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ORIGINAL ARTICLE

Assessing Salivary flow rate after stimulation with Transcutaneous Electrical Nerve Stimulation

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ABSTRACT

Saliva plays a critical role in maintaining oral homeostasis. Various local and systemic factors such as medications, radiation therapy and systemic conditions can cause reduction in salivary flow leading to xerostomia. Systemic agents stimulate salivary flow but often have unfavorable side effects. Usage of transcutaneous electrical nerve stimulation (TENS) in the production of saliva has been studied in the past but showed moderately promising results. TENS is used to increase salivary flow by stimulating the peripheral nerves and it has fewer side effects. The aim of the present study was to assess and evaluate the effect of TENS on whole salivary flow rates in healthy adult subjects. A total of 80 healthy adult subjects were included in the study. Unstimulated and stimulated saliva using TENS was, then, collected for 5 minutes in a graduated test tube fitted with a funnel and the mean salivary flow rates were calculated. The data was analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). Chi-square test was used to test the association between the said parameters while student's t-test was used to compare the means. p-value of <0.05 was considered statistically significant. The mean unstimulated salivary flow rate in males was found to be 1.3±0.062 as against the mean stimulated salivary flow rate of 1.4±0.068 (p<0.001). In females, the mean unstimulated salivary flow rate was found to be 1.2±0.046 while the stimulated salivary flow rate came-out to be 1.3±0.074 (p<0.001). According to age groups, subjects were divided in to three age groups viz. 20-29years, 30-39years and 40-49years wherein the maximum increase in salivary flow rate was seen in the 20-29years age group, though, significant results were seen in all the three said age groups (p<0.001). Transcutaneous electrical nerve stimulation (TENS) comes-out to be a safer, non-pharmacological therapeutic option of treating patients with xerostomia with avoidance of the systemic drugs wherein the unavoidable side effects of such drugs make their use restricted to only specific clinical settings.

Key words: salivary flow rate, xerostomia, stimulation, transcutaneous electrical nerve stimulation (TENS)

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INTRODUCTION

Saliva is a critical fluid necessary for oral health. The 3 major salivary glands along with 300-500 minor salivary glands produce about 1.5 liters of whole saliva daily. At rest, secretion ranges from 0.25 to 0.35ml/min to constitute what is recognized as the unstimulated saliva. Sensory, electrical or, mechanical stimuli can raise this secretion rate to 1.5ml/min to constitute stimulated saliva which is biochemically different from the resting or, unstimulated saliva [1]. Physiologically, salivary secretion is regulated by a three-component reflex arch including (a) afferent receptors and nerves that carry impulses created by taste and mastication activities, (b) a central connection and processing nucleus (salivation center) and

(c) an efferent reflex arm which is constituted by parasympathetic and sympathetic nerves bundles that separately but, in coordination, innervate the salivary gland blood vessels and acini and control salivary outflow. The afferent nerves carry impulses from the periphery to the salivation center in the medulla oblongata and this, in turn, directs signals to the efferent part of the reflex arch leading to salivation [2]. Given the autonomic control of salivary secretion, the electrical stimulation of one of the components of the salivary reflex arch can potentially lead to enhancement of salivary secretion [3]. Transcutaneous electrical nerve stimulation (TENS), by definition, covers the complete range of currents applied transcutaneously for eventuating nerve excitation [4]. Electrostimulation of neural and muscular structures is of therapeutic potential in several areas of medicine with the common and well-known examples being the cardiac pacemakers, phrenic stimulators and so on. Because of this known autonomic control of salivary secretion, a similar approach could potentially be applied for therapeutic stimulation of salivary glands in the management of salivary gland hypofunction. Application of electrical impulses to one or, more of the three components of the salivary reflex arch should, in theory, improve salivary secretion and ultimately, lessen the various long-term effects of hyposalivation [5]. Saliva has many important functions by virtue of its constituents including the so-called protective functions due to lubrication, antimicrobial activity, growth factors present in saliva, the role of saliva in maintaining mucosal integrity and because of the buffering and remineralising capacity of the saliva as well as numerous other roles including the potential role of saliva in the food- and speech- related functions including taste perception, food bolus preparation, deglutition followed by digestion and speech. On account of reduced salivary flow, there is dryness of the mouth termed xerostomia with the resultant saliva being viscous and sticky in nature leading to a compromised function with altered taste perception, a deviant sense of smell, failed speech, trouble with chewing and deglutition, increased predisposition for dental caries, erosions of dental hard tissues, halitosis, esophagitis, aggravated acid reflux reflexes, dysaesthesias and an increased predisposition towards opportunistic candida infections. Xerostomia is a subjective feeling of dry mouth, a symptom that may or, may not be accompanied by hyposalivation, an objective decrease in salivary flow. Salivary gland hypofunction might be associated with various local and systemic conditions and is managed with a plethora of therapeutic options ranging from palliative treatments to systemic medications with associated side effects which are unpreventable due to impact, by and large, on the parasympathetic system of the body, psychological counseling and acupuncture. Transcutaneous electrical nerve stimulation (TENS) is one such option with no known systemic side effects for dealing with this crippling condition [6]. Hence, the present study was planned with the similar intent of assessing the impact of transcutaneous electrical nerve stimulation (TENS) in healthy adult subjects.

