

Since the xerosis meter was being used on the ocular tissue for the first time, it was essential to standardize it, so as to ascertain the normal range of readings of conjunctival resistance. During the process of standardization of the xerosis meter, it was found that anaesthetized eyes (4% xylocaine) gave low resistance readings even in established dry eye cases. This was attributed to the moistening effect of xylocaine. To eliminate this, we recorded the readings in unanaesthetized eyes. Normal eyes of group I were used to standardize the readings of the xerosis meter.

The xerosis meter was then tested on eyes of group II with manifest symptoms and signs of dryness. The xerosis meter readings were recorded before conducting Schirmer's test and measuring BUT, to avoid wetting of the conjunctiva by reflex secretion due to irritation. The mean conjunctival resistance in these eyes was significantly higher than in group I ($p < 0.001$). This implies that the xerosis meter could detect dry conjunctiva. Its sensitivity and specificity were 86.11 and 80.70%, respectively. In other words, the instrument was correctly detecting 86% of dry eyes and 80% of normal eyes.

The xerosis meter was compared with Schirmer's test and BUT. Schirmer's test I was performed to measure total secretion. Since the use of anaesthesia leads to a greater coefficient of variation [4], we did not perform Schirmer's test II. The latter is an inexact method, even when performed strictly according to the rules [7]. The sensitivity of Schirmer's test I in this study was 80.55%, accordance with other reports [1].

Tear film BUT is a test with great intra-individual variations. Taking 10 s as the cutoff value, the sensitivity of BUT in our study was 66.66% as reported by other authors [5, 6]. More recently it has also been shown that the introduction of fluorescein and saline solution into the tear film decreases its stability and that the tear film is actually more stable than shown by the BUT [3].

Thus, we see that the xerosis meter is much more sensitive than Schirmer's test and BUT in detecting dry eye. After analyzing the readings and observation in great detail, the point to be highlighted was the gross incapacity of Schirmer's test I to differentiate between varying degrees of dryness in individuals with established dry eye, as seen in 11 eyes (Table 3). These eyes showed a Schirmer's test reading of 0, though the clinical picture ranged from advanced dry eye to relatively mild dry eye. In other words Schirmer's test put all these 11 cases into the same category, whereas the recordings of the xerosis meter differentiated them (40–60 k Ω) (Table 6).

We conclude that the xerosis meter was successful in detecting early cases of dry eye as well as in picking out eyes that may be at risk of developing dry eye. It was also helpful in differentiating eyes with established dry eye into varying degrees of severity. This was not possible with conventional tests. The xerosis meter was more reliable and convenient, easy to use and a valuable instrument for quick screening of a large number of patients. It could perhaps supplement, if not replace, many conventional tests hitherto used to diagnose and manage dry eye.

A study with a larger number of patients is under way to develop a grading system for ocular dryness. This study will enable us to ascertain the utility of the xerosis meter as a diagnostic and prognostic tool.

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