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CLINICAL INVESTIGATIONS

Comparison Between Dawson, Trick, and Litzkow Electrode and Contact Lens Electrodes Used in Clinical Electroretinography

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Purpose: To determine the reliability of the Dawson, Trick, and Litzkow (DTL) electrode in electroretinographic recordings (ERG) in subjects of all ages, we evaluated ERG responses obtained with the contact lens (CL) and DTL electrodes and estimated a DTL/CL ratio for each sample.

Methods: Seventy-nine volunteers aged 2–84 years (79 normal eyes) were recruited for the study. Electroretinographic recordings elicited by monocular single-flash stimuli delivered by an automatic ERG recording system were recorded using both CL and the DTL electrodes (CL-ERG and DTL-ERG, respectively).

Results: The relative amplitude of the DTL-ERG to the CL-ERG was 79.6–99.8% (mean = 93.4%) for the a-wave and 84.4–106.3% (mean = 92.3%) for the b-wave. The relative latency of the DTL-ERG to the CL-ERG was 86.0–107.6% (mean = 98.2%) for the a-wave and 96.1–113.0% (mean = 97.9%) for the b-wave. The a- and b-wave amplitudes differed significantly between DTL and CL electrodes only in the 40- to 49-year-old age groups ($P < .05$). Regression analysis indicated moderate to strong relationships between the electrodes for amplitude (a-wave, $r = 0.690$; b-wave, $r = 0.824$) and latency (a-wave, $r = 0.667$; b-wave, $r = 0.725$).

Conclusion: The DTL electrode has as high stability as the conventional CL electrodes for ERG recordings in most age groups. **Jpn J Ophthalmol 2000;44:374–380**

Key Words: Contact lens electrode, Dawson, Trick, and Litzkow electrode.

Introduction

Contact lens (CL) electrodes are widely used in recording electroretinograms (ERGs). The International Society for Clinical Electrophysiology of Vision (ISCEV) has proposed standards for recording full-field ERGs,[1] including the specification that electrodes should be of the corneal (CL) type, such as the Burian-Allen electrode.[2] These electrodes have a large optical opening and keep the lids far apart.[1] In addition, the standards[1] permit the use of alternative electrodes that yield waveforms and amplitudes that are equivalent to those of the CL electrodes. On the other hand, several disadvantages have been noted for the corneal electrodes. For instance, they require wide lid opening and they may induce corneal abrasion. Cooperation by subjects is necessary to perform the procedure. This is extremely difficult in pediatric patients. Nearly all children under 4 or 5 years of age must be sedated to obtain artifact-free ERGs when the Burian-Allen CL electrodes are used.[3] In addition, these electrodes are expensive and difficult to obtain on a regular basis. Furthermore, many infectious diseases affect the conjunctiva and, therefore, sterilization of CL electrodes is essential.

Several investigations have turned to alternative electrodes, for example, gold-foil electrodes,[4,5] skin electrodes, and Dawson, Trick, and Litzkow (DTL) fiber electrodes.[6] The DTL electrode, first described by Dawson, Trick, and Litzkow,[6] has increased in popularity since it is better tolerated than the CL as-

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semblies. Many reports have indicated that the DTL electrode is less invasive, does not require topical anesthesia, and can be used for lengthy recording periods.[7–9]

The purpose of the present study was to examine whether the use of the DTL electrodes yields stable electroretinographic recordings in patients of all ages. To further investigate their efficacy and the rationale for selection between the CL and DTL electrodes, both were used with an automatic ERG recording system. We estimated average ratios between the DTL and CL electrodes for each parameter of the ERG.

Materials and Methods

DTL Electrode

The DTL electrode modified and marketed by Tomey (Nagoya) is composed of 7-cm long, low-mass spun nylon fibers, each fiber 12 μm in diameter and impregnated with metallic silver. At both ends are small sponges that are secured with double-sided adhesive tape to internal and external canthi. The DTL electrode is currently available in single-use sterile packs (Figures 1 and 2). The electrode is positioned on the lower tear meniscus or in the lower conjunctival sac.