MATERIAL AND METHODS

The present observational study was planned in the Department of Oral Medicine and Radiology, Saraswati Dhanwantari Dental College and Hospital and Post-Graduate Research Institute, Parbhani, Maharashtra, India on 200 healthy adults. Subjects who were not having any positive systemic history and who did not have any habit and were not on any drugs were included in the study while those with a history of salivary gland pathology, who were suffering from any systemic disease, those who were on medications for any condition, those with a history of radiation to the head and neck region, with a history of psychiatric disorders, pregnant women and patients wearing pacemakers were excluded from the study. All the subjects were explained in detail and vernacular language about the design of the study and were asked to refrain from eating, drinking, chewing gum, smoking and oral hygiene procedures for at least 1 hour prior to the appointment. The subjects were made to sit in an upright position with the head inclined slightly forward. They were asked to swallow saliva first and then, instructed to stay motionless so that the saliva could collect passively in the anterior region of the floor of the mouth. The surface electrode pads of the TENS unit (Digitens) (Fig.1) were placed externally on the skin overlying the parotid gland region (Fig.2) with the unit in the 'off' position. With low forced spitting, unstimulated saliva was, then, collected for five minutes in a graduated test tube fitted with a funnel. The TENS unit was, then, activated and the amplitude was gradually increased to the maximum tolerable level of the patient. The unit was preset at a frequency 50Hz and then, gradually increased to maximum tolerance level of the patients. Stimulated saliva was collected for five minutes in a separate graduated test tube and the flow rate was compared with the unstimulated salivary flow rate.

Statistical analysis

The data was analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). Chi-square test was used to test the association between the said parameters while student's t-test was used to compare the means. p-value of <0.05 was considered statistically significant.

RESULTS

Out of the total 80 subjects, 40 were males and 40 were females. On application of TENS, 62 subjects demonstrated an increase in saliva while 14 subjects demonstrated no increase in salivary flow and 4 subjects showed an unexpected decrease in salivary flow. The mean unstimulated salivary flow rate in males was found to be 1.3±0.062 as against the mean stimulated salivary flow rate of 1.4±0.068 ($p<0.001$). In females, the mean unstimulated salivary flow rate was found to be 1.2±0.046 while the stimulated salivary flow rate came-out to be 1.3±0.074 ($p<0.001$). (Table 1) According to age groups, subjects were divided in to three age groups viz. 20-29years (n = 28), 30-39years (n = 28) and 40-49years (n = 24) wherein the maximum increase in salivary flow rate was seen in the 20-29years age group, though, significant results were seen in all the three said age groups ($p<0.001$). (Table 2).

