Transcutaneous Electrical Acupoint Stimulation (Teas) In The Treatment of Dry Eye Disease

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Research Article

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Abstract

Purpose: To assess effectiveness and safety of the Transcutaneous Electrical Acupoint Stimulation (TEAS) treatment in alleviating symptoms and signs of dry eye disease (DED).

Methods: Patients diagnosed with DED at the Peking University Third Hospital Eye Center from December 2020 to February 2021 were randomly assigned in a 1:1:1 ratio to 5mA, 3mA, or 0mA Group respectively. DED signs and symptoms were evaluated before and 30min after treatment. We compared the clinical improvement among the three groups and between each two groups.

Results: A total of 63 patients were included. 5mA Group had best efficacy in all the signs and most of symptoms ($P < 0.05$), and the symptoms scores in 3mA Group were also significantly improved after treatment except pain, watering and increased secretions ($P < 0.05$). In the comparisons between before and after treatment between each two groups, 5mA Group showed greater improvement in the signs and most of symptoms than other two groups ($P < 0.05$). In addition, 3mA Group had greater improvement than 0mA Group in the symptoms of asthenopia ($P = 0.018$) and blurred vision ($P = 0.001$). During the treatment, we hadn't gotten any adverse events from patients.

Conclusions: TEAS treatment was effective in the treatment of DED, and 5mA provided greater signs and symptoms relief. TEAS might be a new therapeutic option for the treatment of DED.

1. Introduction

TFOS DEWS II in 2017 defined Dry eye disease (DED) as “a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film ... in which tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play etiological roles.”^{1,2} The series of changes trigger a vicious cycle,³ causing eye symptoms, such as pain, asthenopia, and photophobia², which contributes a significant negative impact on the patients' quality of life in severe cases.⁴⁻⁶

Despite the causative mechanisms, artificial tear supplement and improve ocular comfort represent the first line in treatments for patients with DED, and other options include warm compresses, lid hygiene, antibiotics, steroidal anti-inflammatory agents, hormone therapy, symptoms rarely completely disappear.^{7,8} Since current treatments are substantially palliative, no one are capable of restoring the physiological lacrimal, meibomian gland secretion and corneal nerve growth, emerging treatments to enlarge the therapeutic armamentarium are currently focused on new drugs that stimulate tear secretion, or that specifically address the recovering of the meibomian gland (MG), lacrimal and corneal nerve function.⁷

Transcutaneous electrical nerve stimulation (TENS) is a noninvasive treatment of neuromodulation that has been proved effectiveness in numerous pain conditions.^{9,10} A few studies have shown that TENS could improve chronic ocular pain and photophobia,^{11,12} and apply to the treatment of DED¹³. In recent years, acupuncture was considered a potentially effective treatment for DED by promoting tear secretion, corneal staining, and the symptom score.¹⁴⁻¹⁶ Transcutaneous electrical acupoint stimulation (TEAS) is a novel therapy, which combine TENS with acupuncture, in order to apply the electrical stimulation to the corresponding acupoints and has been widely used in analgesia, anesthesia, mental diseases and so on.¹⁷⁻¹⁹ However, its application of ocular diseases is rarely reported. The typical modifiable parameters of a TEAS device are the intensity (mA), and the frequency (Hz). While lower intensities stimulate sensory nerves, higher intensity settings will progressively stimulate an increasing motor nerve response. High frequency (100 Hz) electrical stimulation is known to effective on chronic inflammatory pain, while low frequency (2 Hz) is known to chronic neuralgia. So far, no studies have reported on the effectiveness of TEAS on DED. This study was performed to expand our understanding of TEAS for the treatment of DED, including observation of curative effect of different parameters and safety.

2. Materials And Methods

2.1. Ethical considerations

A prospective, open-label, single-arm pilot study was conducted in Peking University Third Hospital Eye Center, from December 2020 to February 2021, in agreement with the tenets of the Declaration of Helsinki. Ethics Committee of Peking University Third Hospital approval (M2021277) and written patients' informed consent were obtained.