Subjects

Seventy-nine normal subjects with normal eyes (79 eyes), 26 men and 63 women, 2 to 84 years of age were recruited for this study. Age distribution of the participants was as follows: 2–19 years, n = 6; 20–29 years, n = 17; 30–39 years, n = 10; 40–49 years, n = 10; 50–59 years, n = 10; 60–69 years, n = 15; over 70 years, n = 11). The subjects exhibited no ocular disorders with the exception of refractive error within ±4 diopters (D) and mild senile cataract. Informed consent was obtained from all volunteers who participated in the recordings. Electroretinograms were recorded using both CL electrodes (EA-102;Tomey) and DTL electrodes (Tomey).

Stimulus and Recording Configurations

Pupils were fully dilated with 1% tropicamide and 10% phenylephrine. Procaine hydrochloride (0.5%) was instilled to induce topical anesthesia prior to application of the electrodes. When 15 minutes of the initial dark adaptation ended, the DTL electrode was secured with double-sided adhesive tape at external and internal canthi. The reference and ground electrodes were Ag/AgCl EEG electrodes (Tomey). These electrode cups were filled with sodium chloride cream to ensure good electrical contact with the skin and pasted on the earlobe and forehead, respectively, after the skin had been cleaned.

Electroretinograms were recorded by a monocular flash stimulus from an automatic ERG recording system (PE-2000; Tomey). Light-emitting diodes provided a 20-microsecond scotopic stimulus flash of 30 cd/m^2 intensity. We then removed the DTL electrode. After another 15 minutes of dark adaptation, we put the CL electrode on the cornea and a second ERG was recorded from the same eye.

Data Analysis

Analysis of the waveform obtained was limited to the measurements of the a- and b-wave latency and amplitude. The amplitude of the a-wave was measured from the baseline to the a-wave trough and that of the b-wave from the a-wave trough to the b-wave peak.

In the present paper, ERGs recorded with a certain type of electrode are referred to with the name of that electrode, such as DTL-ERG or CL-ERG. The ratio of a certain ERG parameter of the DTL-ERG to the equivalent of the CL-ERG is referred to as the DTL/CL ratio.

To evaluate the relationship between the DTL and CL electrodes, amplitude and latency in ERGs data were correlated using least squares regression (simple regression) analysis between the DTL- and CL-ERGs. The ERG data were compared using Wilcoxon signed-rank test. All statistical analyses were performed on a Macintosh personal computer using the StatView Graphics® statistical analysis software package (version 4.02, Abacus Concepts, Berkeley, CA, USA).

The correlation coefficient, r is used to describe the strength of the relationship between the two groups. If the correlation coefficient is close to 1, then the two groups have a strong positive relationship. If it is 0, then it means that little or no relationship exists (Tables 3 and 4).

Results

Representative CL- and DTL-ERGs are illustrated in Figure 3. Nearly identical waveforms were obtained from both electrodes.

The amplitude and latency of the DTL-ERG and the CL-ERG as well as the DTL/CL ratios are listed in Tables 1 (a-wave) and 2 (b-wave).

The DTL/CL ratio for the a-wave amplitude was 79.6–99.8%; that for the b-wave amplitude, 84.4–