Table 1: Comparison of mean unstimulated and stimulated salivary flow rates according to gender

Gender	n	Mean Unstimulated Salivary Flow Rate	Mean Stimulated Salivary Flow Rate	p-value
Male	**40**	**1.3±0.062**	**1.4±0.068**	**<0.001***
Female	**40**	**1.2±0.046**	**1.3±0.074**	**<0.001***
TOTAL	**80**	**1.32±0.08**	**1.35±0.09**	**<0.001***

p-value <0.001- Highly Significant*

Table 2: Comparison of mean unstimulated and stimulated salivary flow rates according to age groups

Age Group	n	Mean Unstimulated Salivary Flow Rate	Mean Stimulated Salivary Flow Rate	p-value
20-29 Years	28	1.32±0.08	1.37±0.09	<0.001*
30-39 Years	28	1.34±0.08	1.36±0.09	<0.001*
40-49 Years	24	1.30±0.08	1.33±0.07	<0.001*
TOTAL	80	1.32±0.08	1.35±0.09	<0.001*

p-value <0.001- Highly Significant*

Fig.1: TENS Unit;

Fig.2. Patient positioned with surface electrode pads of the TENS unit (Digitens).

DISCUSSION

Saliva plays a significant role in oral homeostasis. The 3 major salivary glands along with 300-500 minor salivary glands produce about 1.5 liters of whole saliva each day. At rest, secretion ranges from 0.25 to 0.35ml/min to constitute what is recognized as the unstimulated saliva. Sensory, electrical or, mechanical stimuli can raise this secretion rate to 1.5ml/min to constitute stimulated saliva which is biochemically different from the resting or, unstimulated saliva [1]. Transcutaneous electrical nerve stimulation (TENS) consists of application of low frequency, pulsed electrical currents. These electrical currents are transmitted via surface electrodes placed on the skin surface of the patients and potentially stimulate the peripheral nerves to produce various physiological effects including the one being stimulation of salivary glands to increase salivary outflow [7]. The first TENS unit was developed in the year 1965 after publication of the well-known Gate Control Theory by Melzack and Wall. Since 1965, TENS has become widely known throughout the world and is, also, considered to be one of the most common therapeutic resources used in clinical practice for the relief of acute and chronic pain syndromes [8]. However, in recent times, many researchers have observed that, in addition, to the common analgesic effects of TENS, it may, also, be used for other potential therapeutic advantages including increasing salivary flow in known patients with glandular hypofunction due to various reasons by stimulation of the peripheral nerves [9]. The impact of transcutaneous electrical nerve stimulation (TENS) has been evaluated in stimulating salivary flow in various clinical settings and has been found to be effective even in patients with xerostomia secondary to radiation therapy for head and neck cancers. Application of electrical current through oral mucosa to afferent neuronal pathways causes neuro-electrical stimulation of the salivary glands in the regional topography and this increases production of saliva, eventually, reducing the symptoms of xerostomia [10]. TENS might, also, directly stimulate the auriculo-temporal nerve (efferent pathway) that supplies the secretomotor drive to the parotid gland, thus, causing increased salivary flow rates [11]. In the first of its kind study, Steller M *et al* [12] reported improved salivary secretion in 3 out of the 29 subjects after electrical neuro-stimulation in Sjogren's syndrome patients with Xerostomia and suggested evaluation in further studies with larger sample sizes. In the present study, 4 subjects revealed a contradictory decrease in salivary flow rates after TENS was applied which might be explained on the basis of the frequency and intensity settings of the associated TENS unit. Also, 5 patients experienced mild twitching of the facial musculature in the present study which ceased once TENS was deactivated. The results of the present study were in close accordance with the results of the study conducted by Aggrawal H *et al* [1] who, in their study, found 65 out of 80 subjects responding with increase in salivary flow rate on application of TENS. Also, 12 subjects showed mild reduction in salivary flow rates and 7 subjects experienced transient mild twitching of the facial musculature as a side effect of TENS therapy as was, also, observed in the present study. Pattipati S [4] divided the study population into three groups based on their age range as group A with an age range of 21 to 35 years, group B with age range of 36 to 50 years and group C in which the patients recruited were above 51 years of age while there were included a total of 30 patients in each group of whom 15 were males and 15 were females and found that subjects belonging to group B showing statistically significant increase in the duration of stimulated parotid salivary flow following the use of TENS. The said study concluded that TENS can be considered as an effective non-pharmacological alternative to improve salivation for prolonged periods of time in xerostomia patients. Dyasnoor S *et al* [5] conducted a study to clinically evaluate the effectiveness of transcutaneous electrical nerve stimulation (TENS) therapy in stimulating the whole salivary flow amongst 40 patients aged between 30 to 75 years with diabetes mellitus categorized as controlled and uncontrolled diabetics and who had subjective symptoms of xerostomia with an objective sign of hyposalivation in a prospective study and found a statistically significant increase in stimulated whole saliva compared with unstimulated saliva after TENS application in continuous mode ($p < 0.001$). This change was even more obvious in xerostomic patients with diabetes mellitus. On the contrary, another significant finding was a statistically significant decrease in salivary flow ($p < 0.001$) when TENS was used in burst mode substantiating the decrease in salivary outflow in numerous studies wherein TENS was used in varying modes. The study concluded with the fact that TENS was highly effective in stimulating whole salivary flow in patients in whom xerostomia and hyposalivation secondary to diabetes mellitus is seen. Likewise, Vijayalaxmi BN *et al* [6], also, found TENS effective in the stimulation of salivary flow. In the said study, 39 patients on day one and 36 patients on day two out of a total of 50 patients (75% of the subjects tested) responded to TENS therapy with an increase in stimulated whole saliva flow rate, though, there was observed a reduction in the quantity of TENS stimulated saliva on day two and this difference accounted for around 4%. They concluded significant increase in salivary flow rates on application of TENS with minimal side effects. Vilas SK *et al* [7] conducted a study to evaluate the effect of transcutaneous electrical nerve stimulation (TENS) on whole salivary flow rate in 100 healthy