2.2. Participants

Patients who were diagnosed with DED at the Peking University Third Hospital Eye Center were enrolled. DED was diagnosed according to the criteria for DED established by the Tear Film and Ocular Surface Society Dry Eye Workshop II.¹ Patients were excluded from the study if they had other corneal diseases, glaucoma, uveitis, retinopathy, optic neuropathy, or complex systemic disease. And patients with recent ocular

surgery within 3 months, current use of punctual plugs, recent MG expression (MGX), or thermal treatment for DED within 3 months and contact lens wear also resulted in exclusion. In addition, we excluded patients with dermatological skin problems and use of non-removable electrical device, such as cardiac pacemaker.

2.3. Trial design

Eligible patients were randomly assigned in a 1:1:1 ratio, by means of an automated Web-based randomization system, to 5mA Group, 3mA Group, or 0mA Group: all patients were administered TEAS (Neuroscience Research Institute, Peking University, China; patent pending), as Fig. 1, generating a 2/100 Hz alternating frequency, and the energy were set up 5mA, 3mA, or 0mA. The last group was the placebo-control. The TEAS uses skin electrodes instead of traditional acupuncture for electrical acupoint stimulation in different acupoints, including Cuanzhu, Chengqi, Tongziliao, Sibai and so on. Before treatment start, eye shields were placed on the eyes and conductive paste was applied on the treating acupoints area. The therapy was performed by the same investigator (YH, an experienced resident). During treatment, we also paid attention to adverse events, including epiphora, exacerbation of pain, electrical burns, irritation of skin.

2.4. Evaluation index

All patients were asked to complete a questionnaire on subjective symptoms^{20, 21} and underwent slit lamp examination to evaluate the signs of DED before and 30 min after treatment. Each examination was performed under unchanged conditions in the same examination room by the same doctor (RXT, an experienced resident).

2.4.1. Symptoms evaluation

All patients completed the same questionnaire to evaluate their DED symptoms before every examination and treatment. The questionnaire included 10 questions related to 10 DED symptoms, including dryness, foreign body sensation, pain, burning, watering, asthenopia, blurred vision, itching, increased secretions, and photophobia. The responses were rated on a 10-point scale that ranged from “not present (score 0)” to “very serious (score 10)”. A total score was also calculated as a sum of all 10 scores for each patient to evaluate the overall DED symptoms of patients.

2.4.2. Signs evaluation

Slit lamp examination was performed by the same doctor (RXT, an experienced resident) to evaluate the tear film quality, including the tear meniscus height (TMH) and tear film break-up time first (TBUTF), as well as assess the expressibility and secreted meibum of the MG. For accuracy, TMH was assessed first. Then, TBUTF was examined by fluorescein staining.

2.5. Statistical analysis

SPSS software version 23 (SPSS Inc, Chicago, IL, USA) was used for statistical analysis. The Kolmogorov-Smirnov test was applied to determine the data normality. The descriptive data were presented as mean and standard deviations (SD). T test was adopted to compare the differences before and after treatment each group for continuous variables and Wilcoxon nonparametric test was applied for ordinal variables. To further reveal the efficacy of 5 mA and 3 mA on DED, the improvement after treatment of each parameter in 5 mA and 3 mA group was calculated by subtracted the baseline measurement from the outcomes at 30 min after treatment and compared. Similarly, t test was adopted for continuous variables and Wilcoxon nonparametric test was applied for ordinal variables. P values less than 0.05 were considered statistically significant.

3. Results

3.1. Patients' general information

A total of 63 subjects were screened eligible for the study, and all subjects in each group finished the treatment and examinations, and there was no maladaptation during the process. Significant age, sex and other relate index differences were not found between the two groups. The general information of the patients are shown in Table 1.

Table 1
Patients' general information

		5mA Group	3mA Group	0mA Group	P
	Sex(M/F)	13/8	13/8	13/8	
	Age(Years)	25.38±3.12	25.42±3.34	25.25±3.59	ns
	Number of eyes	42	42	42	
	OSDI	18.58±16.22	18.13±15.24	16.83±18.11	ns
Sign	TMH (mm)	0.16±0.27	0.17±0.02	0.16±0.16	ns
	TBUT (s)	5.04±2.27	5.39±1.70	5.30±1.73	ns
Symptoms (Scores)	Dryness	3.88±2.63	2.89±2.05	2.93±2.76	ns
	Foreign body sensation	2.12±2.79	1.53±2.04	1.73±2.38	ns
	Pain	1.98±2.42	1.00±1.34	1.20±1.81	ns
	Burning	1.05±2.06	0.82±1.16	0.70±1.40	ns
	Watering	1.64±2.45	0.95±1.63	1.05±1.81	ns
	Asthenopia	3.26±3.05	2.45±2.64	2.25±2.28	ns
	Blurred vision	1.71±1.40	1.13±1.53	1.65±2.40	ns
	Itching	1.33±2.32	1.05±1.72	0.80±1.32	ns
	Increased secretions	0.76±0.53	0.50±1.16	0.80±1.65	ns
	Photophobia	1.12±1.61	0.63±0.97	0.88±1.27	ns
M: male; F: female; ns: no statistical significance					