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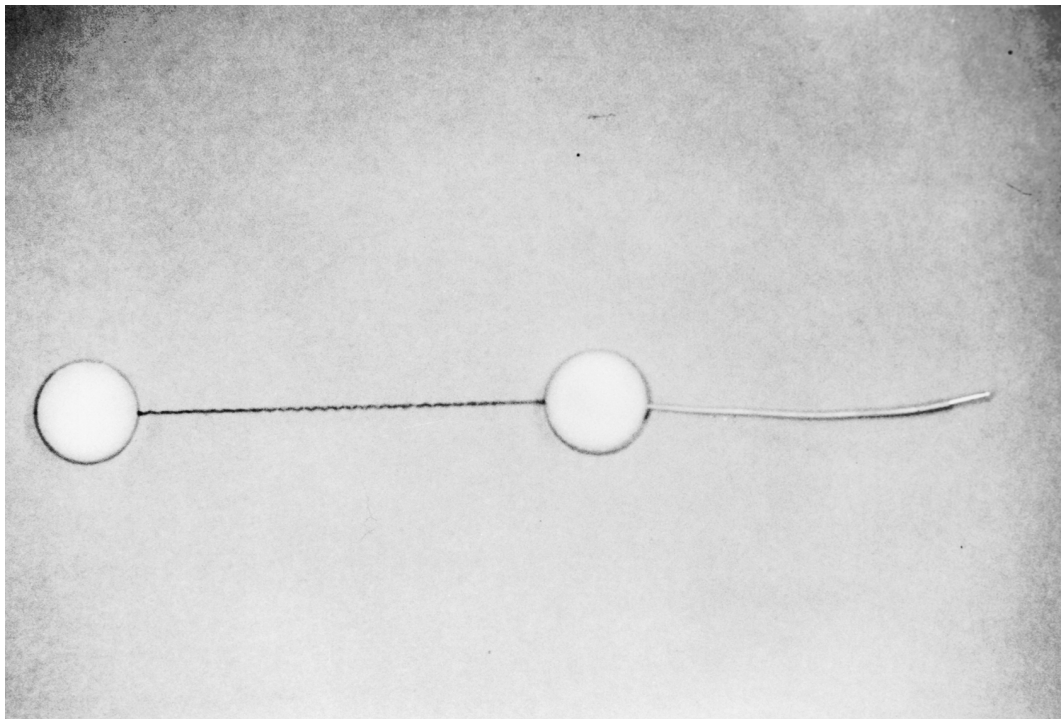

Figure 1. Dawson, Trick and Litzkow (DTL) electrode comprises six silver-coated 2 cm-long nylon fibers (diameter: 12 μm). Both ends are fixed in place with double-sided adhesive tape attached to sponges.

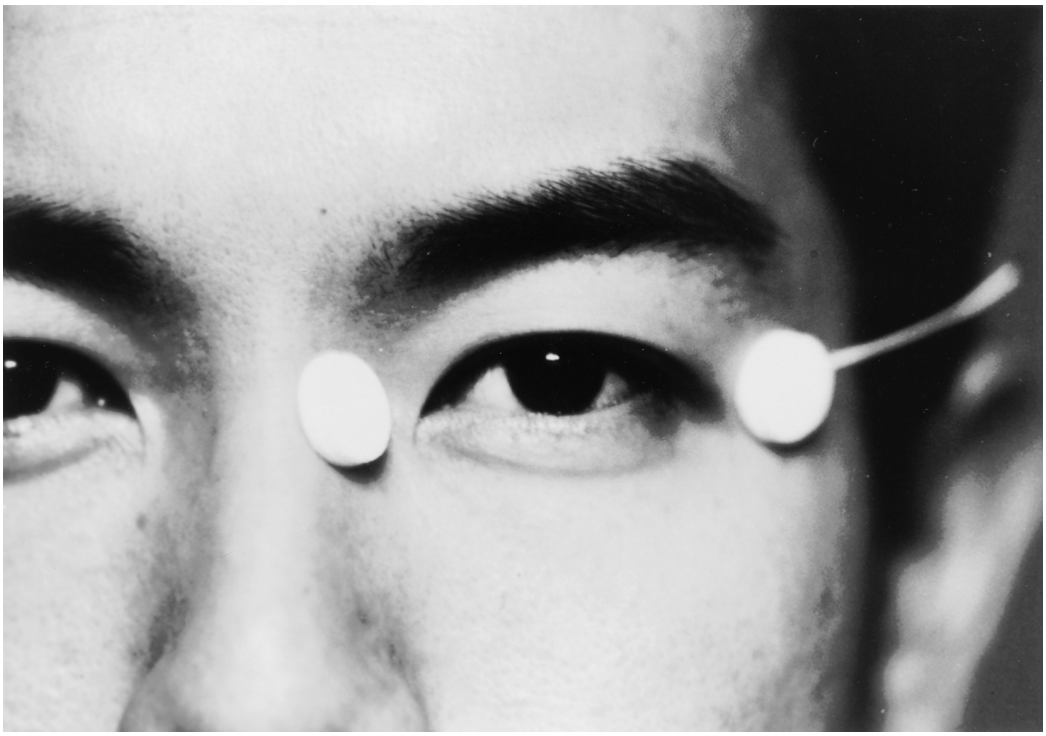

Figure 2. Fitting of Dawson, Trick, and Litzkow electrode. Electrode is secured to both canthi and placed in lower conjunctival sac.