adult subjects including 50 males and 50 females with no history of any salivary gland disorder and observed 85 out of 100 subjects with increased whole salivary flow when stimulated via TENS. Furthermore, 11 subjects experienced no change while 4 experienced a decrease in the salivary flow with the conclusion that TENS unit was effective in increasing the whole salivary flow in 85% of the healthy adult subjects. Bhasin N *et al* [9] studied 100 healthy adult subjects who were divided into five age groups with 20 subjects in each group equally divided into males and females in each group. The mean unstimulated whole saliva flow rate for all subjects (n = 100) was found to be 2.60ml/5mins. which increased to 3.60±0.39ml/5mins.during stimulation. With the said observation, there was found 38.46% increase in salivary flow rate while 96 out of 100 subjects responded positively to TENS therapy. Furthermore, salivary flow rate was observed to remain increased 30mins. as well as 24hrs post-stimulation with the corresponding values being 3.23±0.41ml/5mins. and 2.69±0.39ml/5mins. respectively. They concluded that TENS therapy was effective for stimulation of whole saliva in normal, healthy subjects and its effect was retained till 30mins. and even up to 24hrs post-stimulation. TENS stimulation, thus, may be combined to work synergistically with sialogogues and can be successfully used for the management of persistent xerostomia in chronically ill and post-therapy-morbidity-affected cancer patients. Singh D *et al* [13] conducted a study to evaluate the effectiveness of transcutaneous electrical nerve stimulation (TENS) as a means of stimulating salivary function in healthy adult subjects wherein 50 healthy adult subjects with no history of salivary gland disorder were enrolled while 43 out of 50 subjects demonstrated increased salivary flow when stimulated with application of TENS. The mean unstimulated salivary flow rate, in the said study, was 0.354ml/min (SD 0.19) which increased to 0.49ml/min (SD 0.24) after TENS therapy. Statistical analysis of flow rates utilizing paired t-test demonstrated the difference to be statistically significant ($p< 0.001$). The study concluded TENS unit to be effective in increasing salivary flow in two-thirds of the healthy adult subjects. Dhillon M *et al* [14] performed a study to assess effectiveness of extra-oral transcutaneous electrical nerve stimulation (TENS) as a means of stimulating salivary function in healthy adult subjects as well as to determine the gender-and age-related changes in salivary flow rates of unstimulated and stimulated parotid saliva including 100 subjects divided into two groups with 20-40 years aged subjects in Group I while ≥ 60 aged subjects in Group II. In the said study, 87 of the 100 subjects demonstrated increased salivary flow when stimulated via the TENS unit while 10 experienced no increase and 3 experienced a decrease in the salivary flow. Also, 5 subjects observed side effects, although, minimal and transient. Gender wise, no statistically significant difference could be seen amongst the subjects in both the groups while age wise, the results were found to be statistically significant ($p< 0.001$) with Group I producing more saliva. The study concluded that TENS unit was effective in increasing parotid salivary flow in healthy subjects with age-related but no gender-related variability in parotid salivary flow rate with the application of TENS. Konidena A *et al* [15] conducted a study to evaluate the effects of transcutaneous electrical nerve stimulation (TENS) on whole salivary flow rate in post-menopausal females with and without oral dryness wherein 50 post-menopausal women, based on their response to Xerostomia Inventory, were divided into 2 groups of 25 each with group 1 composed of post-menopausal women with oral dryness (PMD+OD) and group 2 containing post-menopausal women without oral dryness (PMD - OD). The mean salivary flow rates were significantly lower in the PMD + OD group than the PMD-OD group at baseline making them conclude that post-menopausal women with perception of oral dryness had lower salivary flow rates. In the observations of the said study, 90% of the subjects, irrespective of oral dryness status, responded to the TENS therapy making the authors conclude that TENS stimulation resulted in a statistically significant increase in the quantity of whole saliva flow rate in post-menopausal women with or, without oral dryness. Talal N *et al* [16] conducted a multi-center double-blind study in patients of Sjögren's syndrome to evaluate the ability of an electro-stimulator device to increase the production of saliva making 40 out of 77 Sjögren's syndrome patients assigned to active devices while 37 to placebo devices and continued the treatment for a period of 4 weeks. The results of the said study found a statistically greater increase in the production of saliva in patients using active devices than the placebo patients. Wong RK *et al* [17] conducted a single institutional Phase I-II study to assess the effectiveness of AL-TENS device [Codetron™] for relief of dry mouth in 46 patients with radiation-induced xerostomia wherein residual salivary function was present in all recruited patients. In the said study, Codetron™ treatment of acupuncture points pre-selected according to traditional Chinese medicine principles was given over a period of 12 weeks with 2-week break after 6 weeks of treatment. The results of the study indicated that this treatment method improved whole saliva production in the affected patients and the effects were sustained for at least 6 months after treatment completion. In yet another study conducted by the same authors in the year 2012, feasibility of AL-TENS device [Codetron™] delivery in a multicenter setting and its efficacy in reducing radiation-induced xerostomia in 48 patients with radiation-induced