3.2. The effectiveness of the treatment in each group

As shown in Table 2, in the comparisons between before and after treatment for each group, we found significant differences in 5mA Group in all the signs and symptoms except the symptom of increased secretions ($P<0.05$), and the symptoms score in 3mA Group were also significantly different post-treatment except pain, watering and increased secretions ($P<0.05$). However, in the control Group, that is 0mA Group, only the scores relating to dryness, asthenopia and blurred vision were significantly different after treatment. During the process of treatment and examinations, we hadn't found any adverse events.

Table 2
Comparison of pre- and post-treatment in each group

		5mA Group			3mA Group			0mA Group		
		Before	After	P	Before	After	P	Before	After	P
Signs	TMH (mm)	0.16±0.27	0.17±0.18	0.001	0.17±0.02	0.17±0.02	ns	0.16±0.16	0.16±0.18	ns
	TBUT (s)	5.04±2.27	6.29±2.29	0.002	5.39±1.70	5.74±1.29	ns	5.30±1.73	5.35±1.27	ns
Symptoms (scores)	Dryness	3.88±2.63	1.48±1.84	0.000	2.89±2.05	1.63±1.40	0.000	2.93±2.76	1.78±1.85	0.000
	Foreign body sensation	2.12±2.79	0.95±1.59	0.000	1.53±2.04	0.87±1.26	0.008	1.73±2.38	0.80±1.09	ns
	Pain	1.98±2.42	0.81±1.45	0.001	1.00±1.34	0.76±1.50	ns	1.20±1.81	0.68±1.58	ns
	Burning	1.05±2.06	0.38±0.80	0.005	0.82±1.16	0.47±0.89	0.000	0.70±1.40	0.40±1.34	ns
	Watering	1.64±2.45	0.71±1.40	ns	0.95±1.63	0.47±1.01	ns	1.05±1.81	0.73±1.41	ns
	Asthenopia	3.26±3.05	0.69±1.22	0.000	2.45±2.64	0.63±1.05	0.000	2.25±2.28	1.58±1.97	0.034
	Blurred vision	1.71±1.40	0.45±0.94	0.000	1.13±1.53	0.24±0.43	0.000	1.65±2.40	0.53±1.32	0.001
	Itching	1.33±2.32	0.33±0.72	0.002	1.05±1.72	0.37±0.82	0.005	0.80±1.32	0.53±1.06	ns
	Increased secretions	0.76±0.53	0.33±0.79	ns	0.50±1.16	0.24±0.71	ns	0.80±1.65	0.55±1.40	ns
	Photophobia	1.12±1.61	0.38±0.80	0.000	0.63±0.97	0.18±0.39	0.008	0.88±1.27	0.55±0.75	ns
TMH: tear meniscus height; TBUT: tear film break-up time; Before: Pre-treatment; After: 30 minutes Post-treatment. P values of less than 0.05 were considered statistically significant, and are expressed in the table. ns: no statistical significance										

3.3 Comparison of the effectiveness between each two groups

In the comparisons for variation after treatment between each two groups (Table 3), 5mA Group showed greater improvement in the signs than other two groups ($P<0.05$), in the dryness, asthenopia, blurred vision, and photophobia symptom scores than control group (0mA Group), and in the dryness, pain, and blurred vision symptom scores than 3mA Group ($P<0.05$). However, 3mA Group had greater improvement than control Group in the symptoms of asthenopia ($P=0.018$) and blurred vision ($P=0.001$).