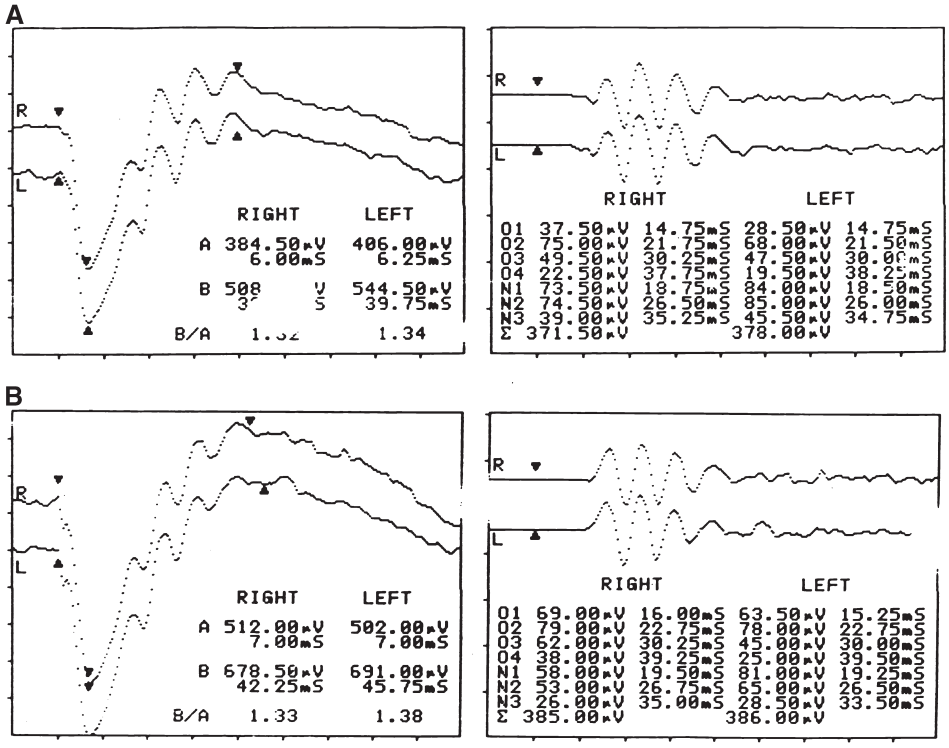

Figure 3. Waveforms obtained by Dawson, Trick, and Litzkow (DTL) electrode and contact lens electrode (CL). (**A**) DTL. (**B**) CL.

106.3%. The DTL/CL ratio for the a-wave latency was 86.0–107.6%, that for the b-wave latency, 96.1–113.0%. The mean latency DTL/CL ratios for the a-wave and the b-wave were 98.9% and 97.9%, respectively. The mean amplitude DTL/CL ratios for the a-wave and the b-wave were 93.4% and 92.2%, respectively (Tables 1 and 2).

The a- and b-wave amplitudes differed significantly between the DTL- and CL-ERGs only in the 40- to 49-year age group ($P < .05$). The latency was significantly longer for the CL-ERGs only in the over-70-year age group ($P < .05$). Thus, although the DTL-ERGs were generally faster and smaller than the CL-ERGs, variation within measurements might

Table 1. a-Wave Latency and Amplitude with Contact Lens (CL) and Dawson, Trick, and Litzkow (DTL) Electrodes

Age Group (y)	Latency (ms)					Amplitude (μV)				
	CL		DTL		DTL/CL*	CL		DTL		DTL/CL*
	Mean	SD	Mean	SD	(%)	Mean	SD	Mean	SD	(%)
<20	9.3	1.5	8.0	1.2	86.0	326.6	45.5	319.2	92.5	97.8
20–29	8.5	1.6	8.1	0.2	95.3	415.2	85.2	385.3	87.6	92.8
30–39	7.1	1.4	7.2	0.6	101.0	430.5	28.6	342.7	33.1	79.6
40–49	7.8	0.5	7.8	0.8	100.0	417.0	62.6	359.7	73.9	86.3†
50–59	8.4	0.6	7.6	1.1	90.5	400.6	74.5	372.4	76.6	93.0
60–69	7.6	1.5	7.3	0.9	96.1	378.9	80.1	345.0	73.2	91.1
70+	7.7	1.9	7.5	1.2	97.4† (98.2)	327.2	76.5	326.4	74.2	99.8 (93.4)

*DTL/CL: DTL/CL ratio (%).
†Statistical significance (Wilcoxon signed-rank test $P < .05$).