xerostomia was assessed while Codetron™ treatment was given for 20 minutes for two times a week for 12 weeks. The study concluded that it is feasible to use the device in multicentre settings as they got 94% patient compliance. Also, a positive treatment response was noted in 86% of the patients recruited [18]. Aparna PV *et al* [19] conducted study to assess the effectiveness of transcutaneous electrical nerve stimulation (TENS) on salivary gland function in 25 subjects with complaint of hyposalivation and found a significant increase in parotid salivary flow in 19 of the 25 patients after TENS application. Also, there was observed a statistically significant difference in the salivary flow based on gender wherein males showed a higher increase salivary secretion when compared to the females patients. The study concluded TENS to be effective in increasing the salivary flow rate in patients with subjective complaint of hyposalivation. Likewise, Mittal K *et al* [20], also, demonstrated increased salivation with TENS in 47 out of 50 patients in their study with similar results in the studies conducted by Domingo DL [21] and Strietzel FP *et al* [22] who demonstrated significant decrease in dryness following TENS therapy, although, they, also, concluded that the effectiveness of TENS depends on the functional capability of the glands to respond and that TENS was not found to be effective if there was an absolute absence of salivary secretion at the baseline.

CONCLUSION

To conclude, within the limitations of the present study, there was an increased salivary flow rate observed with the basic settings of the TENS unit. Transcutaneous electrical nerve stimulation (TENS), thus, comes-out to be a safer, non-pharmacological therapeutic option of treating patients with xerostomia with avoidance of the systemic drugs wherein the unavoidable side effects of such drugs make their use restricted to only specific clinical settings and that, too, in the context of prolonged usage of the drugs required to manage this chronic complaint of the patients.

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