Table 3
The comparison of improvement after treatment in each two groups

		5mA vs. 0mA Group			3mA vs. 0mA Group			5mA vs. 3mA Group		
		5mA	0mA	P	3mA	0mA	P	5mA	3mA	P
Signs	TMH (mm)	0.02±0.02	-0.00±0.00	0.001	0.00±0.01	-0.00±0.00		0.02±0.02	0.00±0.01	0.004
	TBUT(s)	1.24±2.45	0.05±1.52	0.01	0.34±1.17	0.05±1.52		1.24±2.45	0.34±1.17	0.038
Symptoms (scores)	Dryness	-2.40±1.75	-1.15±1.72	0.002	-1.26±1.39	-1.15±1.72		-2.40±1.75	-1.26±1.39	0.002
	Foreign body sensation	-1.16±1.74	-0.93±2.20		-0.65±1.44	-0.93±2.20		-1.16±1.74	-0.65±1.44	
	Pain	-1.16±2.09	-0.52±1.82		-0.24±1.20	-0.52±1.82		-1.16±2.09	-0.24±1.20	0.016
	Burning	-0.67±1.44	-0.30±1.73		-0.34±0.48	-0.30±1.73		-0.67±1.44	-0.34±0.48	
	Watering	-0.93±1.70	-0.33±0.86		-0.47±1.52	-0.33±0.86		-0.93±1.70	-0.47±1.52	
	Asthenopia	-2.57±2.52	-0.68±1.94	0.000	-1.82±2.19	-0.68±1.94	0.018	-2.57±2.52	-1.82±2.19	
	Blurred vision	-1.26±1.74	-1.13±2.07	0.042	-2.65±1.92	-1.13±2.07	0.001	-1.26±1.74	-2.65±1.92	0.016
	Itching	-1.00±1.98	-0.28±0.64		-0.68±1.42	-0.28±0.64		-1.00±1.98	-0.68±1.42	
	Increased secretions	-0.43±1.02	-0.25±0.98		-0.26±0.55	-0.25±0.98		-0.43±1.02	-0.26±0.55	
	Photophobia	-0.74±1.25	-0.33±0.73	0.046	-0.45±0.98	-0.33±0.73		-0.74±1.25	-0.45±0.98	
The improvement of each index was calculated by the data of 30 minutes post-treatment minus pre-treatment. Data are expressed as mean ± SD. TMH: tear meniscus height; TBUT: tear film break-up time. P values of less than 0.05 were considered statistically significant. ns: no statistical significance										

4. Discussion

DED is a multifactorial disease with various symptoms and signs, which has gained increasing attention, and various treatment options have emerged.^{1,5,7} In the light of new data, the pathophysiology of DED involves a combination of tear film instability, hyperosmolarity, neurosensory abnormalities and ocular surface inflammation and damage.^{1,3} The common conservative options, including artificial tear supplement, warm compresses, lid hygiene, steroidal anti-inflammatory agents, hormone therapy, rarely focus on the meibomian gland MG, lacrimal and corneal nerve function, which could be a fundamental solution to the problem.⁷ To the best of our knowledge, our study is the first worldwide to adopt TEAS therapy in the treatment of DED.

Its potential effects make TEAS a candidate for the off-label treatment of DED. To better understand its utilization patterns, we assessed off-label use of different current intensities. In this study, TMH, TBUT and almost all symptoms showed significant improvement after treatment in 5mA group, and the symptoms except pain, watering and increased secretions were also significantly improved in 3mA Group. However, in the control group, only the symptoms of dryness, asthenopia and blurred vision were significantly different after treatment.

These results indicated that all group could improve the symptoms of dryness, asthenopia and blurred vision, which was likely due to its effect, as an eye shield, of reducing ocular exposure time, stimulating contraction of the orbicularis oculi muscle and squeezing the meibomian glands (MGs). Consequently, the tear film became stable, and the muscles around the eyes were relaxed, which brought the relief of dryness, asthenopia and blurred vision. However, it is a pity that we didn't assess MGs expressibility and secretion quality after each treatment, which could be included in our long-term observation of treatment in the future. 3mA and 5mA group both showed remarkable relief in symptoms of burning and photophobia, probably because TEAS could stimulate the trigeminal nerve to act on the photophobia pathway (trigeminal–thalamic–cortical pathways), which similar to those of previous studies.^{11–13} All the four acupuncture points (Cuanzhu, Chengqi, Tongziliao and Sibai) have been proved the effect of alleviating eye pain asthenopia.^{14,15} However, the pain relief, and TMH, TBUT significant improvement only in 5mA group, which might indicate that 5mA is the better parameter for DED treatment, and this parameter could act on analgesic pathway. Eellan et al. noticed that TENS, whose difference is that not acting on specific acupoints compared with TEAS, significantly reduced the pain intensity and photophobia in both eyes five min after treatment.¹² In long-term sequential treatment at least three months of these patients, pain intensity decreased by approximately 27.4% and no adverse events associated with TENS were reported.¹¹ Emilio et al. manifested transcutaneous periorbital electrical stimulation could improve OSDI, TBUT and Schirmer I after 6-months and 12-months.¹³ And