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Table 2. b-Wave Latency and Amplitude with Contact Lens (CL) and Dawson, Trick, and Litzkow (DTL) Electrodes

Age Group (y)	Latency (ms)					Amplitude (μV)				
	CL		DTL		DTL/CL*	CL		DTL		DTL/CL*
	Mean	SD	Mean	SD	(%)	Mean	SD	Mean	SD	(%)
<20	42.3	9.2	47.6	9.2	113.0	351.7	32.0	322.5	86.1	91.7
20–29	47.4	11.2	45.9	9.6	96.8	457.9	134.8	400.0	123.4	87.4
30–39	40.6	4.8	43.7	2.9	107.6	419.4	117.0	389.2	187.6	92.3
40–49	46.4	7.1	47.3	5.2	101.9	466.1	60.0	393.3	80.6	84.4†
50–59	51.7	9.5	51.6	9.5	99.8	395.0	143.9	377.5	121.7	95.6
60–69	41.3	6.2	42.3	7.3	102.4	362.2	97.2	342.4	79.5	94.5
70+	43.5	5.3	41.8	3.0	96.1† (97.9)	326.1	107.7	348.0	117.4	106.7 (92.2)

*DTL/CL: DTL/CL ratio (%).
†Statistical significance (Wilcoxon signed-rank test $P < .05$).