Xie et al. found that the eye symptom score, BUT, TMH and visual analogue scale (VAS) score were improved after 1-month Electroacupuncture (EA) treatment.¹⁵ In addition, Cheng et al. discovered that 1-month eye acupuncture combined with conventional acupuncture could relieve subjective symptom scores, TBUT, TMH, corneal staining for DED patients, compared with control group, which proved that eye acupuncture might increase the secretion of tears, prolong the break up time of tear film, and restore the integrity of corneal epithelium.¹⁴ There are reasons to believe that our TEAS, which combined the TENS and eye acupuncture, could relieve the signs and symptoms for DED. However, the long-term effect remains to be further observed in our ongoing research. During the process of treatment and examinations, we hadn't found any adverse events.

In the comparisons for variation between each two groups, 5mA Group showed greater improvement in the signs than other two groups, in the dryness, asthenopia, blurred vision, and photophobia symptom scores than 0mA Group, and in the dryness, pain, and blurred vision symptom scores than 3mA Group. However, 3mA Group had greater improvement than 0mA Group in the symptoms of asthenopia and blurred vision.

Again we explained 5mA could be a better parameter, which might be applied to long-term research. In the comparison of 5mA and 3 mA, we might speculate the greater the energy is, the better promote for lacrimal glands, MGs and nerves, which contribute more tear production, better secretions of MGs and less ocular pain. And more stable tear film brought the relief of dryness and blurred vision, and more activation of analgesic pathways brought the relief of pain. Maybe we could include higher energy in our future observation. However, the comparison of 0mA and 3 mA might expose low-energy acupoint stimulation could also better improve asthenopia. We suspect that its squeezing for MG as a patch might work.

The strength of our study is that it provided new therapeutic option for DED treatment, as well as reasonable guidance and recommendations for parameter adjustment. There are also limitations to our study. First, the following-up duration was rather short, only half an hour after treatment was assessed. Our ongoing study will be further improved. Second, parameter optimization could not be performed, and we will try higher energy and include comparative assessment below safe premise. The frequency dependent should also be explored. Third, we did not evaluate the MGs expressibility and secretion quality, corneal staining, corneal sensitivity and so on. Further long-term studies should include a larger sample size, optimized parameters and additional examinations, including eyelid margins for conditions such as telangiectasia, irregularity, and neovascularity, corneal nerve layer detection, for further confirmation of our conjecture. The therapeutic mechanisms for TEAS will be further aided by vitro studies of molecular biology. Animal studies may involve its effect on lacrimal glands, MGs and nerves.

In summary, we found that TEAS were effective in the treatment of DED. However, 5mA provided greater signs and symptoms relief. TEAS can be a new therapeutic option for the treatment of DED.

Declarations

Conflict of interest statement: There is no Conflict to disclose

Ethics approval and consent to participate: In agreement with the tenets of the Declaration of Helsinki. Ethics Committee of Peking University Third Hospital approval (M2021277)

Consent for publication: Yes.

Availability of data and materials: No.

Acknowledgments and Authors' contributions

Xiaotong Ren: research design, data acquisition, data analysis, and manuscript preparation;

Jiarui Yang: research design, treatment operation;

Hao yuan: data acquisition;

Rong zhang: research design;

Xuemin Li: research design.

All authors read and approved the final version of this manuscript.

Competing interests: None.

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Figures

Figure 1

As Fig.1, generating a 2/100 Hz alternating frequency, and the energy were set up 5mA, 3mA, or 0mA.