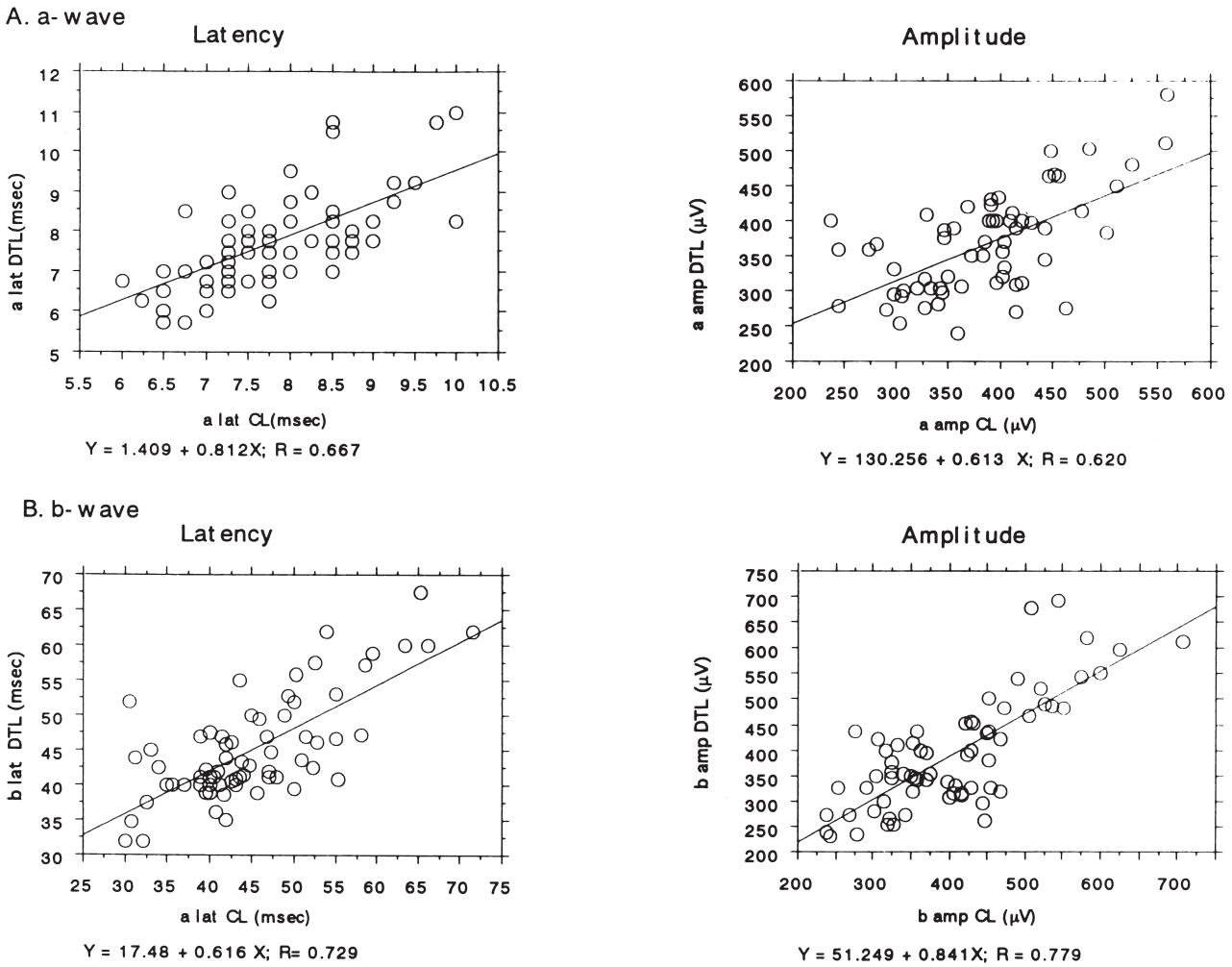

Figure 4. Scattergrams of Dawson, Trick, and Litzkow (DTL) electroretinograms (ERGs) compared with contact lens (CL) ERGs. Each data point represents value obtained from one subject. (**A**) Amplitudes and latencies of a-wave in 79 eyes. In left panel, amplitudes obtained from both DTL and CL electrodes are compared. In right panel, latencies are compared. (**B**) Amplitudes and latencies of b-wave. Straight lines represent best-fit lines as determined by regression analysis.

Table 3. Relationship Between Dawson, Trick, and Litzkow (DTL) and Contact Lens (CL) Electrode; a-wave

Age Group (y)	Latency		Amplitude	
	Correlation Coefficient	Number of Eyes	Correlation Coefficient	Number of Eyes
<20	0.782	6	0.249	6
20–29	0.630*	17	0.870†	17
30–39	0.877†	10	0.378	10
40–49	0.505	10	0.894†	10
50–59	0.546	10	0.782*	10
60–69	0.581*	15	0.477	15
70+	0.679*	11	0.595	11
	0.667†		0.620†	

*$P < .05$.
†$P < .01$.

have masked differences between electrodes because in some age groups the sample size was too small.

In the regression analysis, r indicated moderate to strong relationships between the two electrodes for amplitude (a-wave $r = 0.69$, b-wave $r = 0.824$) and latency (a-wave $r = 0.667$, b-wave $r = 0.725$) (Figure 4 and Tables 3 and 4). Regression equations are presented in Figure 4. Tables 3 and 4 present the analyses of the latency and the amplitude for each age group.

Table 5 presents the analysis of coefficients of variation between the two electrode sessions. The coefficients of variation for the two electrodes are basically the same except for a few age groups.

Discussion

The choice of an electrode in recording ERG for clinical use remains disputable. Corneal non-CL electrodes are believed to yield less stable and less reproducible electroretinographic responses than standard CL electrodes.

Table 4. Relationship Between Dawson, Trick, and Litzkow (DTL) and Contact Lens (CL) Electrode; b-wave

Age Group (y)	Latency		Amplitude	
	Correlation Coefficient	Number of Eyes	Correlation Coefficient	Number of Eyes
<20	0.353	6	0.379	6
20–29	0.787†	17	0.753†	17
30–39	0.344	10	0.805*	10
40–49	0.362	10	0.689	10
50–59	0.852†	10	0.978†	10
60–69	0.725†	15	0.798†	15
70+	0.731	11	0.759*	11
	0.725†		0.779†	

*$P < .05$.
†$P < .01$.

Table 5. Coefficients of Variation Obtained from Both Dawson, Trick, and Litzkow (DTL) and Contact Lens (CL) Electroretinograms a- and b-Waves

	Latency		Amplitude	
	CL	DTL	CL	DTL
a-wave	1.179	0.220	0.173	0.119
b-wave	0.330	0.324	0.178	0.152

In this present study, the DTL/CL ratio, which reflects the similarity between the DTL- and the CL-ERGs, indicated that the ERGs obtained by the two electrodes were nearly identical. The correlation coefficient is a good indicator of the closeness of the relationship between the two groups; thus, we take it as indicator of the equivalence between the two groups. We presume that this equivalence attests that the DTL electrode is no less useful than the CL electrode.

Many kinds of electrodes have been invented. Compared with the CL electrode, the skin electrode is better tolerated by young children because it is less traumatizing and does not require anesthetic eye drops. Polyvinyl alcohol (PVA) gel electrodes also exhibit stable electrical recording properties.[10,11] The skin/PVA amplitude ratios range between 43% and 73%, and generally, the skin ERG ratios were about half as great as the averaged DTL-ERG or PVA-ERG.[7] We understand that the ratios observed in our study are acceptable when compared with those obtained from other types of CL electrodes. Although a significant difference between the DTL-ERGs and the CL-ERGs was noted in a particular age group, no significant difference was proved in other age groups. We assume that a significant difference would arise in a particular age group, the reasons being insufficient subjects in a group or because only a single-flash recording was made. It is possible that these factors might have led to the differences. The coefficients of variation obtained from the two electrode groups were low enough and there seems to be no greater difference between the DTL- and CL-ERGs. Taking all these data into consideration, we can state that the DTL electrode has stability comparable to that of the conventional CL electrodes.

The present study indicated that quantitative measurements of the DTL-ERGs are also adequate for diagnostic purposes and for standard ERG recordings in most age groups. Regarding the DTL elec-

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trode, many investigations have mentioned its stability and value. Hebert et al[12] also reported a similarity in waveform between two different sessions separated by an interval of 7–14 days and high test-retest interclass correlation coefficients. Prager et al[8] reported that in pattern ERG recordings, the amplitude obtained by the DTL electrode was 50% lower than that obtained with the gold-foil electrode. Hennessy and Vaegen[3] compared the DTL electrode to other electrodes, for example the Burian-Allen or gold-foil electrodes, and described the DTL electrode as being the only one not showing statistical differences in test-retest reliability performances, and emphasized its usefulness. These findings show that the DTL electrode is reliable and would consequently be considered a valid alternative to the CL electrode.

Although the data is not shown in the present paper, we experienced the same problems as previously reported by Lachapelle et al,[9] that the ERG amplitudes are maximal at the center of the cornea and gradually decrease as the electrodes are displaced away from the center. They reported that the oscillatory potentials recorded when the DTL electrode is positioned deep in the conjunctival bag were 30% smaller than those with the DTL electrode in the center of the cornea. The fibers of DTL electrodes had a tendency to move to the lower conjunctival sac in most subjects. Thus we found that the method of DTL electrode placement also influences the ERGs. However, we also confirmed that the variability of DTL-ERG waveforms are small enough to be overlooked, as mentioned in previous reports.[3,4,7,10,11]

Eye movement and electrode type can greatly affect the quality of ERG recordings. We also noticed that the movement or uneven fitting of the DTL electrodes on the cornea produces artifacts. To maximize its stability, the electrode should be placed relatively loosely in the conjunctival sac. If the DTL fibers are placed tightly in the conjunctival sac, blinking or eye movements can pull them out easily. This affects the amplitude of the responses and reduces reliability. We consider that these amplitude attenuation characteristics can be controlled and corrected if the examiner is careful about the sudden change of responses during the recording. Another inevitable source of artifacts occurs when photopic stimulation strikes the electrode surface and generates a photovoltaic potential that appears as a spike on ERGs. However, because the DTL electrode consists of fine fibers, photovoltaic artifacts are minimized.

In conclusion, our findings clearly indicate that the DTL electrode is reliable and can be easily applied to clinical ERG recordings. It also eliminates the risk of corneal abrasion and conjunctival infection, and is an economical alternative for ERG recordings in most age groups. The possibility of extended usage without damage to corneal physiology or discomfort for subjects will lead to new applications for ERG.

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